Respiratory Poisons

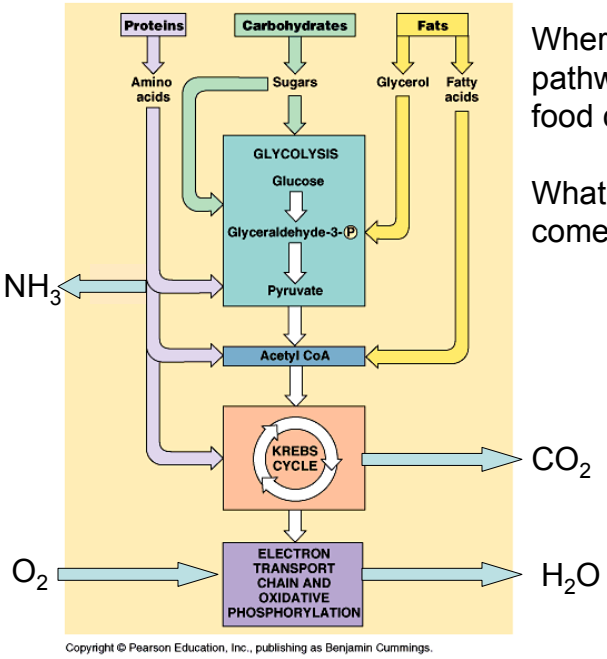
Cyanide (CN)

- blocks transfer of H. to oxygen
- Jim Jones, millipedes

DNP (dinitrophenol)

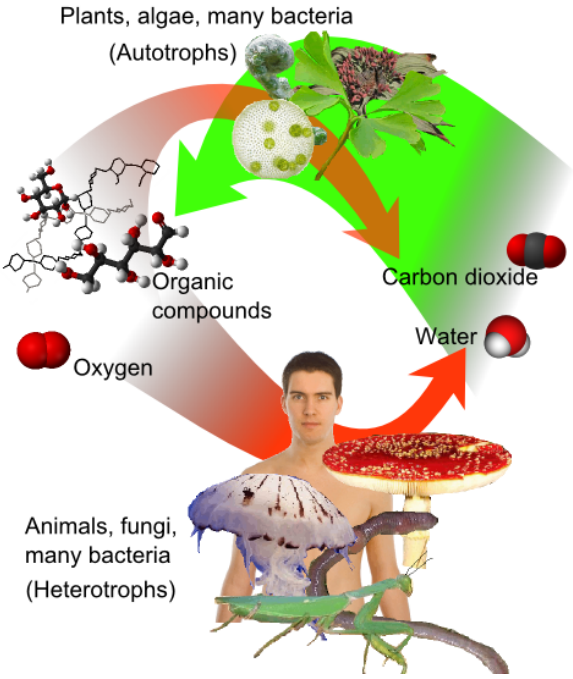
- makes inner mt membrane leak H^+
- “short circuits” oxidative phosphorylation
- diet pills and bug poison

The catabolism of various food molecules



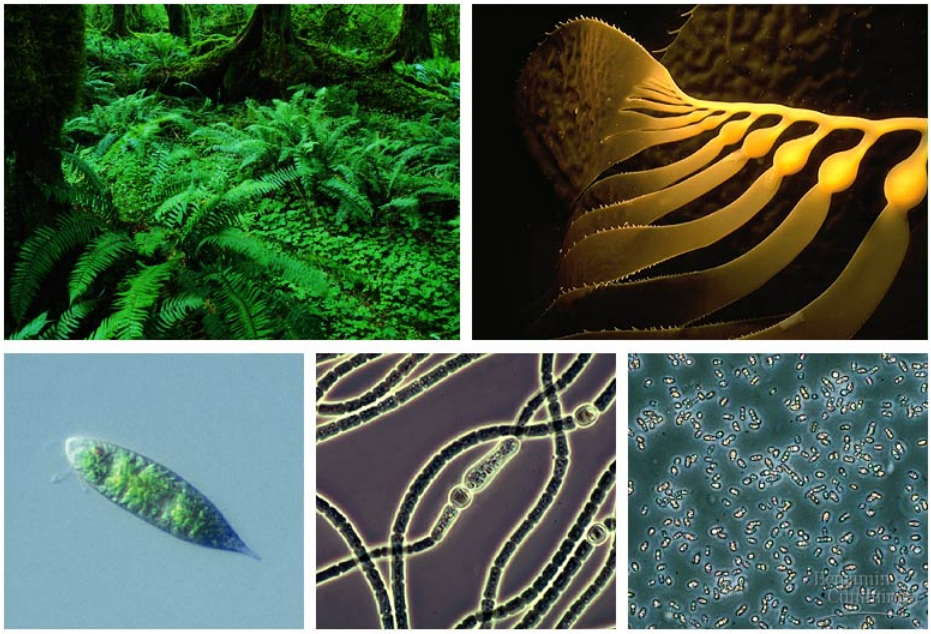
Where your food goes… pathways for products of food catabolism.

What goes in, what comes out, and where



The cycle of materials between autotrophs and heterotrophs

Photoautotrophs



Chemoautotrophs (hydrothermal vent community)

$CO_2 + O_2 + 4H_2S \rightarrow CH_2O + 4S + 3H_2O$

Photosynthesis

- Occurs in some prokaryotes (bacteria, blue-green algae) and in the chloroplasts of eukaryote protists and plants.
- Light drives formation of ATP and NADPH
- These compounds power synthesis of carbohydrate and O_2 using CO_2 as source of C and H_2O as source of H and O

In a net sense, photosynthesis is the reverse of respiration

Photosynthesis

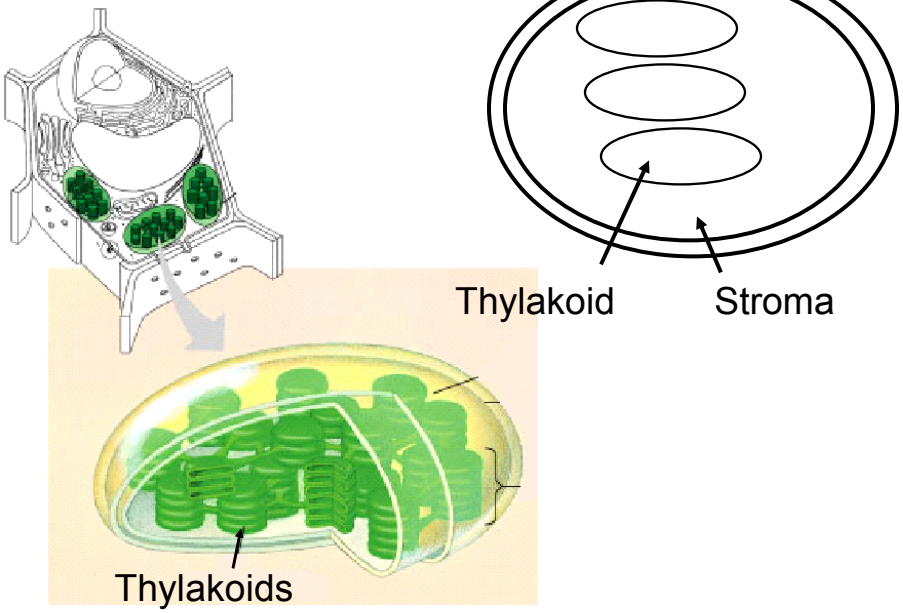
$6(CO_2) + 6(H_2O) + 686 \text{ kcal/mole} \rightarrow C_6H_{12}O_6 + 6(O_2)$

Respiration

$C_6H_{12}O_6 + 6(O_2) \rightarrow 6(CO_2) + 6(H_2O) + 686 \text{ kcal/mole}$

- This is an endergonic process – so it is part of a larger exergonic process.
- The energy for this larger process arrives as certain wavelengths of light.

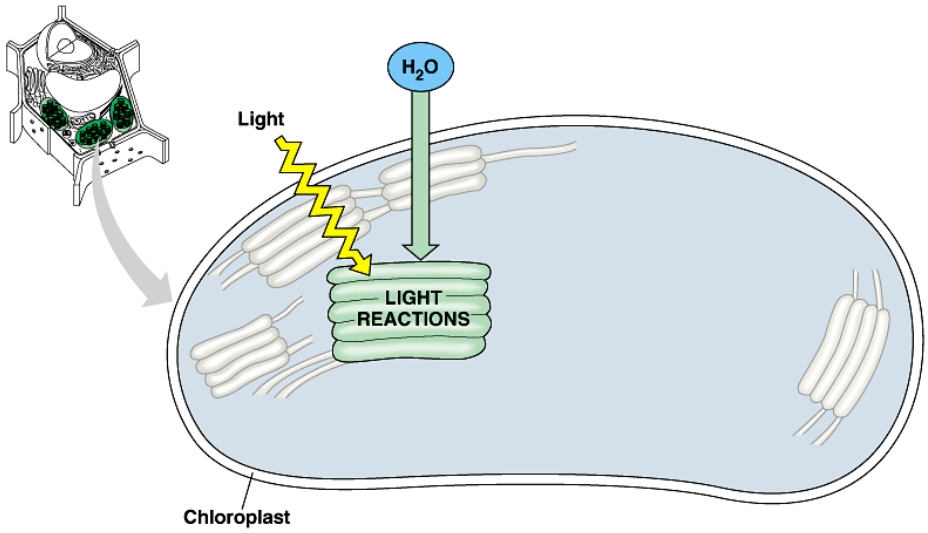
The chloroplast



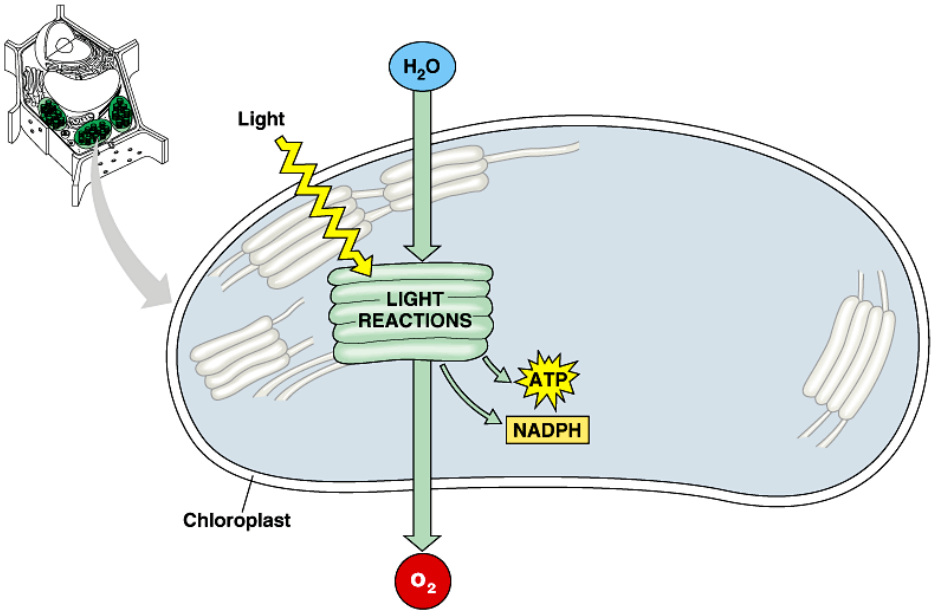
Two stages of photosynthesis

- Light reactions in thylakoids
  - make ATP, NADPH, O_2
  - Mechanisms are photooxidation, proton pumping, ATP synthase
- Dark reactions in stroma (Calvin cycle)
  - use ATP and NADPH
  - convert CO_2 into sugars

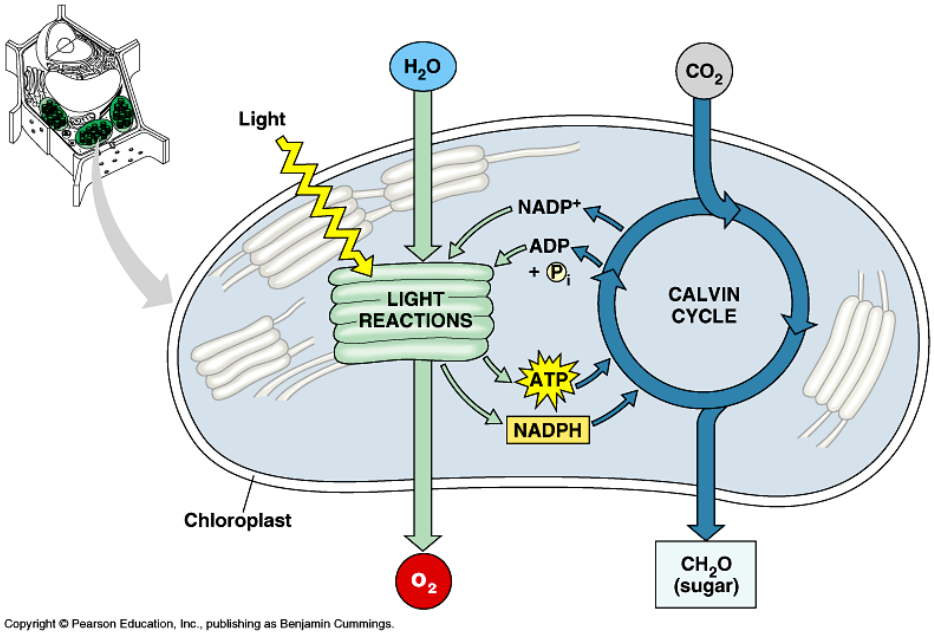
1. Light reactions make ATP, NADPH, O_2



1. Light reactions make ATP, NADPH, O_2



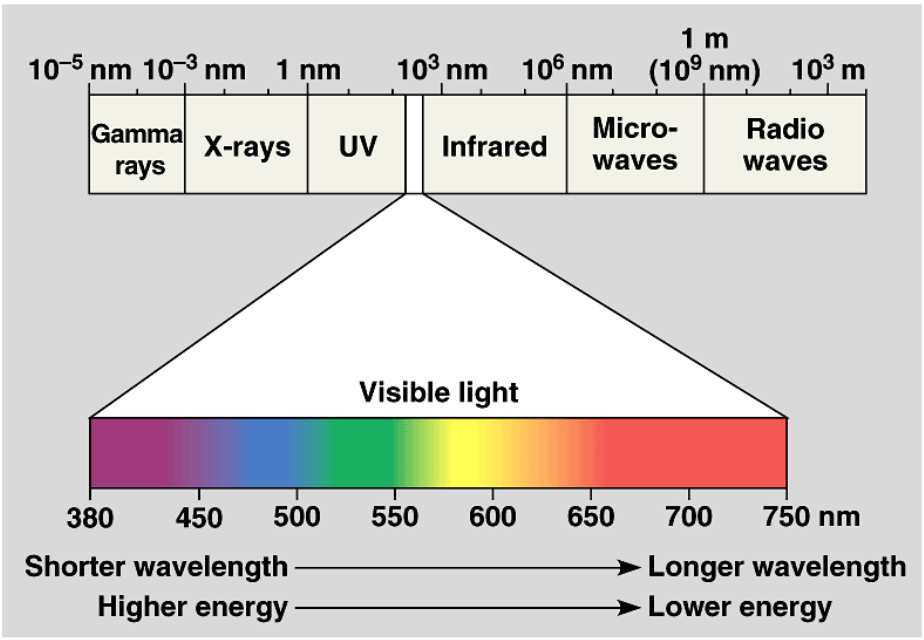
2. Calvin Cycle synthesizes carbohydrate



Electromagnetic energy

- Radiant energy - transmitted through space by electromagnetic particles/waves
- Particles are called 'quanta' or 'photons'
- Quanta have property of wavelength.
- Shorter wavelength = higher energy per quantum.
- Electromagnetic spectrum relates wavelength to forms of radiation

The electromagnetic spectrum



Matter and radiant energy:

Incoming radiant energy can be…

…reflected – (bounce off)

…transmitted – (pass through)

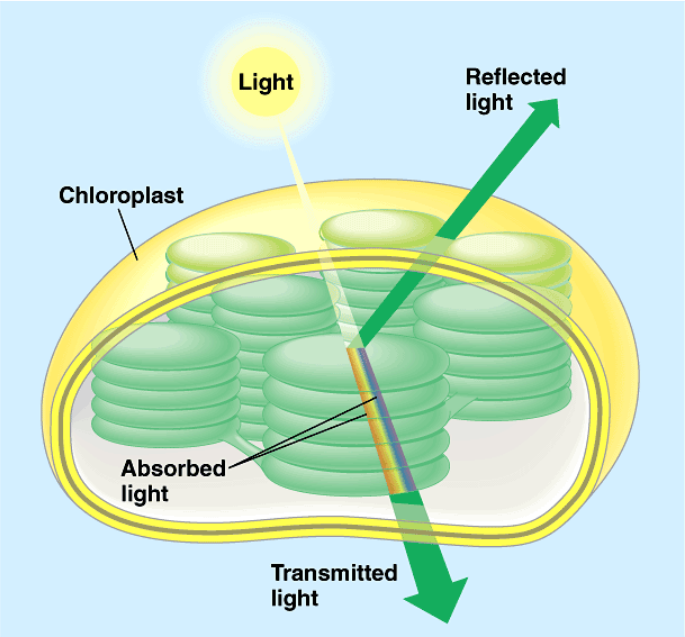
…or it can be absorbed by electrons

Radiant energy that is absorbed can cause chemical reactions via photooxidation

Light & pigments.

- “White light” consists of multiple wavelengths
- A “pigment” is a molecule that absorbs some wavelengths but not all.
- The color of a pigment is the wavelengths that are reflected, transmitted, or emitted.

Why leaves are green



How is light coupled to chemical reactions?

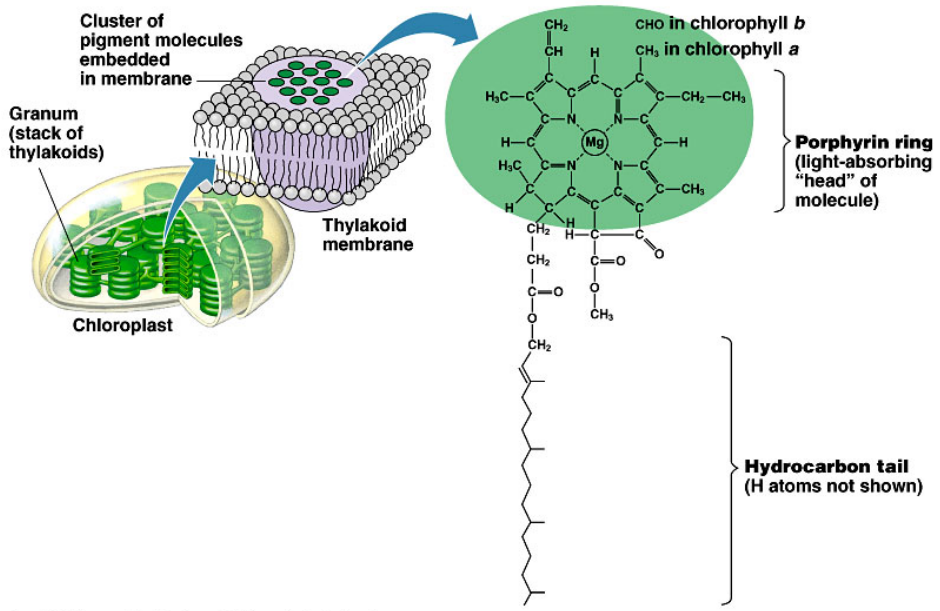
- An electron absorbs a photon of specific wavelength and moves to a higher energy level.
- It may drop back, emitting a photon = fluorescence
- or it may move to another atom, retaining most of the energy = photooxidation

Photooxidation of chlorophyll powers photosynthesis

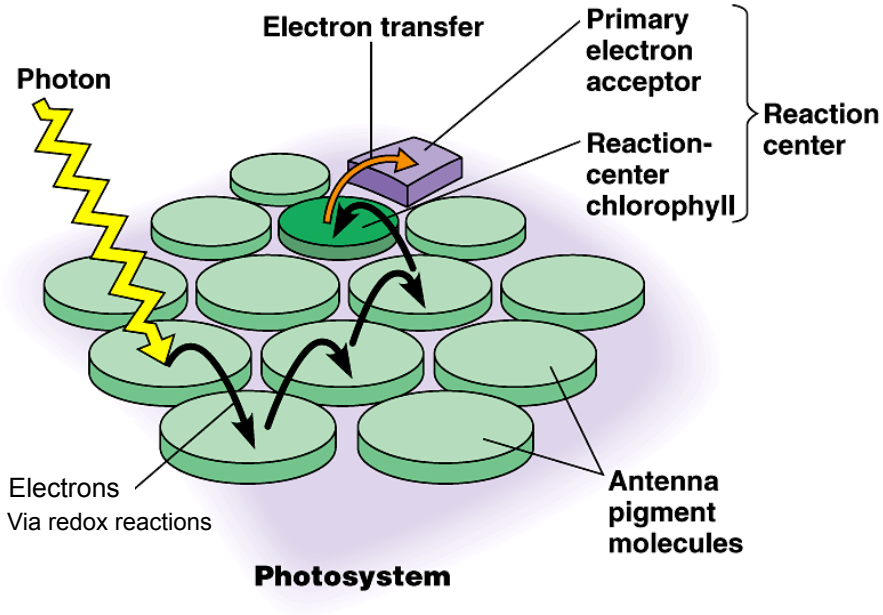
- Light knocks electrons off of chlorophyll
- These electrons reduce other molecules
- They are passed from one molecule to another in an electron transport chain of redox reactions.
- ETC pumps protons & powers ATP synthase to make ATP

- The light reactions also reduce $NADP^+$
  $NADP^+ + H^- \rightarrow NADPH$
- The protons and electrons to reduce $NADP^+$ to NADPH are from water, leaving oxygen
- NADPH supplies H and electrons in the Calvin cycle to combine with CO_2 to produce carbohydrate

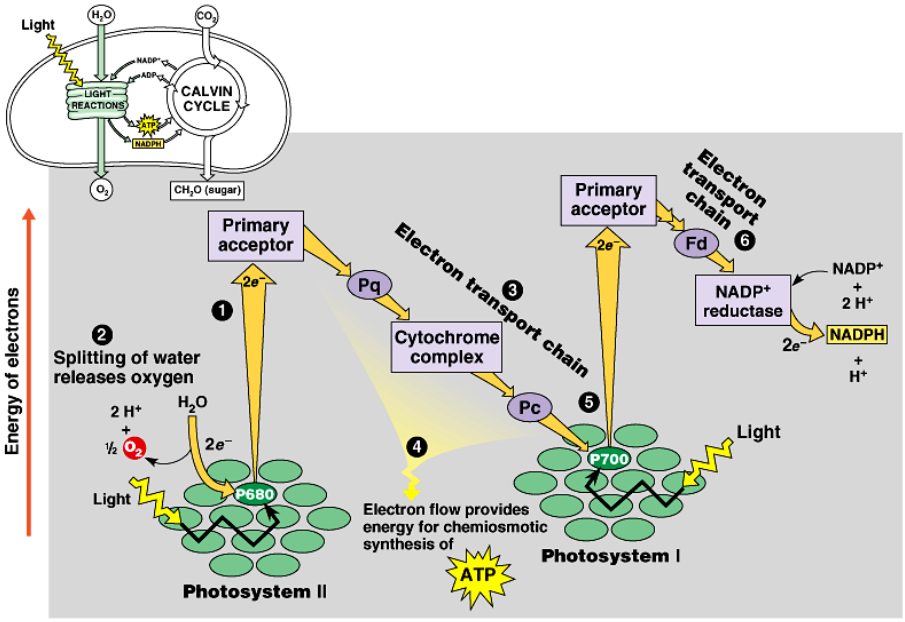
Location and structure of chlorophyll molecules in plants



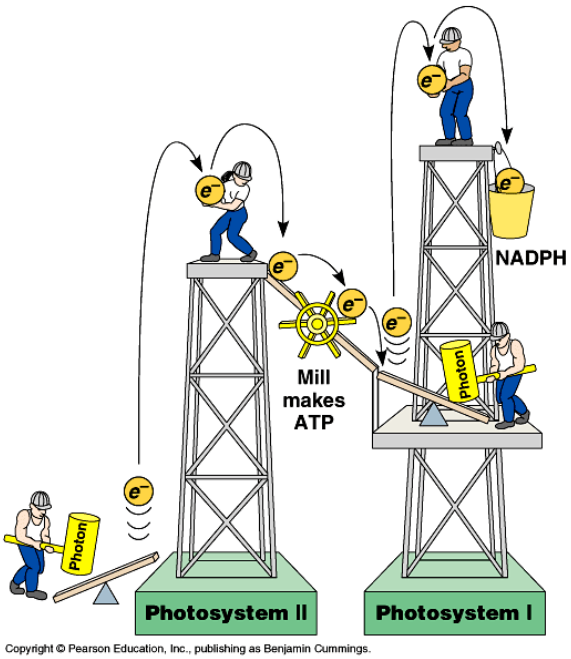
How a photosystem harvests light



Electron flow during the light reactions generates ATP and NADPH



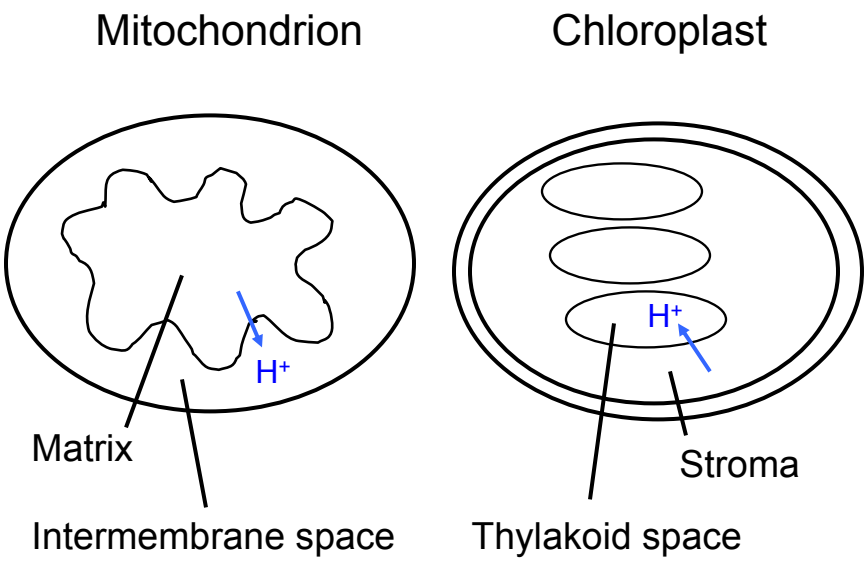
A mechanical analogy for the light reactions



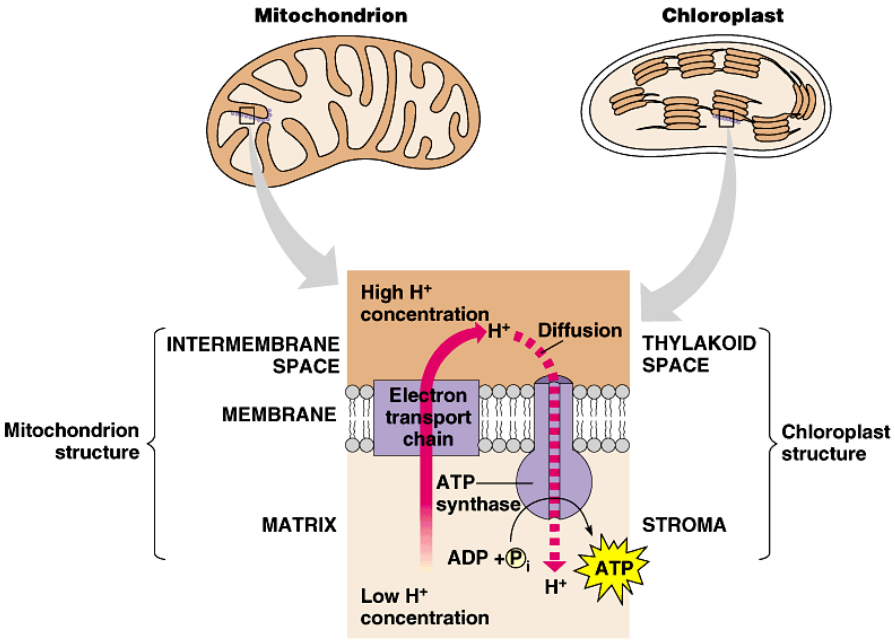
Light reactions.

- occur on the thylakoid membranes
- PII is photooxidized and reduces the ETC, powering ATP synthase to make ATP.
- PI is photooxidized and reduces other proteins that reduce $NADP^+$ to NADPH
- The electrons and H are replaced by splitting water to H^+ and O_2

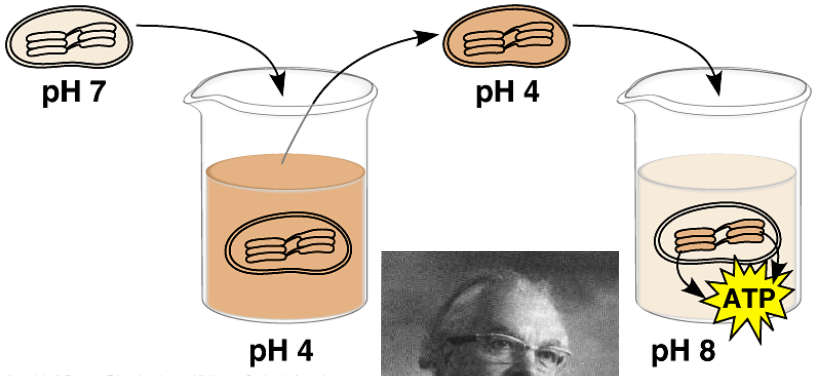
Comparison of inner membranes in mitochondria and chloroplasts

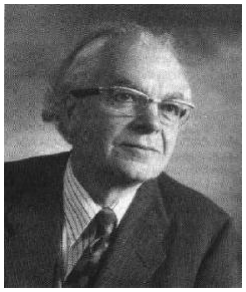


Comparison of chemiosmosis in mitochondria and chloroplasts



Discovery of “chemiosmosis” in ATP synthesis





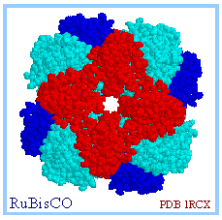
Peter Mitchell 1961
Nobel Prize 1978

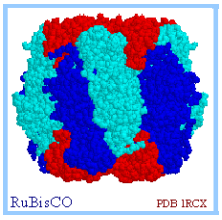
Calvin Cycle ("dark" reactions)

- metabolic pathway that synthesizes sugars
- Uses ATP, and NADPH from the light reactions.
- Takes place in stroma of the chloroplast
- Starts with "CO_2 fixation" …incorporation of CO_2 into organic molecules.

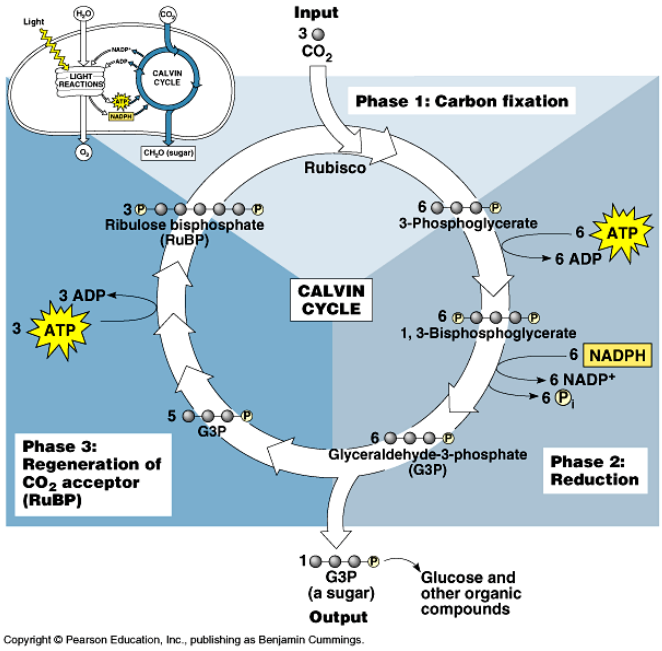
Rubisco

- The enzyme that catalyzes CO_2 fixation, the first reaction in the Calvin cycle.
- It is the most abundant protein on earth. 1/3 of chloroplast protein





The Calvin cycle



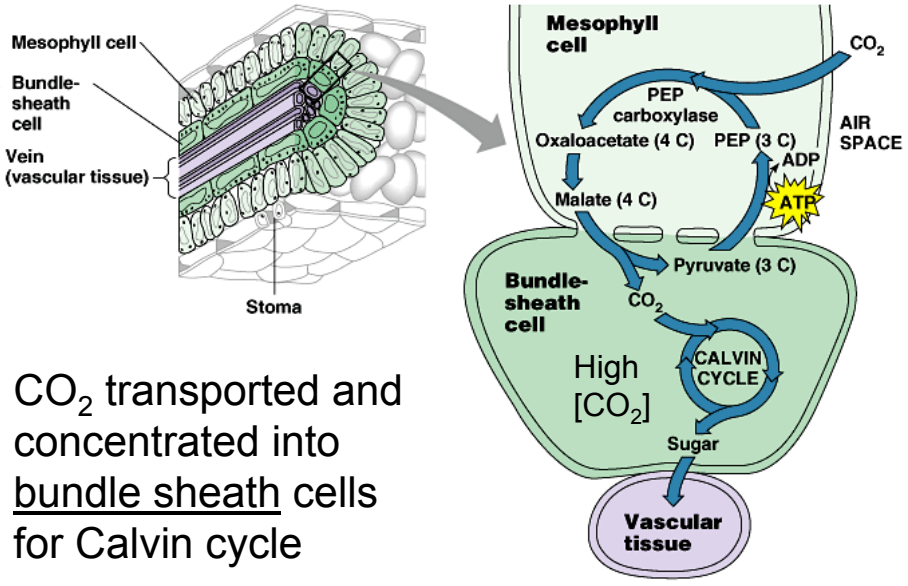
Rubisco and photorespiration

- Rubisco is slow and inefficient – curiously so
- O_2 competes with CO_2 and interferes with CO_2 fixation, inhibits photosynthesis
- Dry or hot conditions lead to water loss, which causes stomate closure, which leads to high O_2 and low CO_2 in the leaf, which leads to photorespiration.

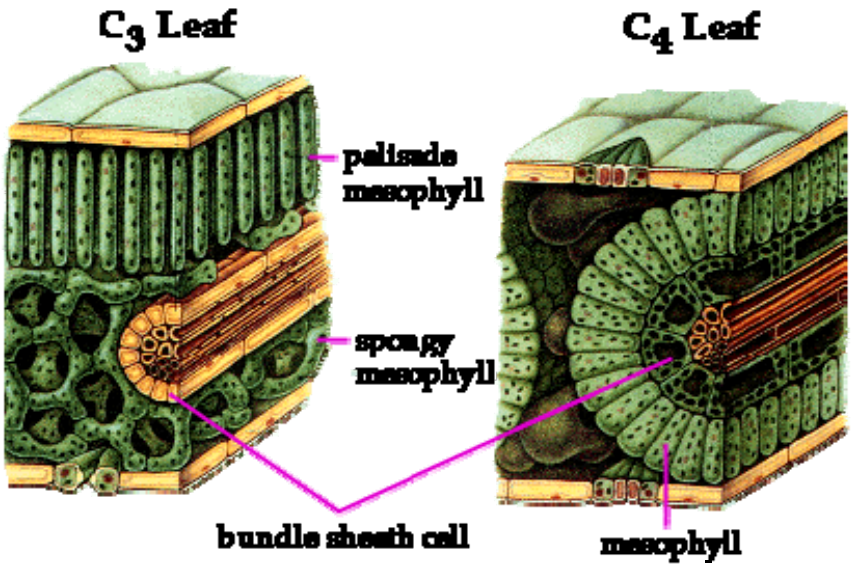
C3 and C4 plants

- C3 plants use rubisco to fix CO_2 ,and produce 3-carbon compounds
- C4 plants use PEP carboxylase to fix CO_2 into a 4-carbon compound before Calvin cycle
- PEP carboxylase not limited by O_2
- C4 plants also have special leaf anatomy to separate CO_2 fixation and Calvin cycle.

C_4 leaf anatomy and the C_4 pathway



CO_2 transported and concentrated into bundle sheath cells for Calvin cycle



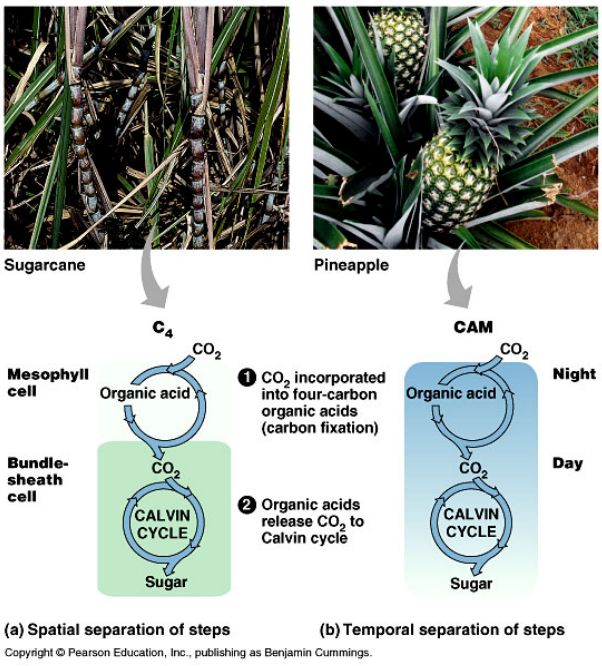
C3, C4, CAM plants

- Most plants are C3 e.g. rice, wheat, oats, soybeans, and potatoes
- At least 8,000 species are C4, including most grasses, corn, sorghum, agaves
- CAM plants are mainly desert-adapted succulents- cacti, etc

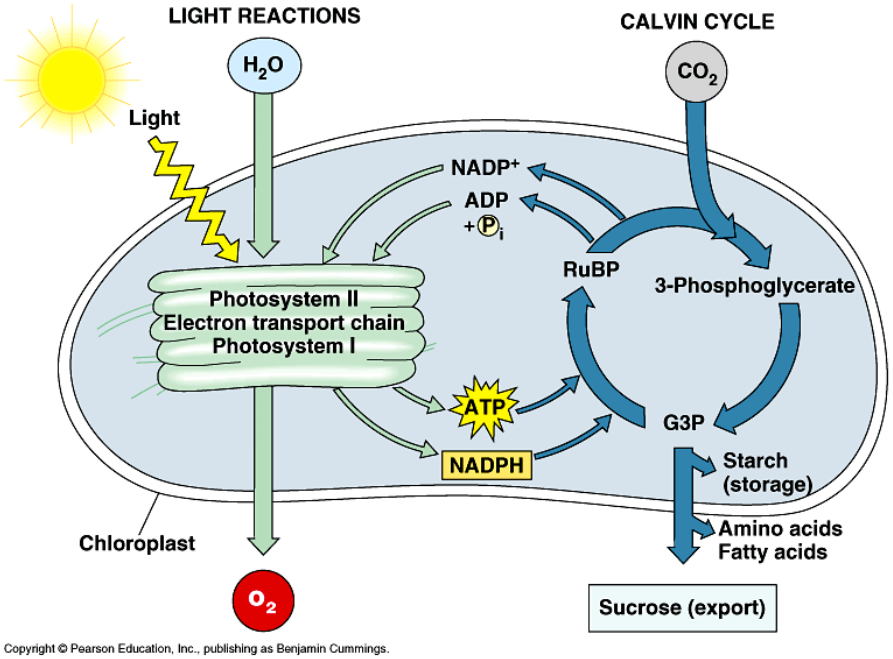
CAM plants

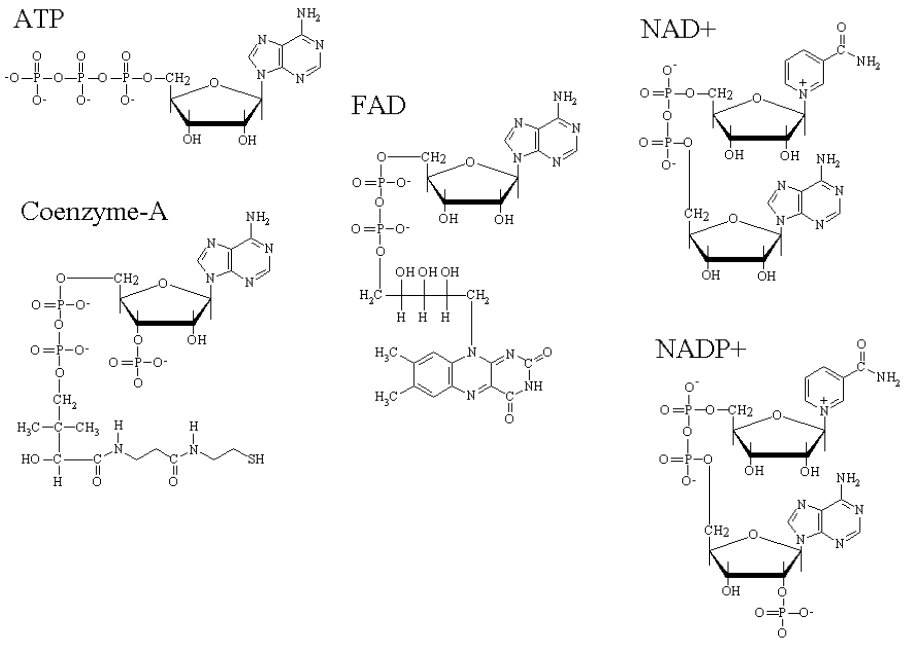
- Crassulacean Acid Metabolism
- Timing (rather than anatomy) separates carbon fixation from the Calvin cycle.
- Stomates open at night, CO_2 is fixed by PEP carboxylase into malate, which is stored in vacuoles
- During the day, stomates close, CO_2 is released from malate for rubisco to use

C_4 and CAM photosynthesis compared

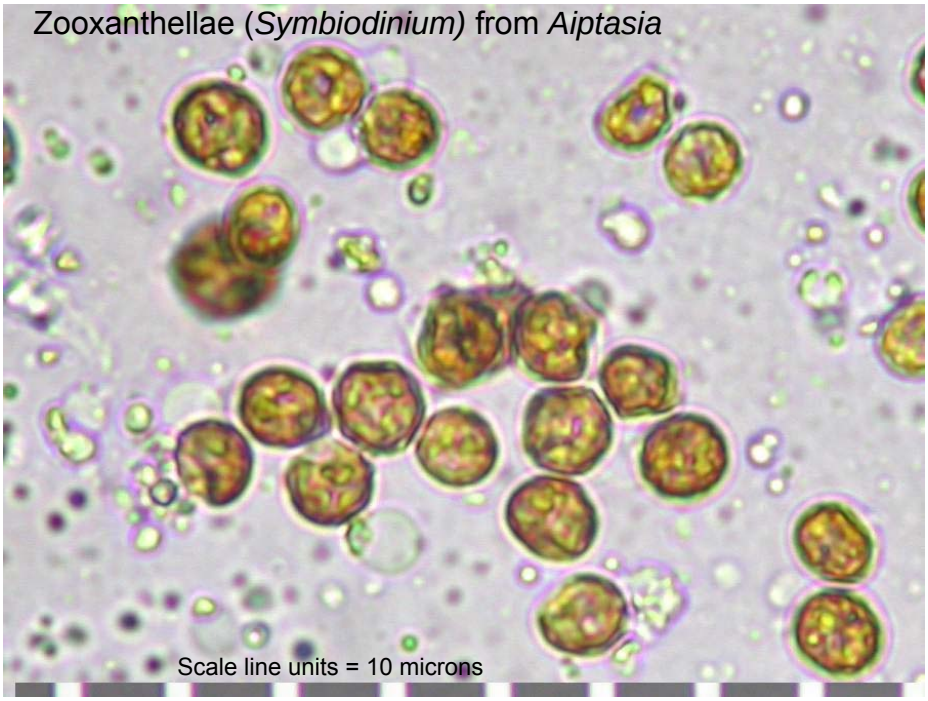


A review of photosynthesis



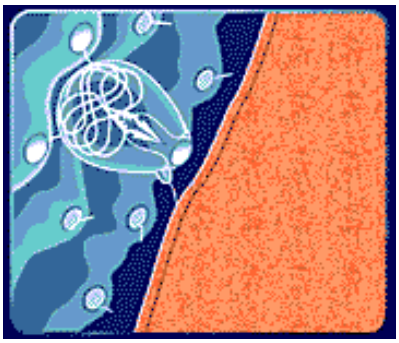


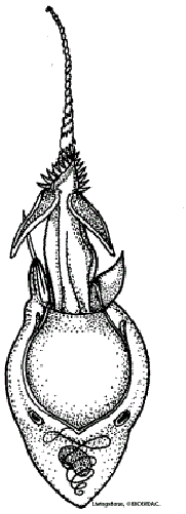

Aiptasia pallida

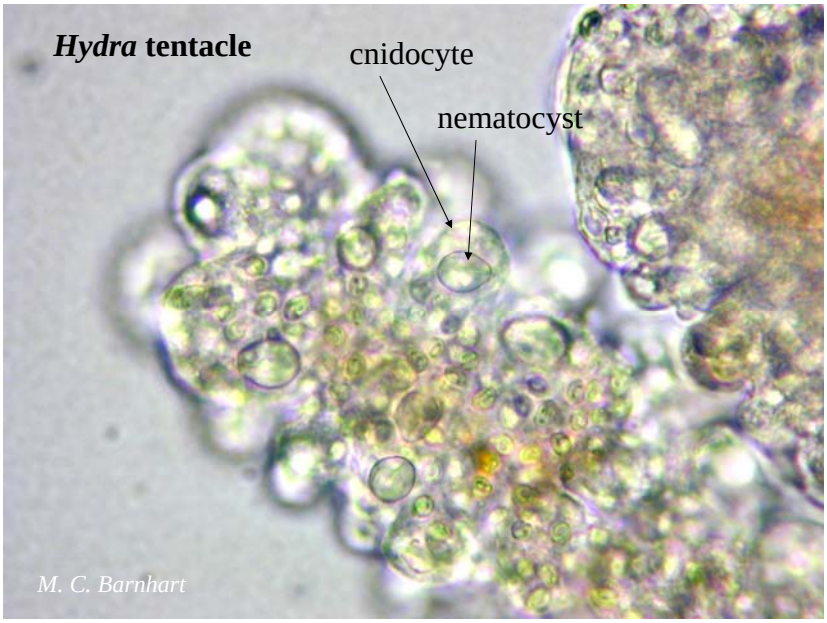

Zooxanthellae (*Symbiodinium)* from *Aiptasia*
Scale line units = 10 microns

Nematocysts

Stinging organelles found in all Cnidarians







Borrowed weapons

Aeolids feed on cnidarians and store the functional nematocysts at the tips of their cerata in cnidosacs

Each ceras contains a branch of the digestive gland. A duct connects the cnidosac to the digestive gland.


Stained section of cnidosac showing nematocysts at tip

Solar-powered Opisthobranchs

Left: sacoglossan *Placida* showing network of ducts containing green chloroplasts from its algal food.

Right: aeolid nudibranch *Pteraeolidia* "farms" colonies of brown single-celled algae (zooxanthellae) in its cerata (stolen from cnidarian prey).