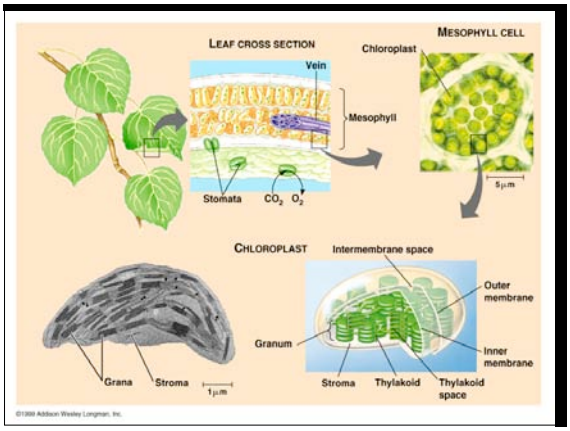
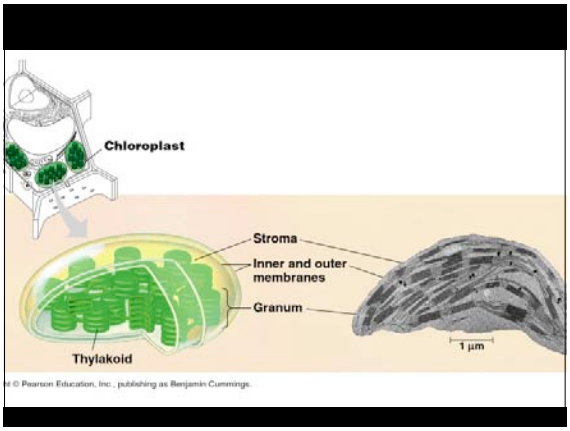
Photosynthesis

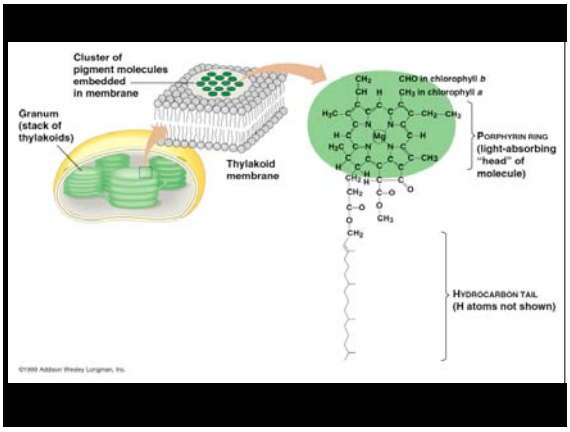
- Photsynthesis in eukaryotes takes place in chloroplasts
- Mesophyll is a layer of cells in plant leaves and stems. Mesophyll cells contain many chloroplasts.
- Chloroplasts contain chlorophyll, a light absorbing molecule

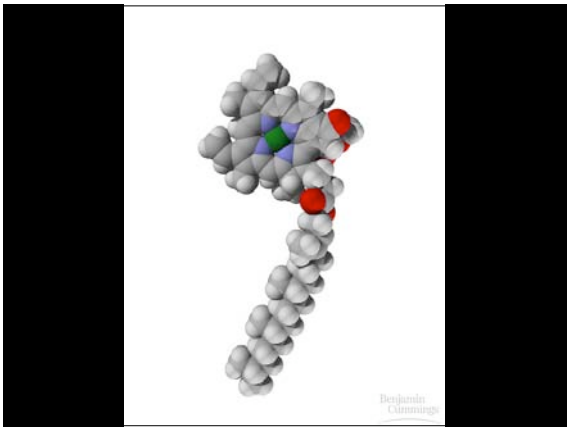


The chloroplast has a double membrane

- Thylakoids are small coin-shaped structures made of membrane
- The thylakoid membrane encloses the thylakoid space
- Stacks of thylakoids are known as grana
- Outside the thylakoids is the stroma
- Chlorphyll and other pigments are embedded in the thylakoid membrane



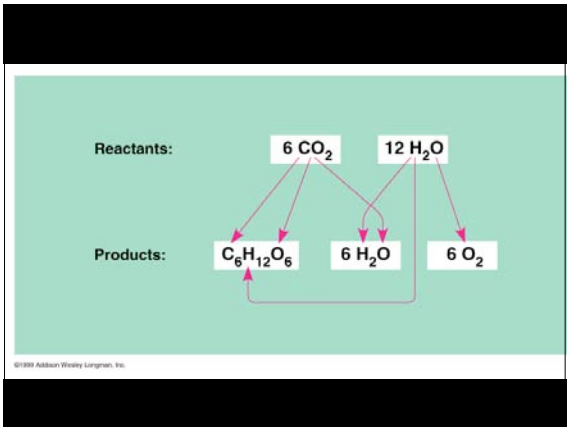




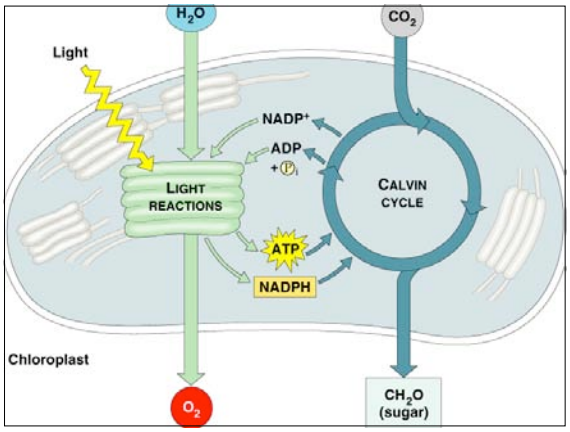
Photosynthesis is the conversion of light energy to chemical bond energy

$6\ CO_2 + 6\ H_2O + \text{energy} \rightarrow C_6H_{12}O_2 + 6\ O_2$

(compare with aerobic respiration)



Photosynthesis can be divided into the light-dependent reactions and the carbon fixation (light independent) reactions.

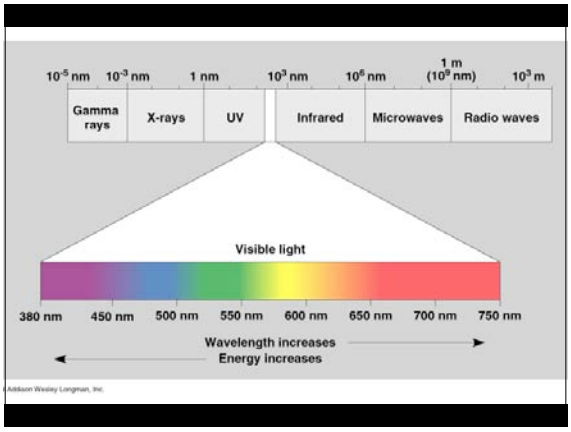


Overview of Light-dependent reactions

- The *Light-dependent reactions form* ATP and NADPH
  - Reactions occur at the thylakoid membrane
  - Energy from light causes chlorophyll to expel a high-energy electron
  - High energy electron powers ATP synthesis (by "photophosphorylation") and *may* reduce $NADP^+$ to NADPH

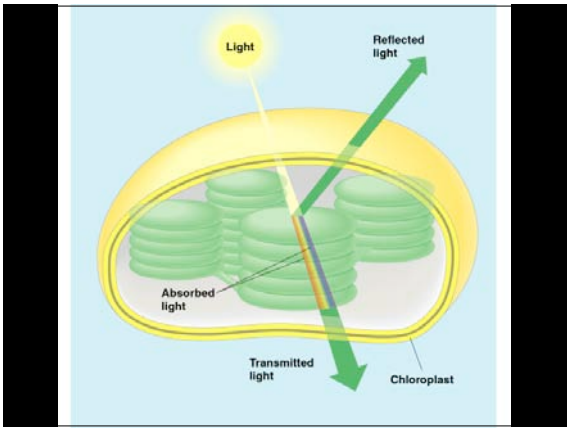
L.D.R., background

- Light is composed of photons, particles that travel as waves
- Photons with short wavelength have higher energy
- The visible light spectrum ranges from 380-760nm
- Photosynthetic pigments respond to photons within the visible light spectrum
- When photons collide with a pigment molecule, they raise an electron to an excited state



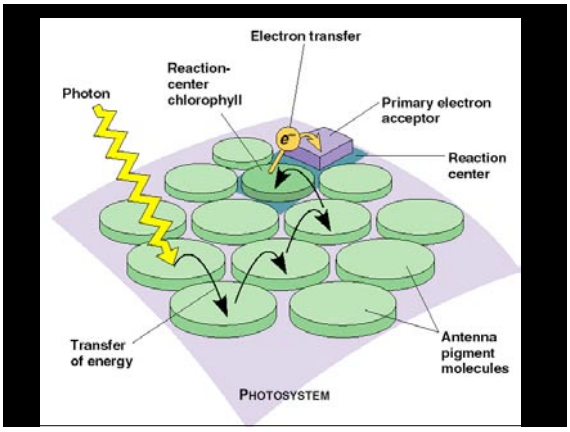
LDR, cont.

- Chlorophyll is the main photosynthetic pigment, and it absorbs red and blue light
- Carotenoids are accessory pigments, which absorb different wavelengths than chlorophyll



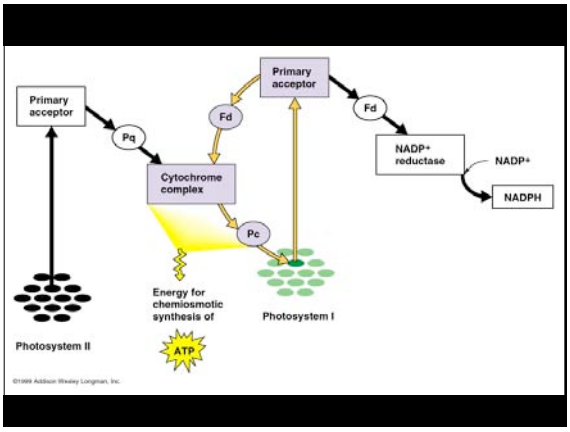
Photosystems

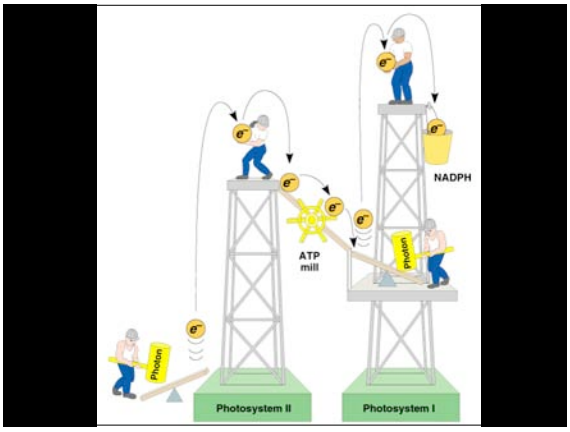
- Pigment molecules are aggregated into "antenna complexes" on the surface of the thylakoid membrane
- A photosystem includes antenna complexes and electron acceptor molecules.

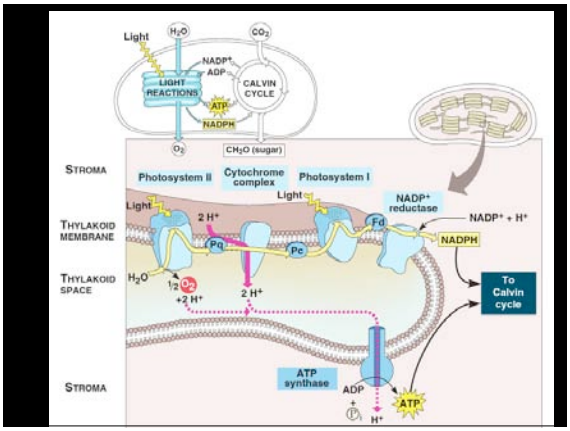


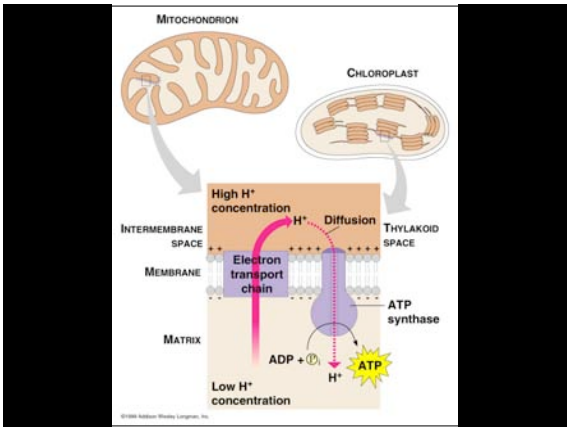
LDR

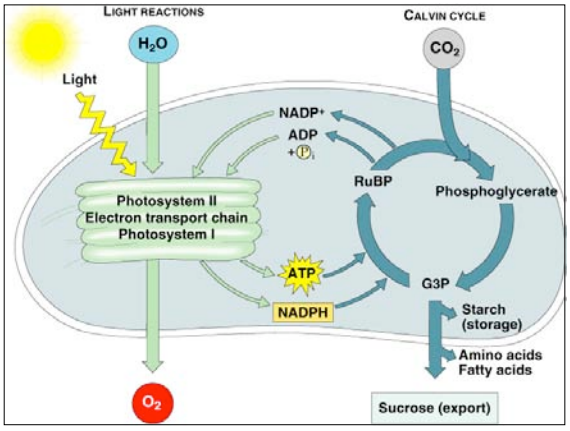
- In the light-dependent reactions, excited electrons coming out of a photosystem are passed through an electron transport chain in the thylakoid membrane that produces ATP (by chemiosmosis - *just like in cellular respiration!*).
- This kind of ATP synthesis is called photophosphorylation because driven by light.
- Some excited electrons are passed to NADP+ and leave the system
- Cyclic vs. noncyclic photophosphorylation





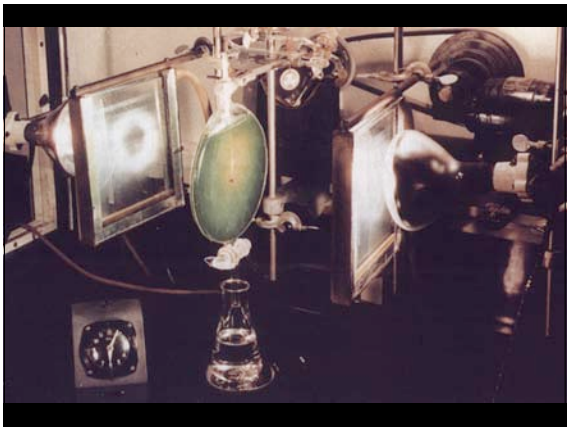


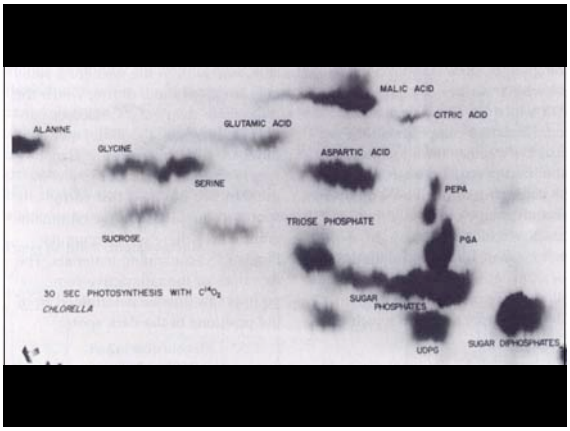


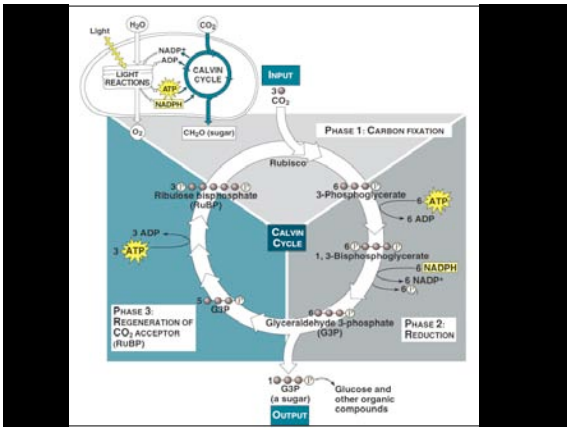


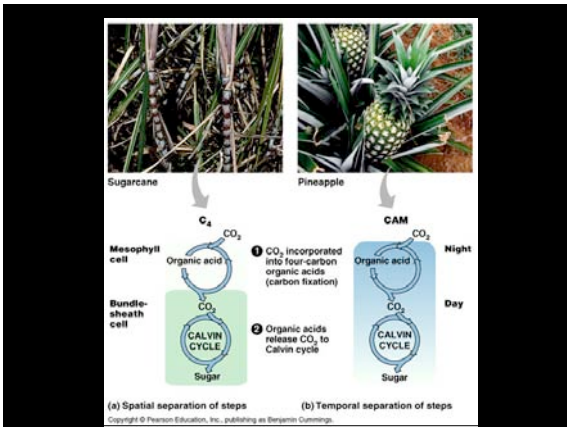
Carbon Fixation Reactions

- The carbon fixation reaction create carbohydrates from CO2 and water
- These reactions occur in the stroma of the chloroplast
- Driven not by light, but by products of light-dependent reactions




MALIC ACID
CITRIC ACID
ALANINE
GLUTAMIC ACID
GLYCINE
ASPARTIC ACID
SERINE
PEPA
TRIOSE PHOSPHATE
SUCROSE
PGA
30 SEC PHOTOSYNTHESIS WITH $C^{14}O_2$
CHLORELLA
SUGAR PHOSPHATES
UDPG
SUGAR DIPHOSPHATES


Light
H_2O
CO_2
NADP+
ADP
LIGHT REACTIONS
CALVIN CYCLE
ATP
NADPH
INPUT
3 CO_2
O_2
CH_2O (sugar)
PHASE 1: CARBON FIXATION
Rubisco
3 Ribulose bisphosphate (RuBP)
6 3-Phosphoglycerate
6 ATP
6 ADP
3 ADP
3 ATP
CALVIN CYCLE
6 1, 3-Bisphosphoglycerate
6 NADPH
6 NADP+
6 P
5 G3P
PHASE 3: REGENERATION OF CO_2 ACCEPTOR (RuBP)
6 Glyceraldehyde-3-phosphate (G3P)
PHASE 2: REDUCTION
1 G3P (a sugar)
Glucose and other organic compounds
OUTPUT


Sugarcane
Pineapple
C_4
CAM
CO_2
Mesophyll cell
Organic acid
1 CO_2 incorporated into four-carbon organic acids (carbon fixation)
Night
Bundle-sheath cell
Day
2 Organic acids release CO_2 to Calvin cycle
CALVIN CYCLE
Sugar
(a) Spatial separation of steps
(b) Temporal separation of steps
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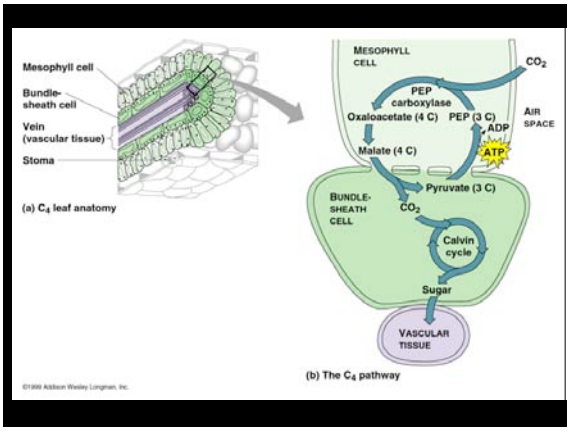
Mesophyll cell
Bundle-sheath cell
Vein (vascular tissue)
Stoma
(a) C_4 leaf anatomy
MESOPHYLL CELL
CO_2
PEP carboxylase
Oxaloacetate (4 C)
PEP (3 C)
ADP
ATP
AIR SPACE
Malate (4 C)
Pyruvate (3 C)
BUNDLE-SHEATH CELL
CO_2
Calvin cycle
Sugar
VASCULAR TISSUE
(b) The C_4 pathway
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