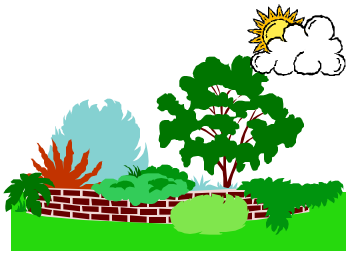
Fig. 10.1

Capturing Energy

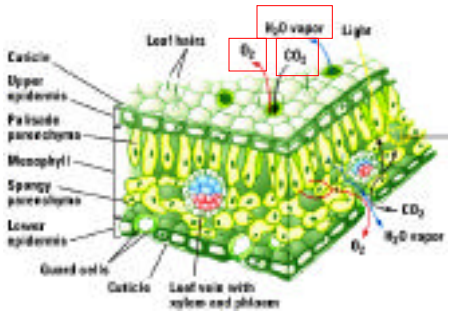
Photosynthesis:
How do organisms get energy from the sun?

Autotrophic organisms

✓Carbon dioxide
✓Water
✓Sunlight



Leaf structure



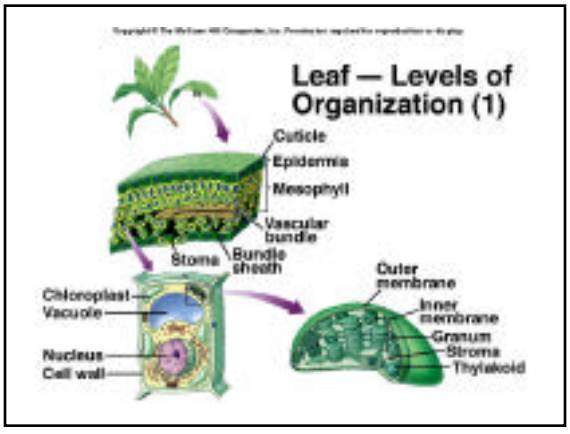
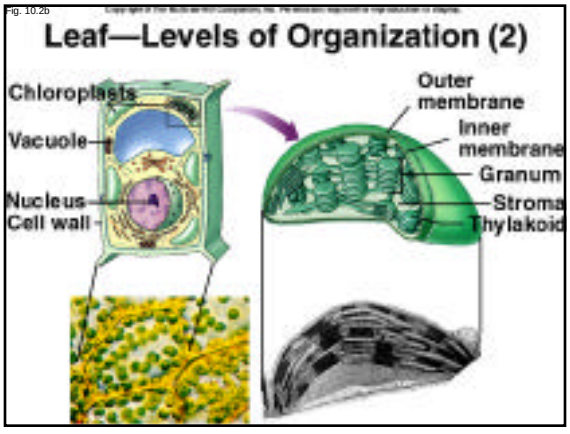
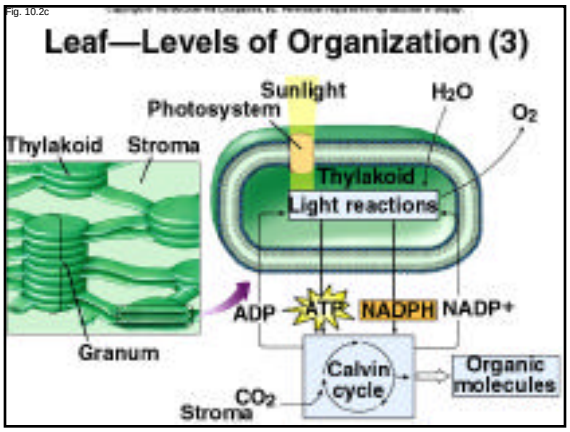
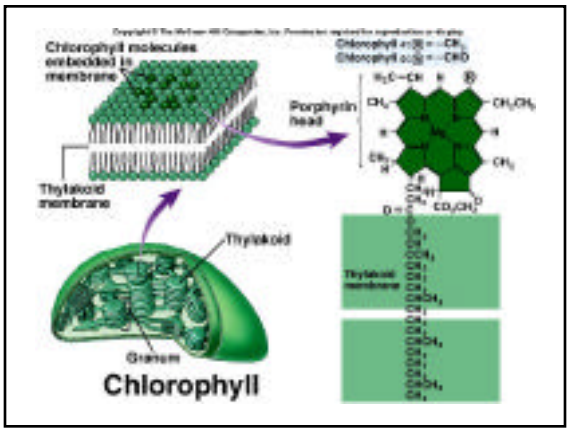


Fig. 10.2b

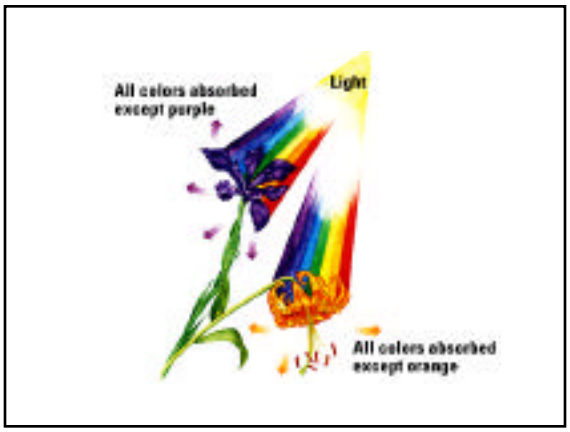






Photosynthesis

$$6CO_2 + 6H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$


All colors absorbed except purple
Light
All colors absorbed except orange

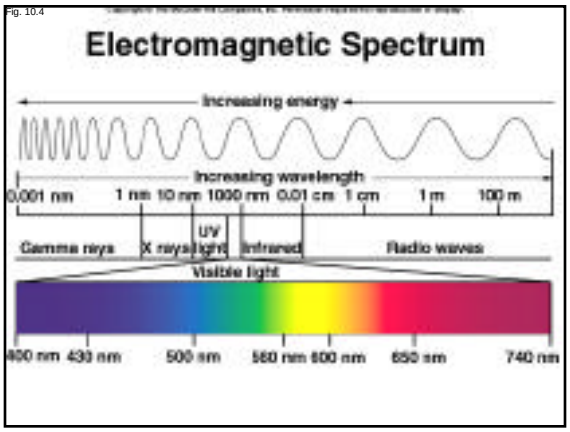


Fig. 10.4
Electromagnetic Spectrum
Increasing energy
Increasing wavelength
0.001 nm
1 nm
10 nm
1000 nm
0.01 cm
1 cm
1 m
100 m
UV light
Gamma rays
X rays
Infrared
Radio waves
Visible light
400 nm
430 nm
500 nm
560 nm
600 nm
650 nm
740 nm

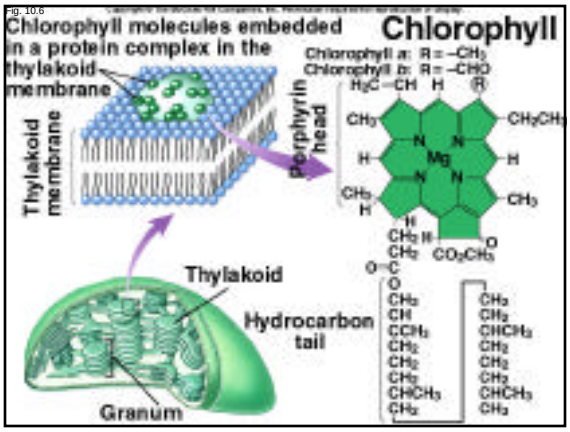


Fig. 10.6
Chlorophyll molecules embedded in a protein complex in the thylakoid membrane
Chlorophyll
Chlorophyll a: R = –CH3
Chlorophyll b: R = –CHO
Thylakoid membrane
Porphyrin head
Thylakoid
Hydrocarbon tail
Granum

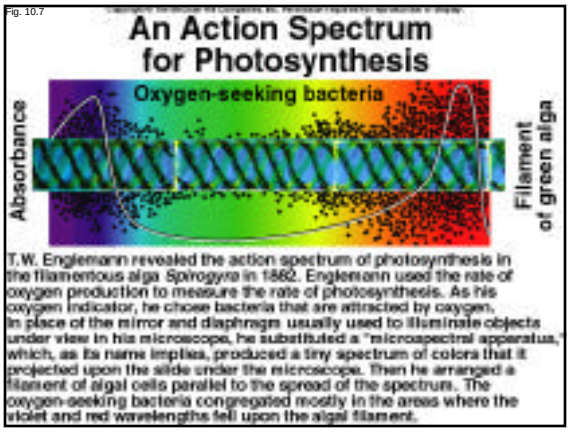


Fig. 10.7
An Action Spectrum for Photosynthesis
Oxygen-seeking bacteria
Absorbance
Filament of green alga
T.W. Engelmann revealed the action spectrum of photosynthesis in the filamentous alga Spirogyra in 1882. Engelmann used the rate of oxygen production to measure the rate of photosynthesis. As his oxygen indicator, he chose bacteria that are attracted by oxygen. In place of the mirror and diaphragm usually used to illuminate objects under view in his microscope, he substituted a "microspectral apparatus," which, as its name implies, produced a tiny spectrum of colors that it projected upon the slide under the microscope. Then he arranged a filament of algal cells parallel to the spread of the spectrum. The oxygen-seeking bacteria congregated mostly in the areas where the violet and red wavelengths fell upon the algal filament.

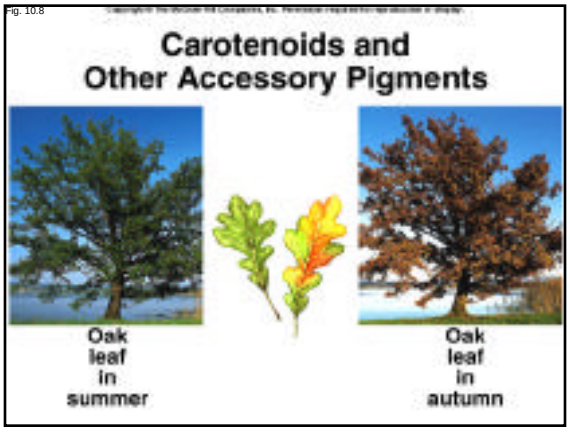


Fig. 10.8
Carotenoids and Other Accessory Pigments
Oak leaf in summer
Oak leaf in autumn

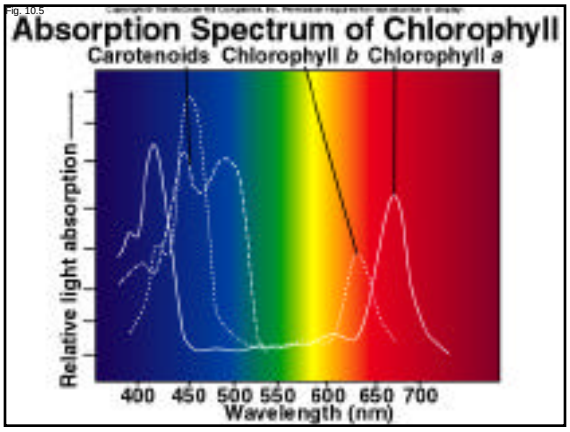
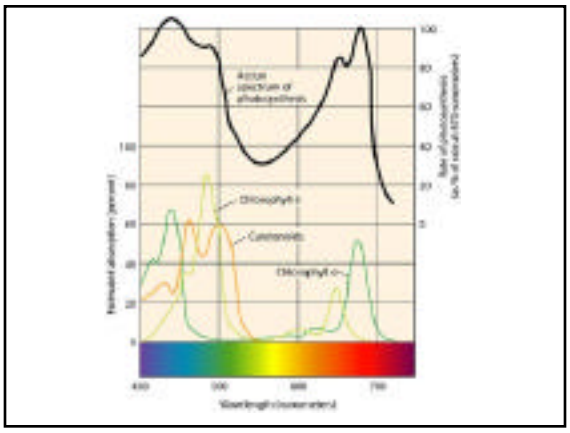
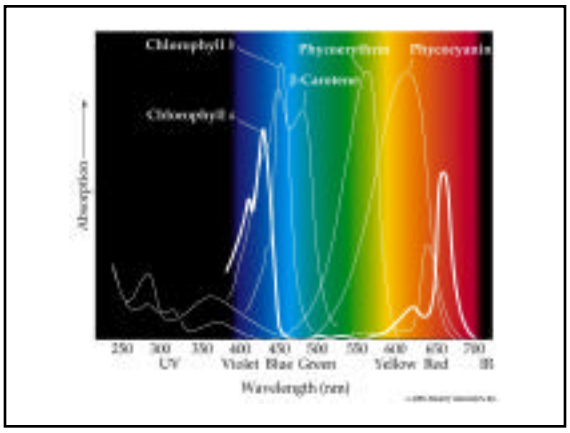
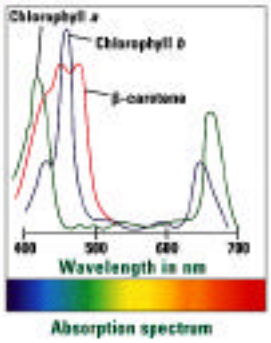


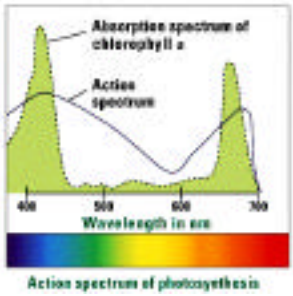
Fig. 10.5
Absorption Spectrum of Chlorophyll
Carotenoids
Chlorophyll b
Chlorophyll a
Relative light absorption
400
450
500
550
600
650
700
Wavelength (nm)



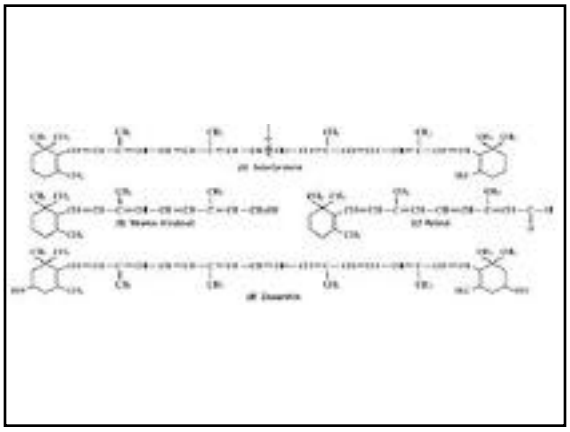


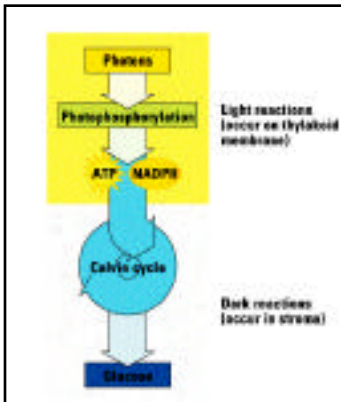


Chlorophyll absorbs red and blue photons



Other pigments (orange/yellow carotenoids) absorb light (blue/green) energy. It is transferred to chlorophyll





Photosynthesis occurs in light reactions and dark reactions

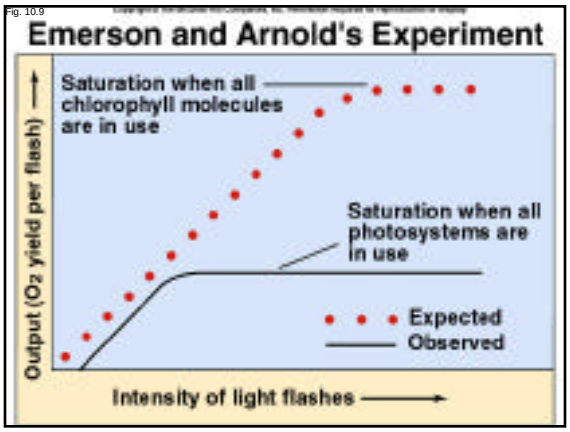


Fig. 10.9
Emerson and Arnold's Experiment
Saturation when all chlorophyll molecules are in use
Saturation when all photosystems are in use
Expected
Observed
Output (O_2 yield per flash)
Intensity of light flashes

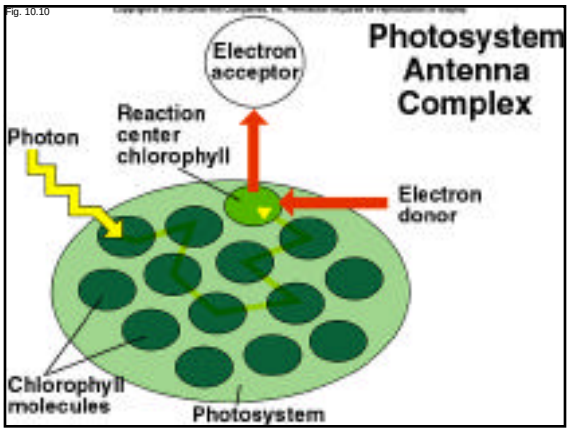


Fig. 10.10
Photosystem Antenna Complex
Electron acceptor
Reaction center chlorophyll
Photon
Electron donor
Chlorophyll molecules
Photosystem

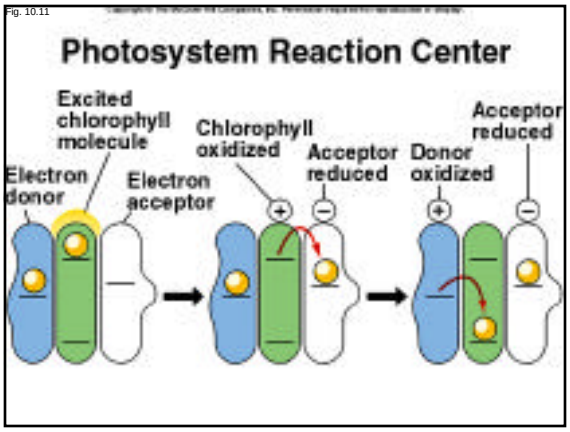


Fig. 10.11
Photosystem Reaction Center
Excited chlorophyll molecule
Electron donor
Electron acceptor
Chlorophyll oxidized
Acceptor reduced
Donor oxidized
Acceptor reduced

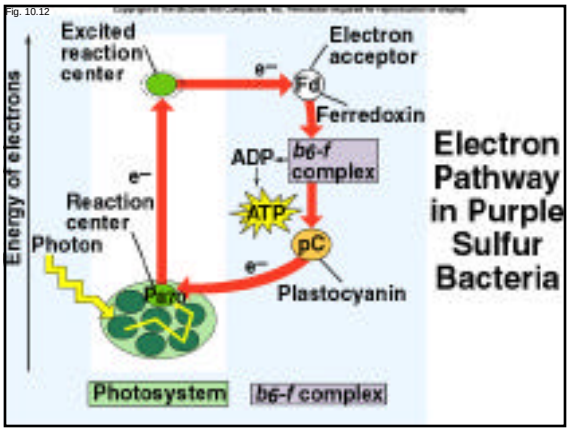
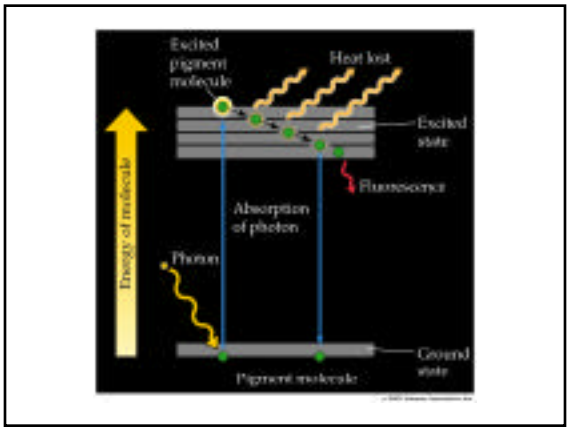


Fig. 10.12
Excited reaction center
Electron acceptor
Fd
Ferredoxin
ADP
b6-f complex
ATP
pC
Plastocyanin
Reaction center
Photon
Energy of electrons
Electron Pathway in Purple Sulfur Bacteria
Photosystem
b6-f complex


Excited pigment molecule
Heat lost
Excited state
Fluorescence
Absorption of photon
Photon
Energy of molecule
Ground state
Pigment molecule

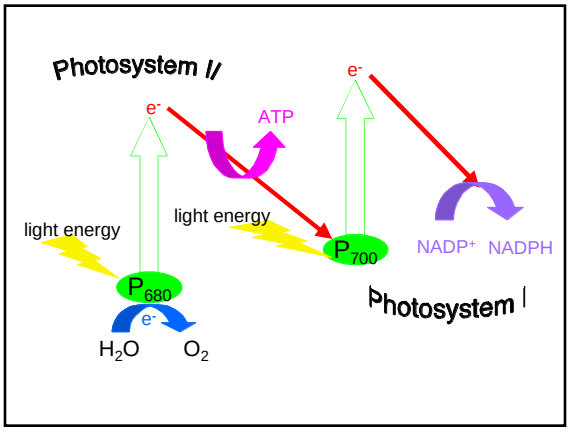

Photosystem II
e-
ATP
light energy
light energy
e-
P700
NADP+ NADPH
P680
e-
H2O
O2
Photosystem I

Fig. 10.14

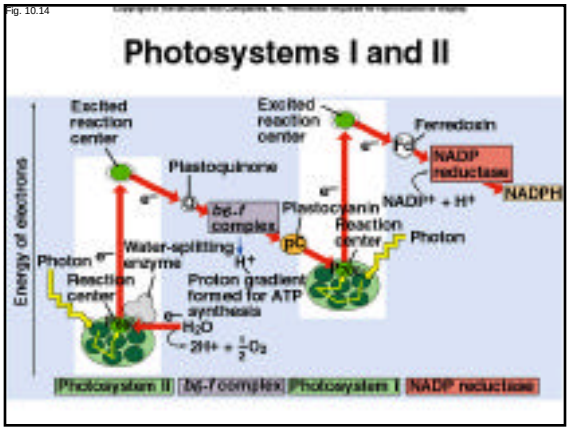


Fig. 10.13

Two photosystems working together

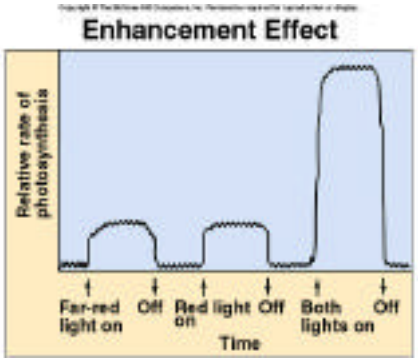
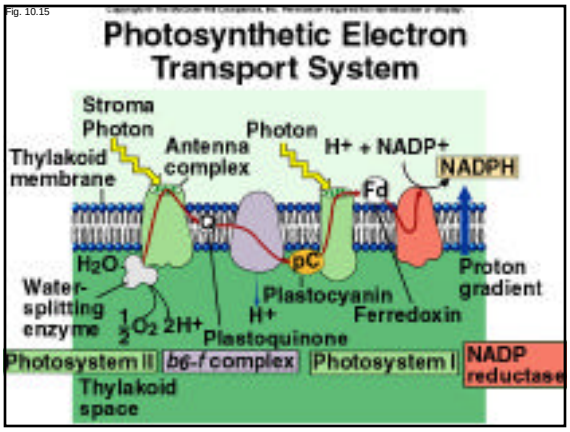
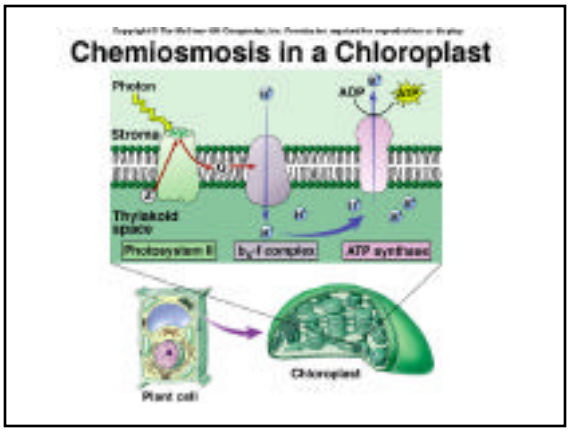
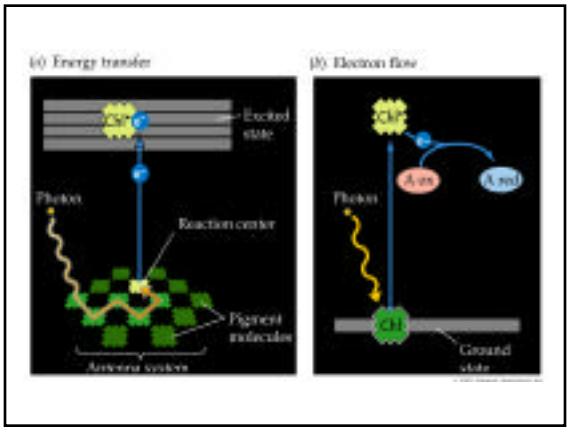
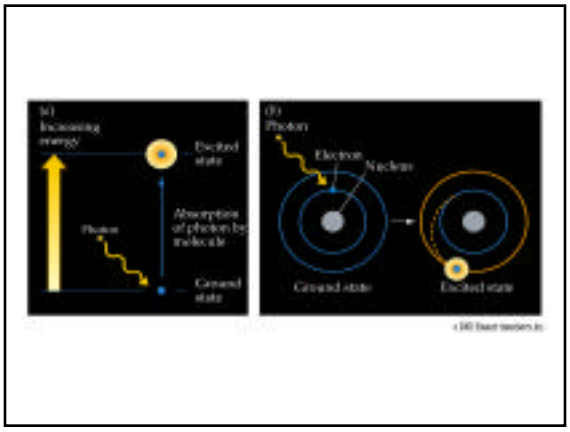


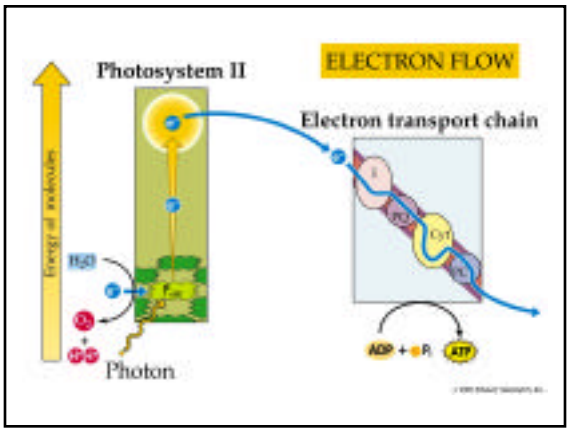
Fig. 10.15

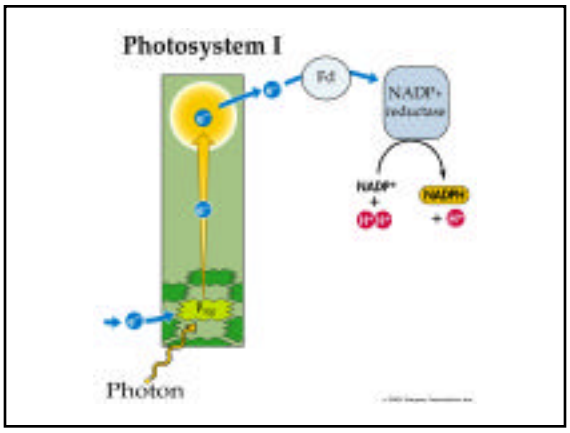


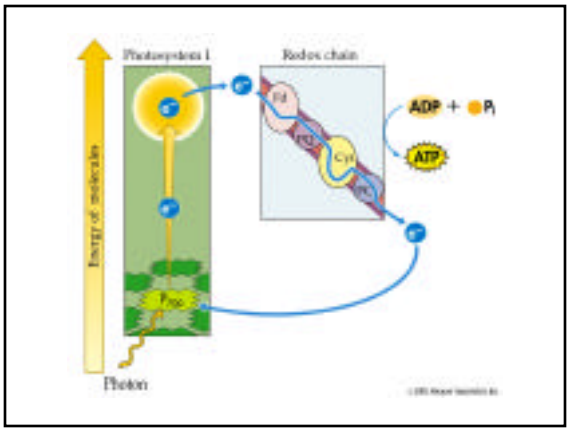


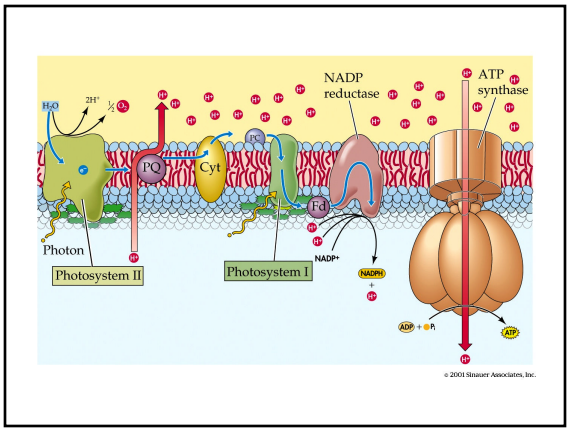






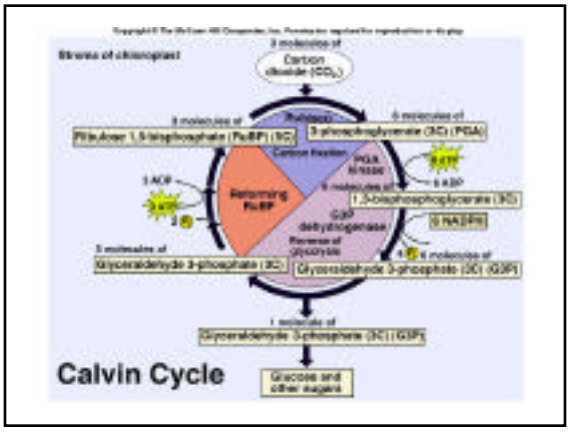


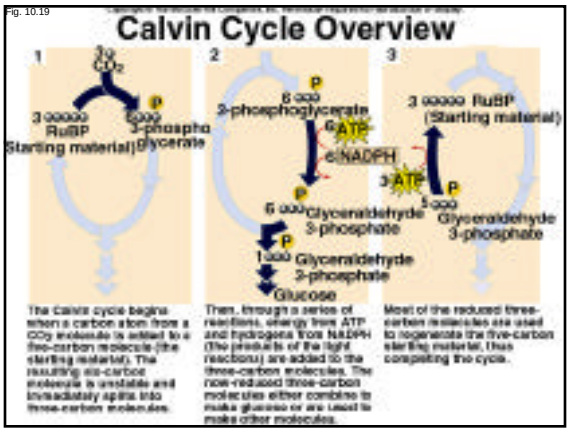


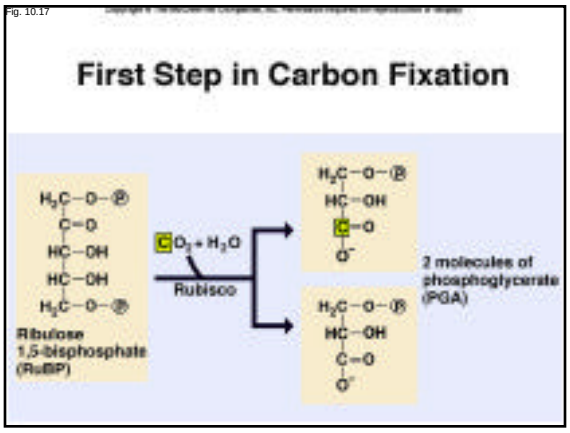


Light-dependent reactions

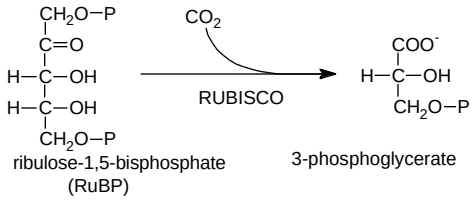
- ✓Occur in thylakoid membranes.
- ✓Photosystem II generates ATP using a proton motive force.
- ✓Photosystem I provides high energy electrons to $NADP^+$ to produce NADPH.
- ✓ATP and NADPH are used in the dark (light independent) reactions.



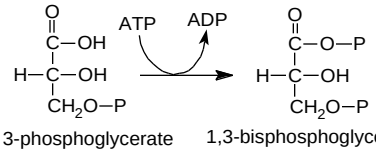




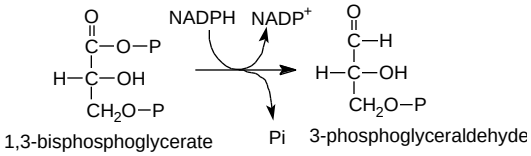
Dark reactions I: Carbon fixation



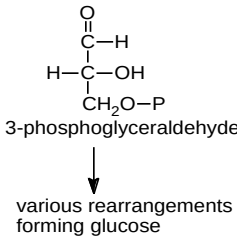
Activating the carbon chain



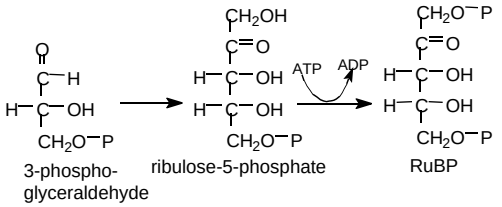
Reducing 3-PGA

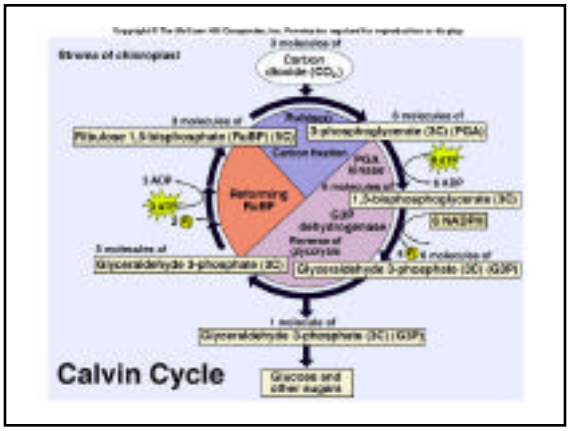


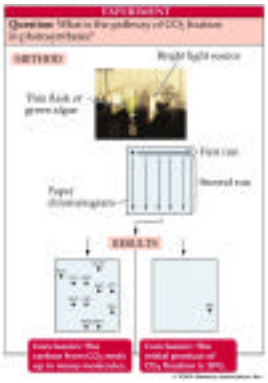
Dark reactions II: Producing sugars



Dark reactions III: Regenerating RuBP





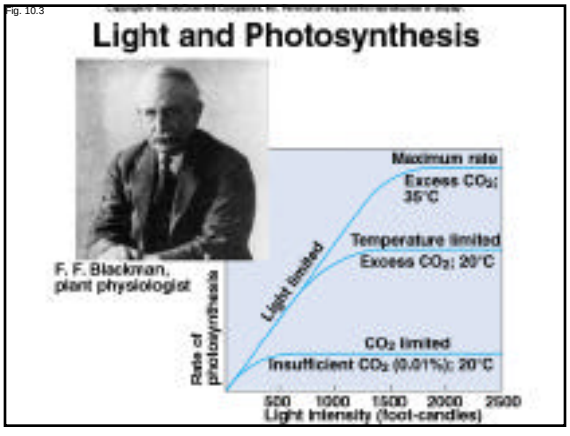


Photosynthesis

$$6CO_2 + 6H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

Factors Influencing Rate of photosynthesis

- ✓ H_2O
- ✓ CO_2
- ✓ Light
- ✓ Nutrients
- ✓ Temperature

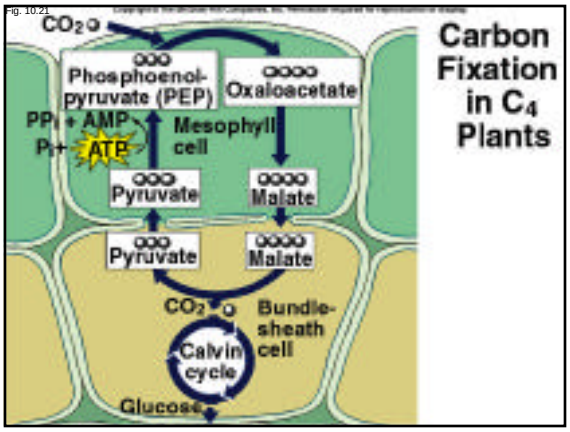


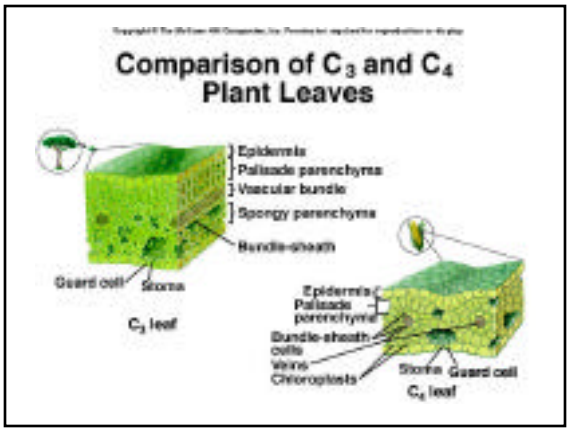
C3 plants

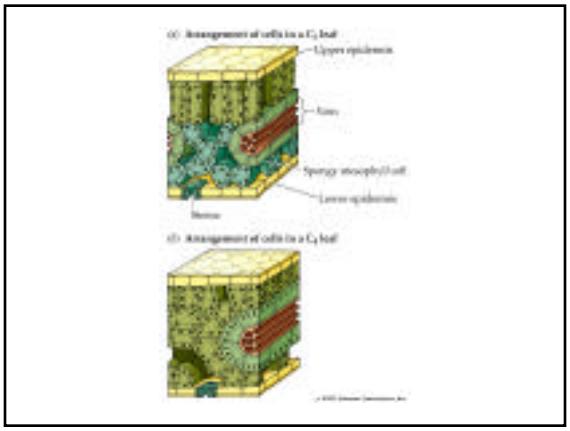
- ✓Fix CO_2 into the 3-carbon phosphoglycerate
- ✓Most trees, shrubs, wheat, oats, rice, and bamboo, Kentucky blue grass.
- ✓Survive in a warm/cool and moist climate.

C4 plants

- ✓Fix CO_2 into oxaloacetate (and then malate). This serves as a CO_2 storage.
- ✓2 types of photosynthetic cells
  - ✒Mesophyll cells and bundle sheath cells
- ✓Sugarcane, maize, sorghum, other grasses (crab grass) and sedges.
- ✓Effective when CO_2 is limiting and minimizes water loss.
- ✓Hot and dry climates



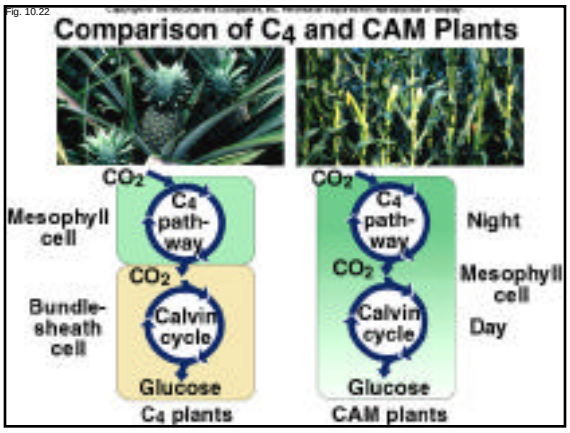


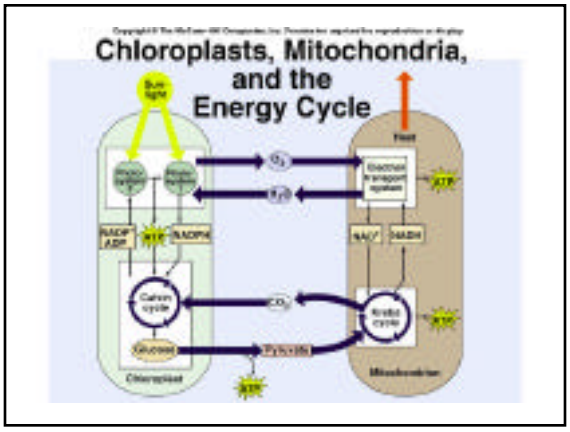


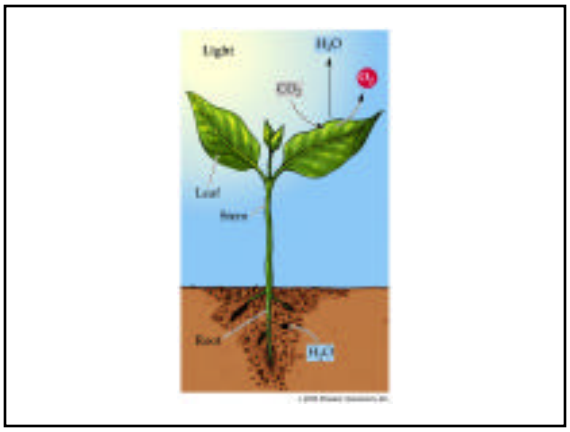
CAM plants

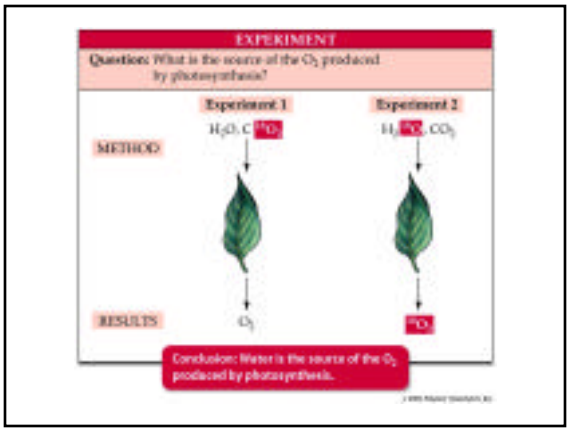
- ✓Crassulacean Acid Metabolism
- ✓Succulents, cacti, pineapples, lilies, orchids
- ✓Drought tolerant plants.

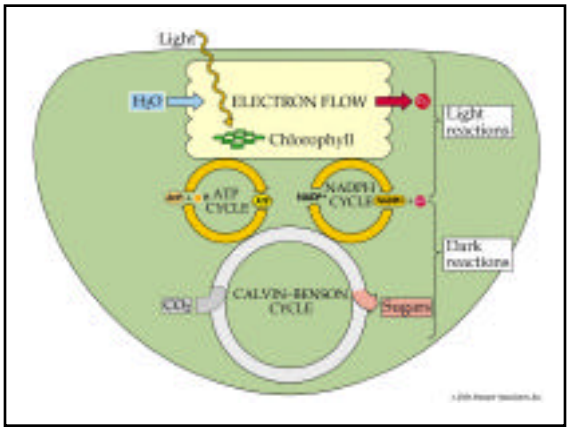
Fig. 10.22

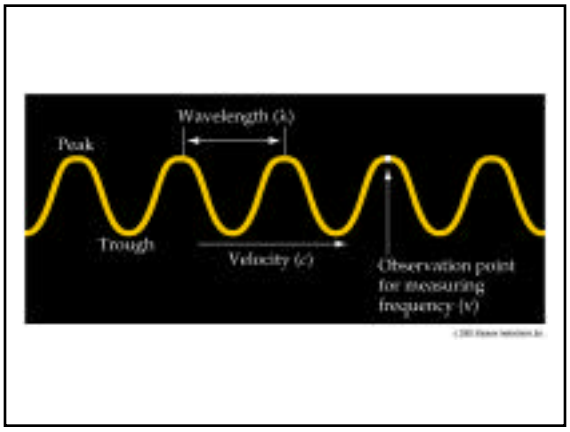

Comparison of C4 and CAM Plants
CO2
C4 path-way
Mesophyll cell
CO2
Calvin cycle
Bundle-sheath cell
Glucose
C4 plants
CO2
C4 path-way
Night
CO2
Calvin cycle
Mesophyll cell
Day
Glucose
CAM plants


Chloroplasts, Mitochondria, and the Energy Cycle
Sun light
ATP
NADP+ ADP
NADPH
NAD+
NADH
Calvin cycle
Glucose
Pyruvate
Chloroplast
Mitochondrion


Light
H2O
CO2
O2
Leaf
Stoma
Root
H2O


EXPERIMENT
Question: What is the source of the O2 produced by photosynthesis?
Experiment 1
Experiment 2
METHOD
RESULTS
Conclusion: Water is the source of the O2 produced by photosynthesis.


Light
H2O
ELECTRON FLOW
Chlorophyll
Light reactions
ATP CYCLE
NADPH CYCLE
Dark reactions
CO2
CALVIN-BENSON CYCLE
Sugars


Wavelength (λ)
Peak
Trough
Velocity (c)
Observation point for measuring frequency (ν)

The End.