Photosynthesis: Light Reactions

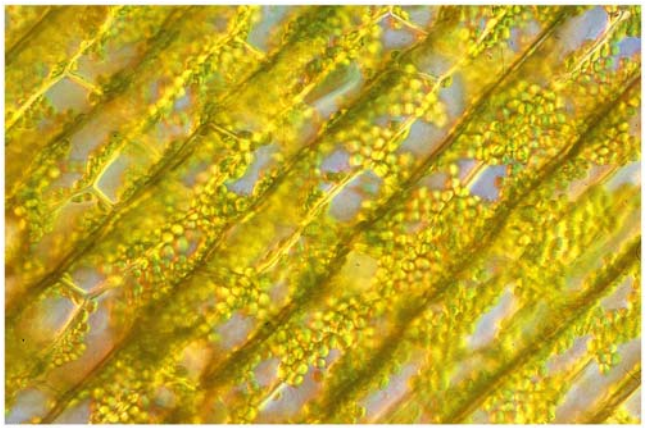
- Overview
- Structure of chloroplast
- Absorption of Light
- Photosystems
- Electron transport chain
- Photophosphorylation
- Electron flow water to oxygen
- Light energy

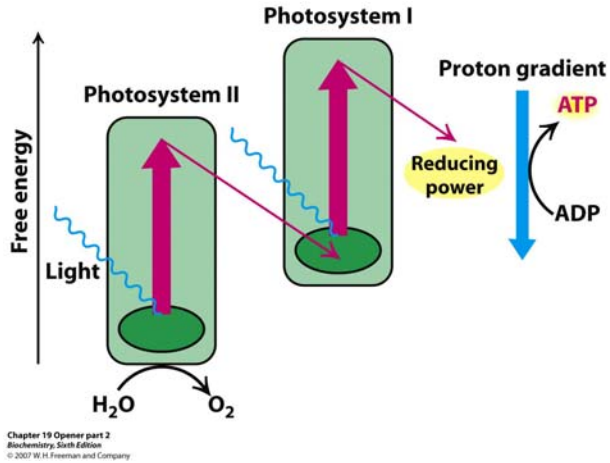
Cyanobacteria

TABLE 19.1 Major Groups of Photosynthetic Prokaryotes

Bacteria	Photosynthetic electron donor	O_2 use
Green sulfur	H_2, H_2S, S	Anoxygenic
Green nonsulfur	Variety of amino acids and organic acids	Anoxygenic
Purple sulfur	H_2, H_2S, S	Anoxygenic
Purple nonsulfur	Usually organic molecules	Anoxygenic
Cyanobacteria	H_2O	Oxygenic

Overview





- Located in the chloroplast
- Converts light energy into chemical energy
- requires pigments to absorb light energy

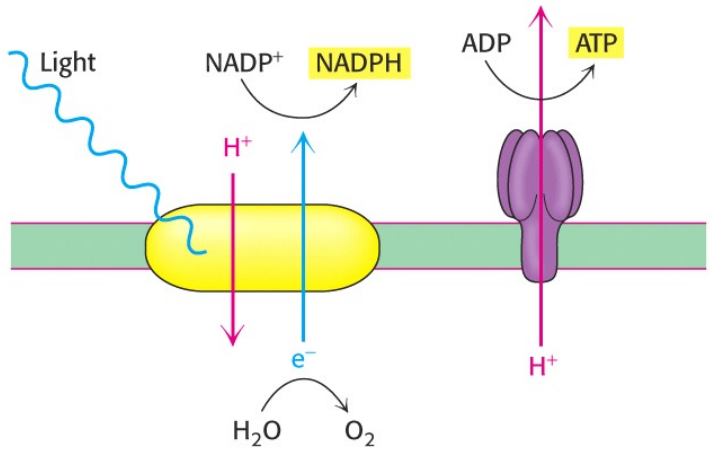
$$CO_2 + H_2O \xrightarrow{+\text{light}} (CH_2O) + O_2$$

$H_2O \rightarrow 1/2\ O_2 + 2e + 2H^+$ $\quad E'_0 = -0.82$ V (R9-

$NADP^+ + 2e + H^+ \rightarrow NADPH$ $\quad E'_0 = -0.32$ V (R9-1

$H_2O + NADP^+ \rightarrow$

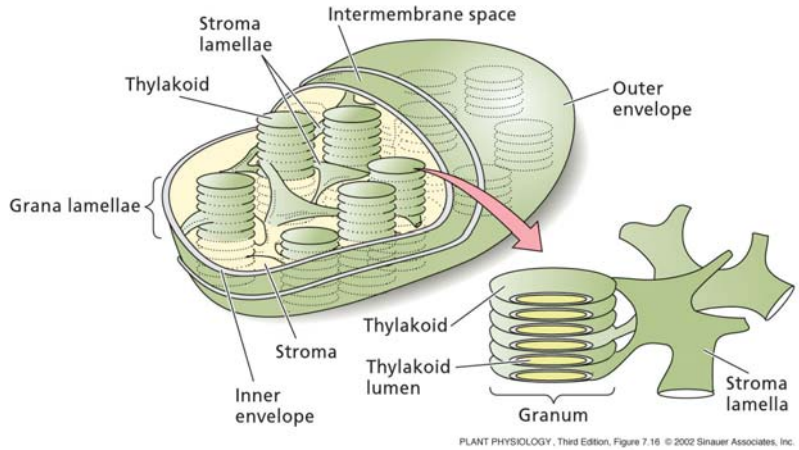
$1/2\ O_2 + H^+ + NADPH$ $\quad \Delta E = -1.14$ V (R9-1

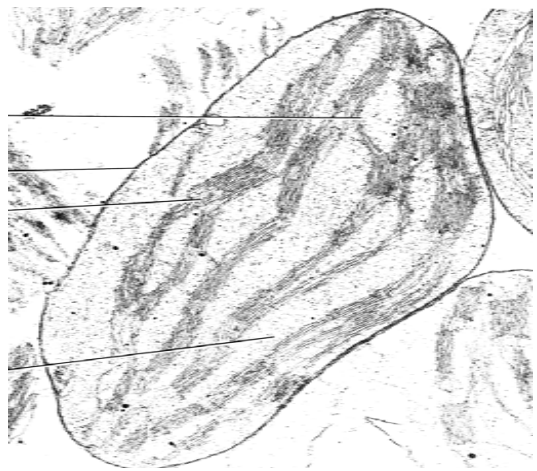


- Light Reactions of photosynthesis
- Take place on thylakoid membranes
- In Eukaryotic cells this is in the chloroplast

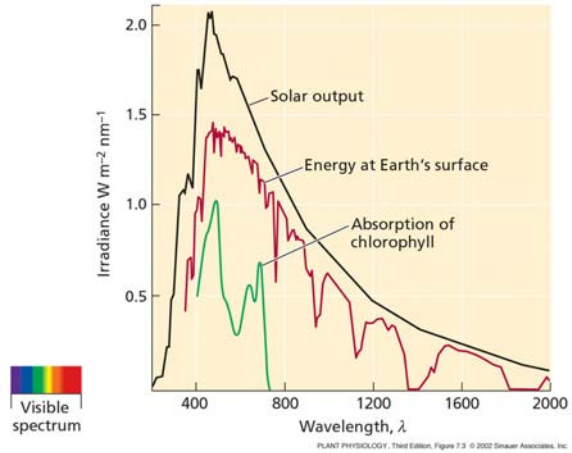
Structure of chloroplast

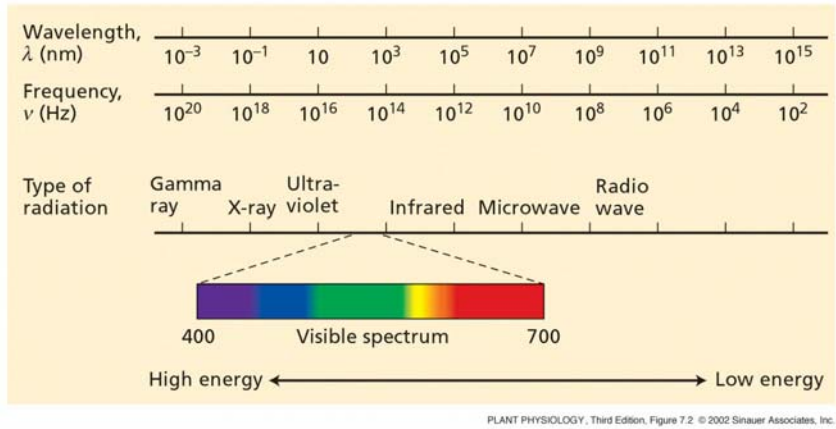
- **Leaf cells contain between 1-100 chloroplasts**
- **Double membrane organelle, 5-20 um size**
- **Outer membrane: freely permeable to small molecules**
- **Inner membrane: mostly impermeable**
- **Stroma: Contains DNA, RNA, ribosomes**
- **Third membrane system: Thylakoids**
- **Five major protein complexes on the thylakoid membranes**
- **Thylakoid lumen**
- **Stroma lamellae**





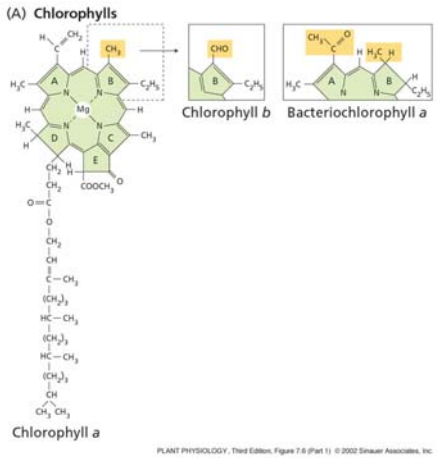
Light Energy

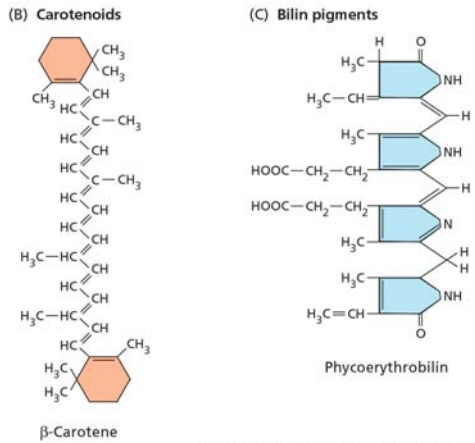




- Light energy = mol of photons (Einstein)
- Relationship between wavelength and energy
- E = hv; Planck's constant (h) = 4.12 x 10^{-15} eV/s, λ= c/V; speed of light (c) = 3 x 10^{8} cm/s
- Blue Light (450nm) energy = 2.75 eV (64 kcal/Einstein)
- Red light (700nm) energy = 1.77 eV (41 kcal/Einstein)

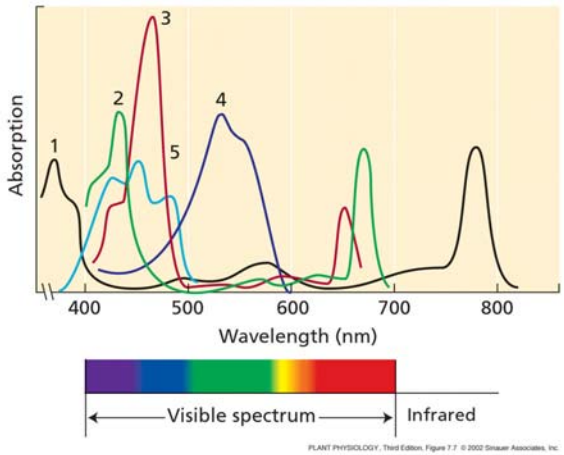
Pigments

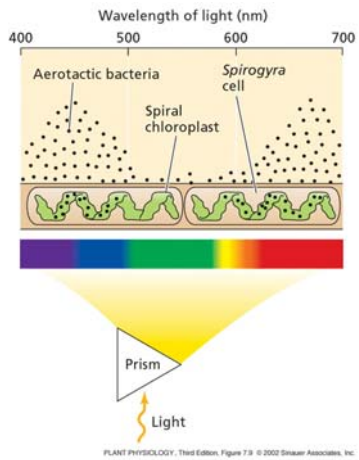


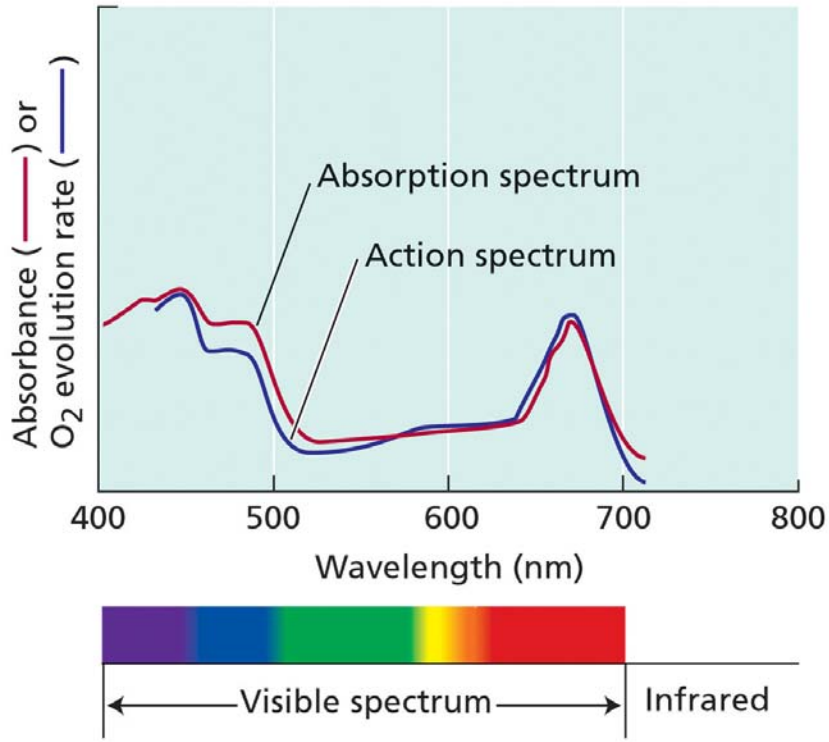


- Types of Pigments:
- Chlorophyll: a, b and bacteriochlorophylls
- Carotenoids: xanthophylls and β-carotene

Absorption spectrum and action spectrum







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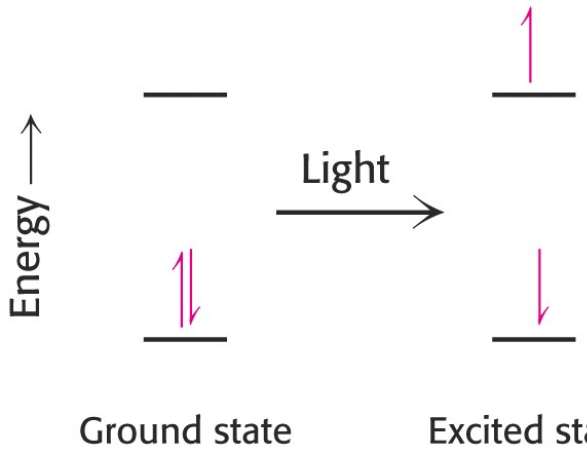
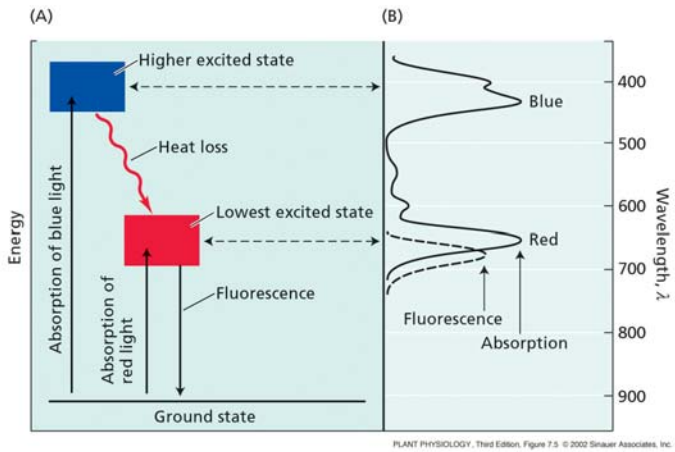
Fate of a photon of light absorbed

- **Different orbital levels**
- **Heat loss**
- **Fluorscencse = longer wavelength of light**
- **Phosphorescence and the triplet state**
- **Resonance energy transfer equal or lower energy**
- **Photochemistry** = loss of electron,





Electron Orbitals

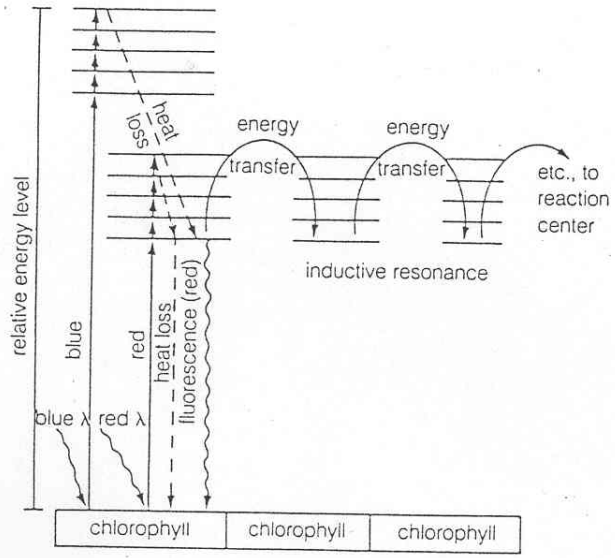
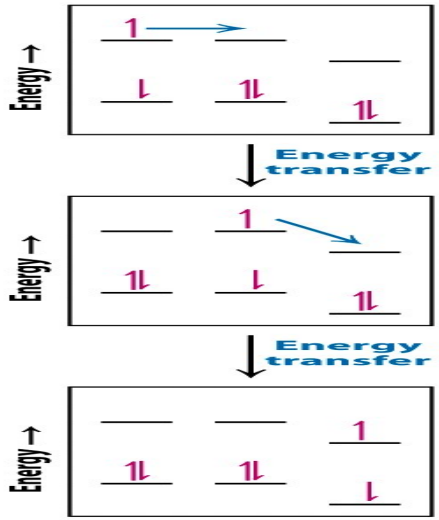


Figure 9-5 Simplified model to explain how light energy striking a chlorophyll molecule is given up. Note that excitation by blue or red light leads to the same final energy level (often called the first excited singlet). From here, the energy can be lost by decay back to the ground state (heat loss or fluorescence of red light) or can be transferred to an adjacent pigment by inductive resonance. Each time a pigment transfers its excitation energy to an adjacent pigment, the excited electron in the first pigment returns to the ground state.



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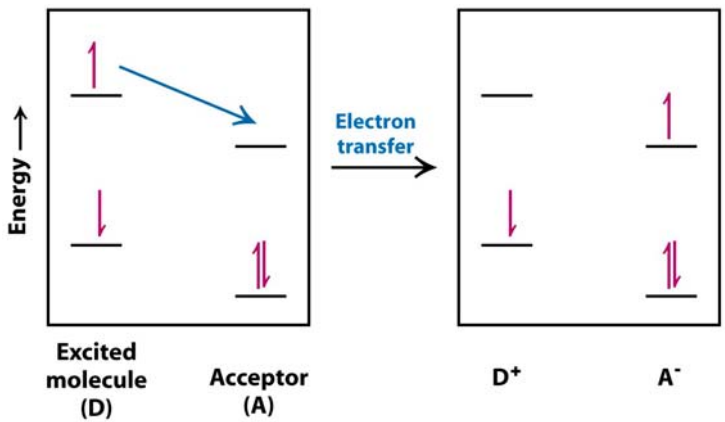

Figure 19-8
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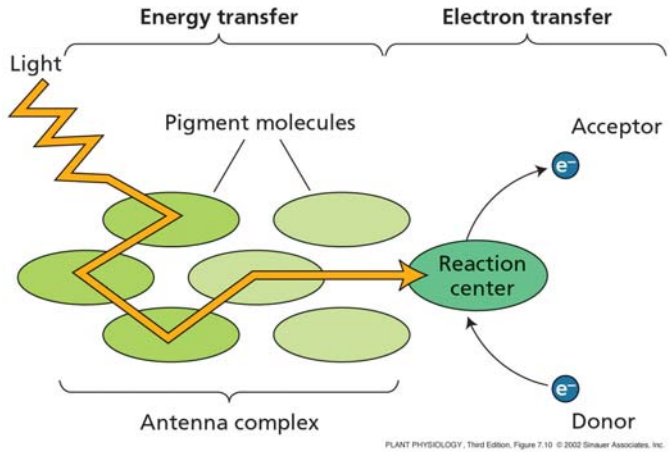
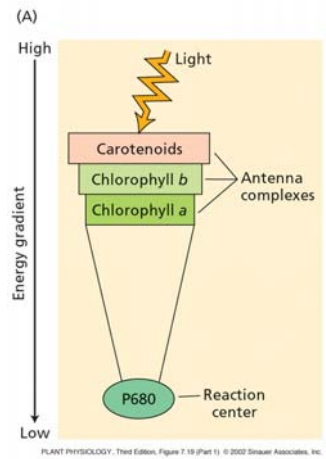
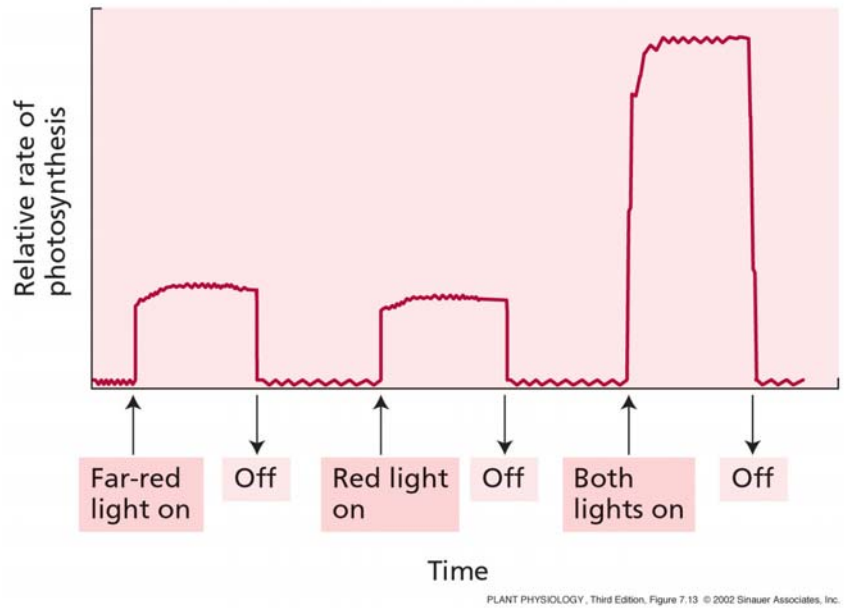
Photosystems

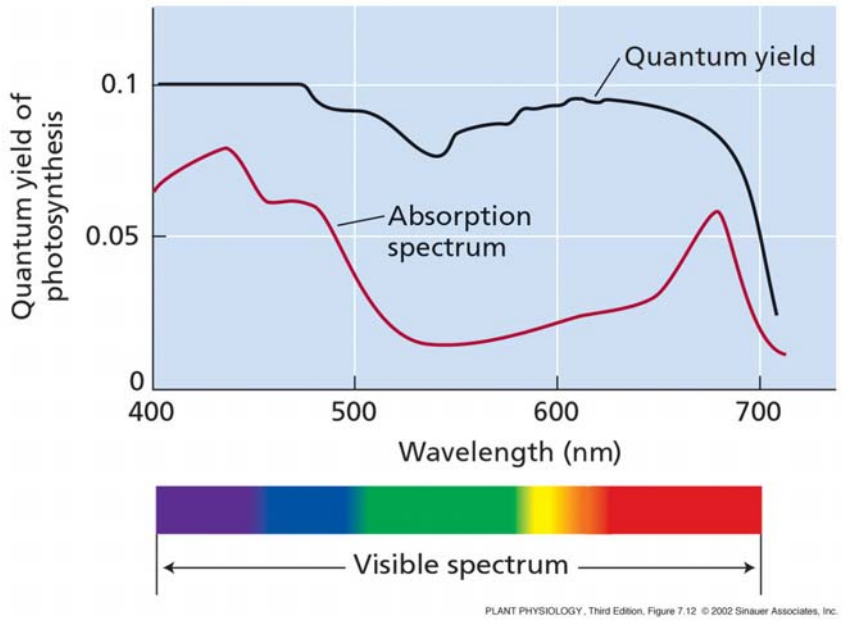
- **Located in thylakoid membranes, stacked and unstacked regions**
- **PS II-- P_{680}**
- **PS I-- P_{700}**
- **Reaction centers = 2 chl a molecules**
- **Emerson Enhancement effect and the far red drop-off**
- **Evidence for 2 photosystems**





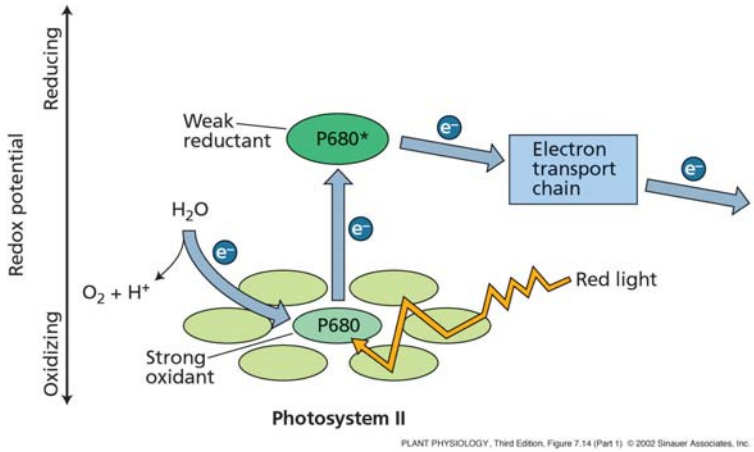
Emerson Enhancement effect and the far red drop-off

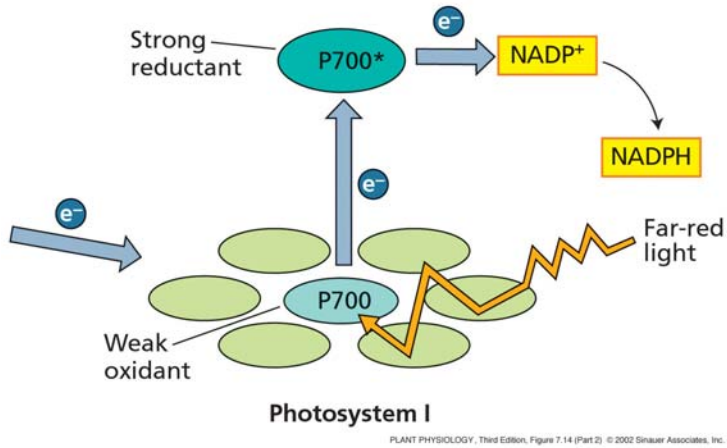




Quantum yield = amt O_2 produced / number of photons absorbed
If 1 then all photons contribute to process.

Electron transport chain

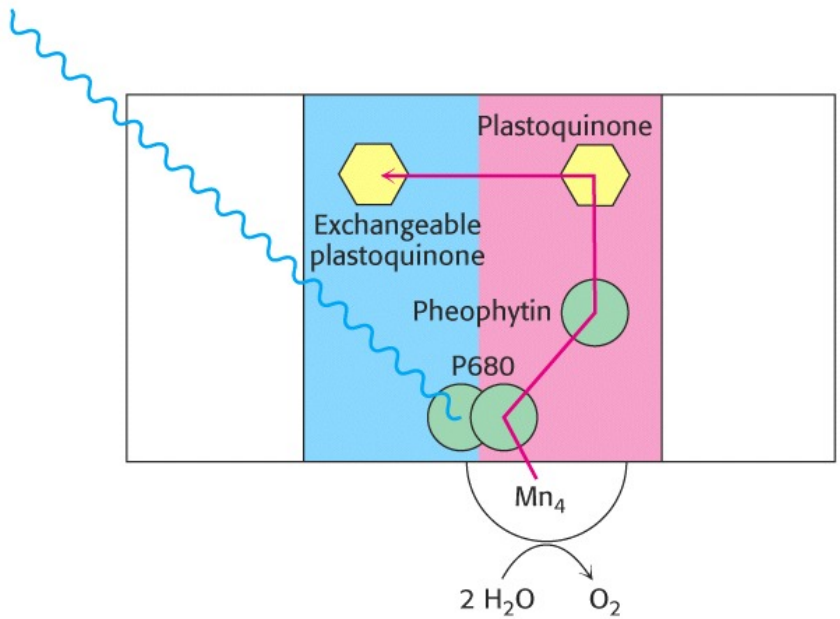




- Location and order
- Transport of e^- and protons between photosystems
- Electron carriers
- Production of NADPH

Photosystem II

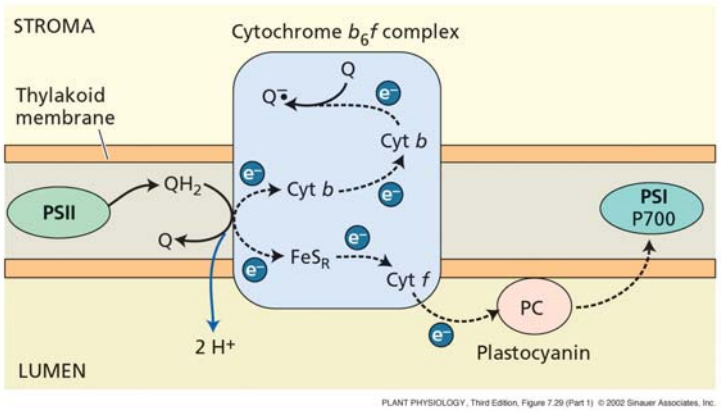
- Pair of chl a molecules in D1 and D2 sub-unit
- Pheophytin acceptor of electrons (2H+ instead of Mg)
- Transferred to plastoquinone



Cytochrome bf complex

Plastocyanin is a Cu containing protein

(A) First QH_2 oxidized



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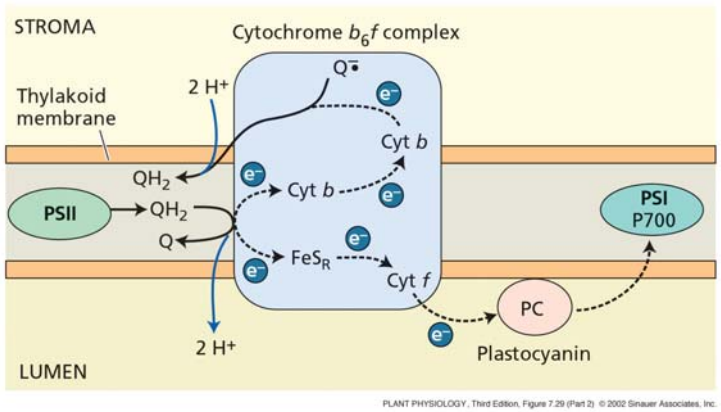
(B) Second QH_2 oxidized



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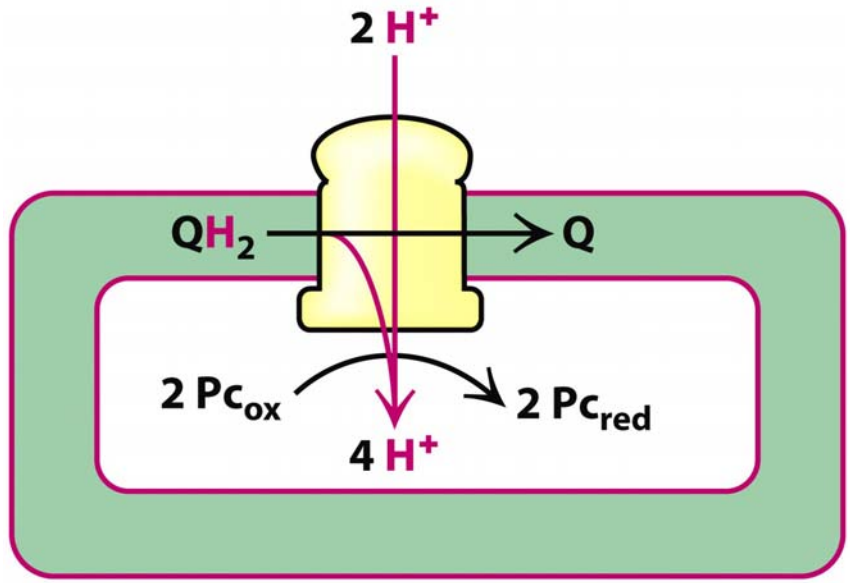

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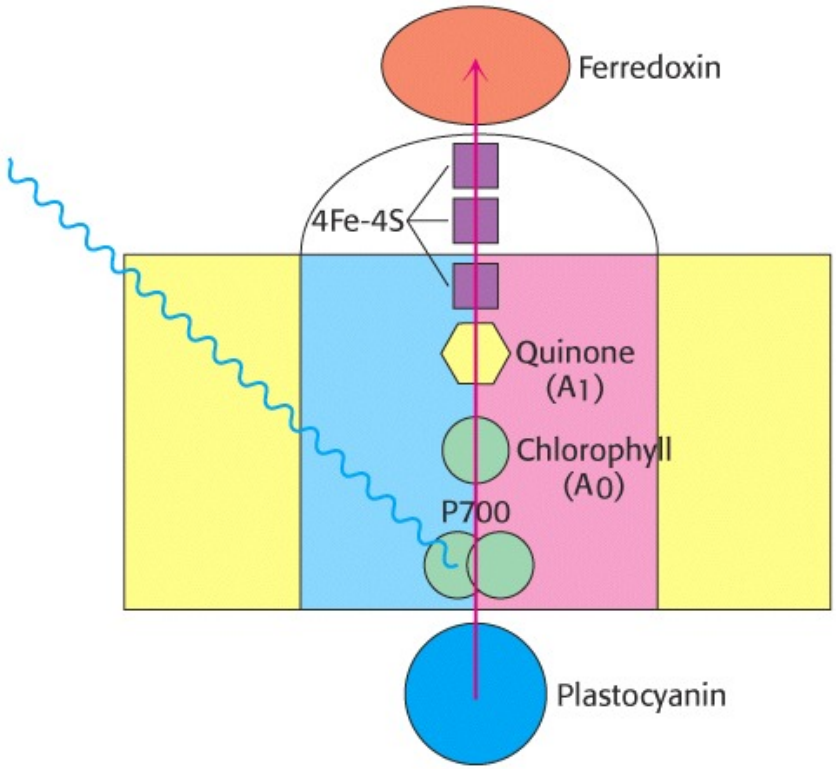
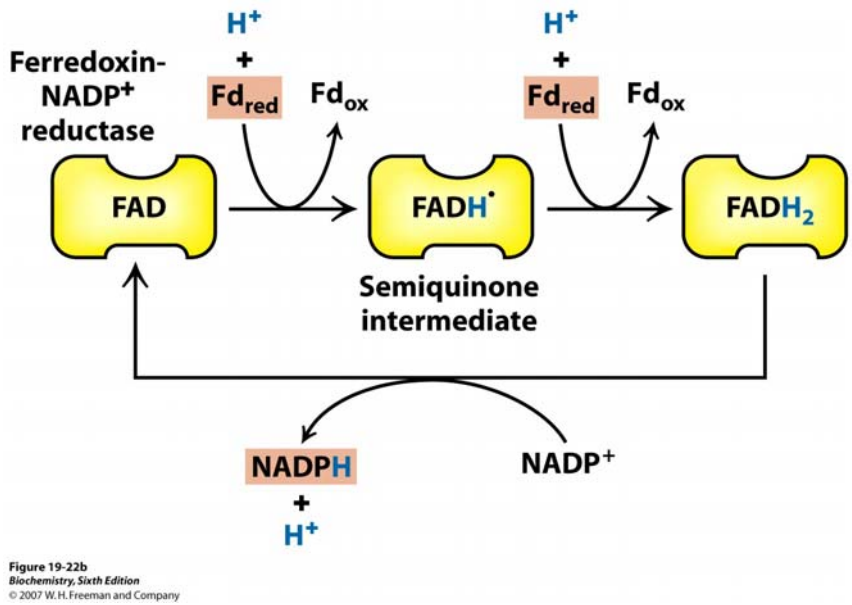
Photosystem I





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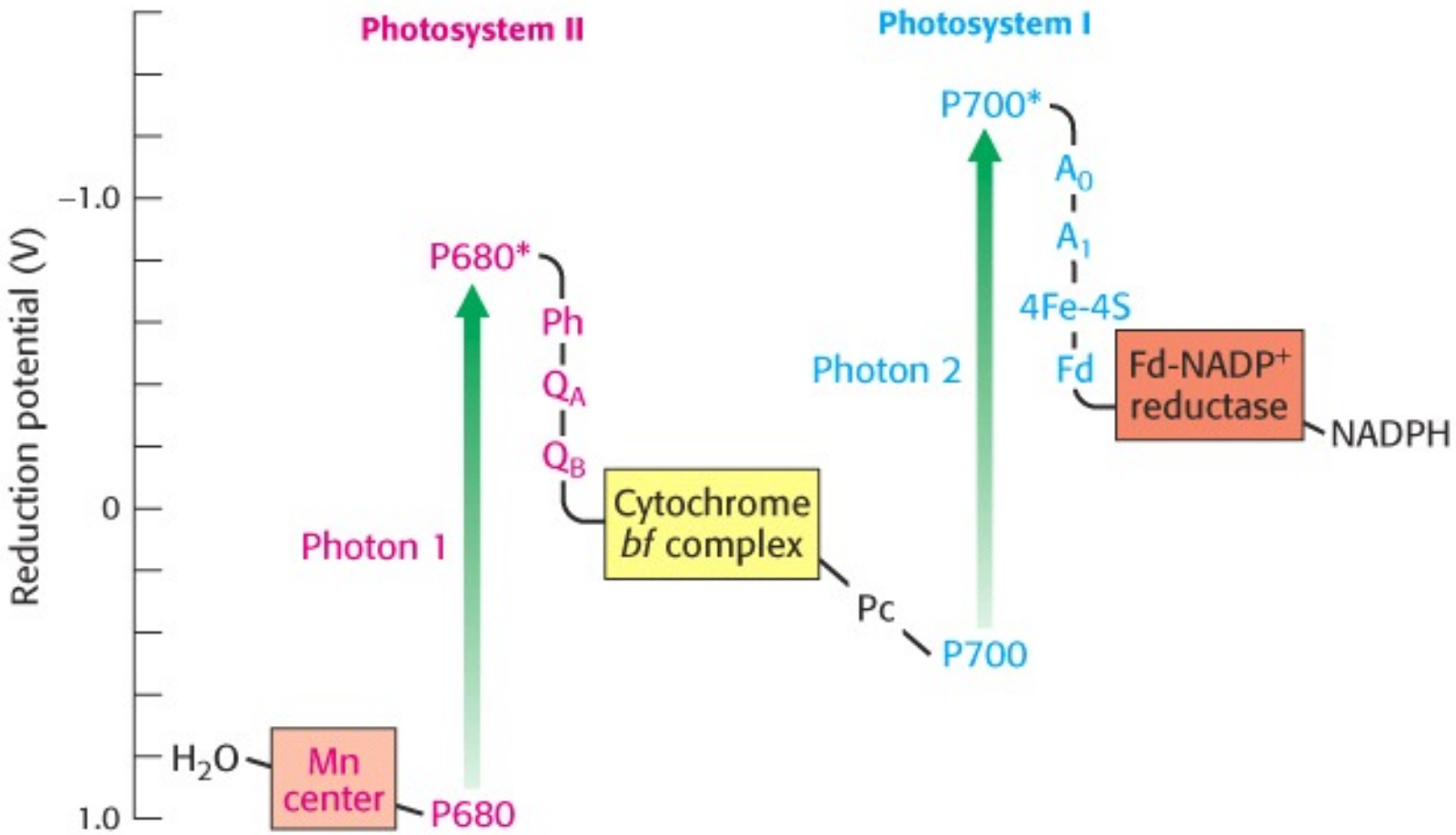
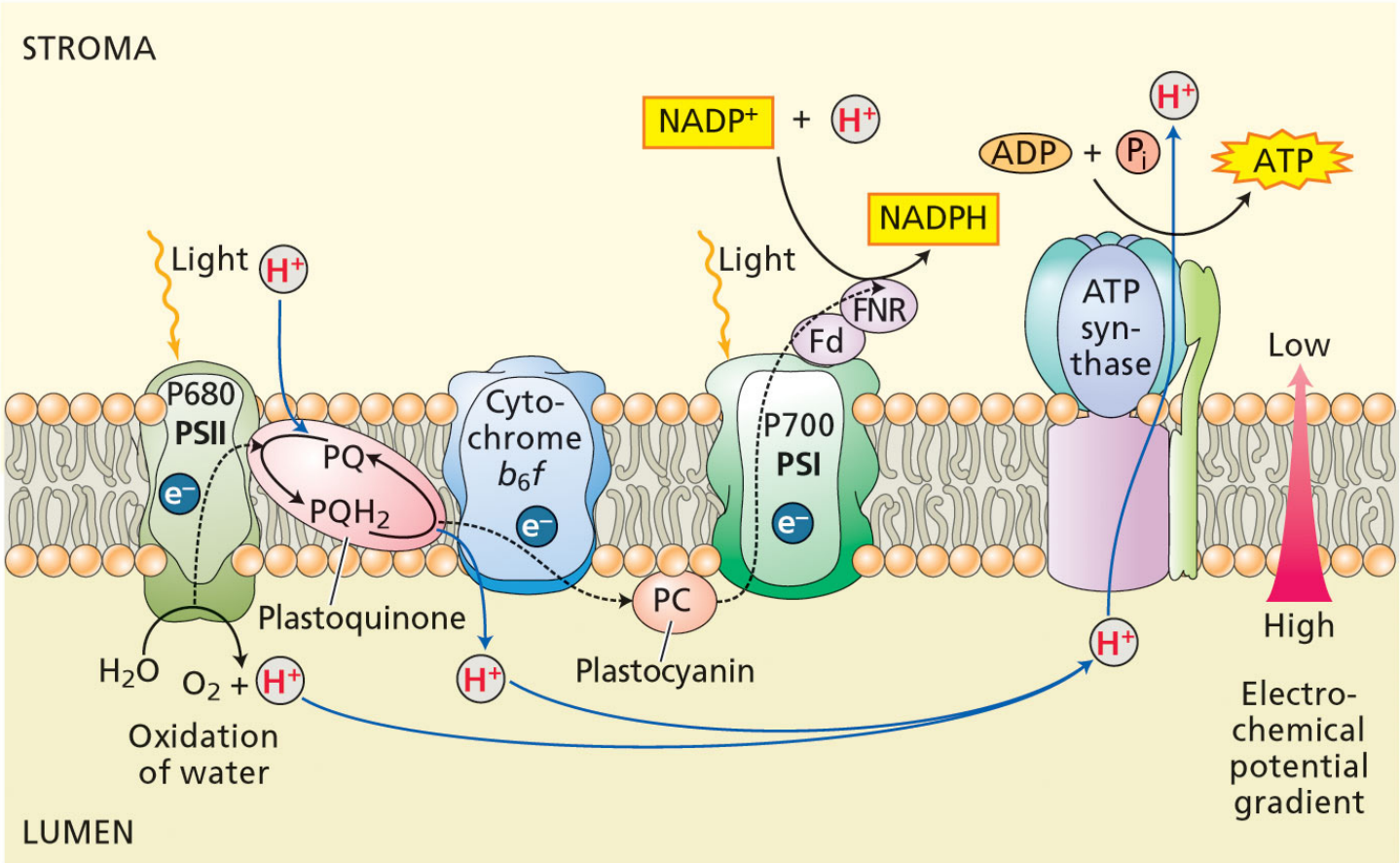
Z scheme


Photosystem II
Photosystem I
Reduction potential (V)
−1.0
0
1.0
P680*
Ph
Q_A
Q_B
Cytochrome *bf* complex
Pc
P700
P700*
A_0
A_1
4Fe-4S
Fd
Fd-NADP+ reductase
NADPH
Photon 1
Photon 2
H_2O
Mn center
P680

Orientation in thylakoid membrane



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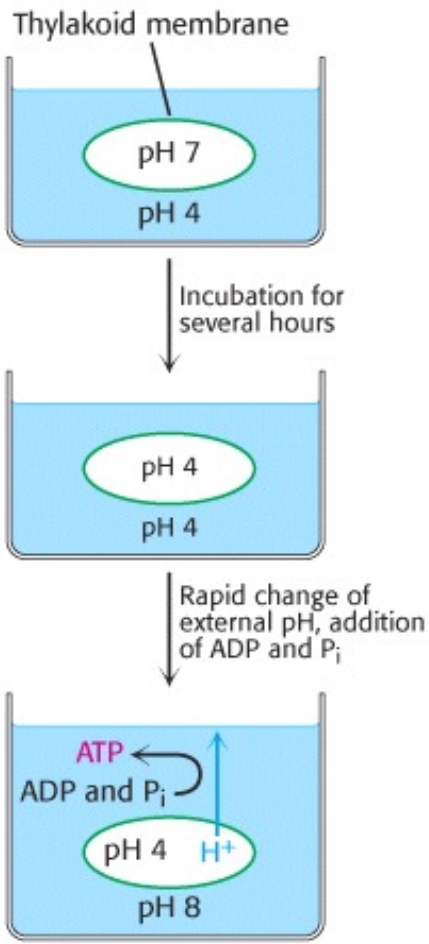
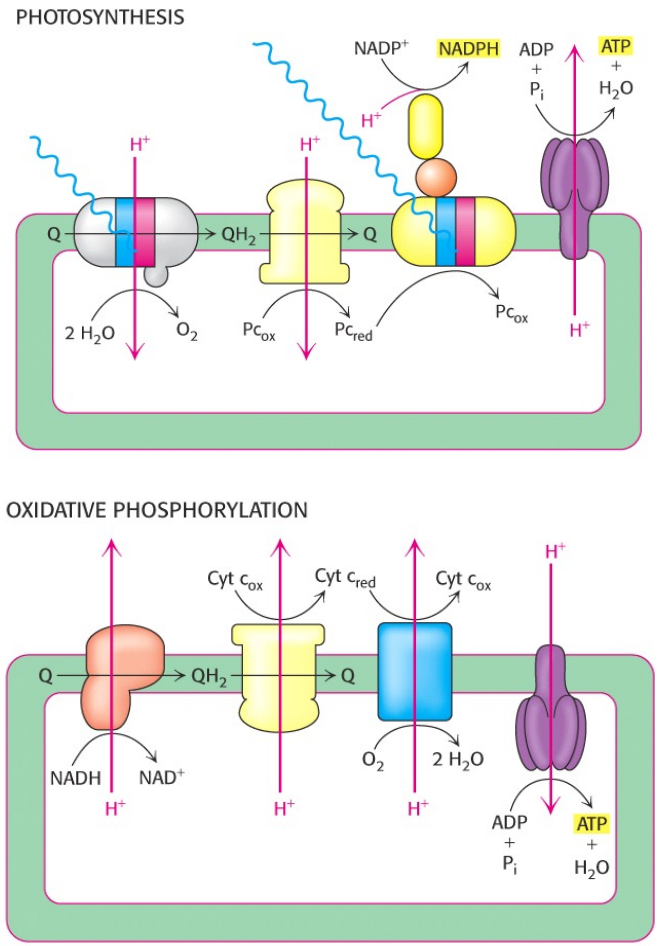
Non-cyclic Photophosphorylation

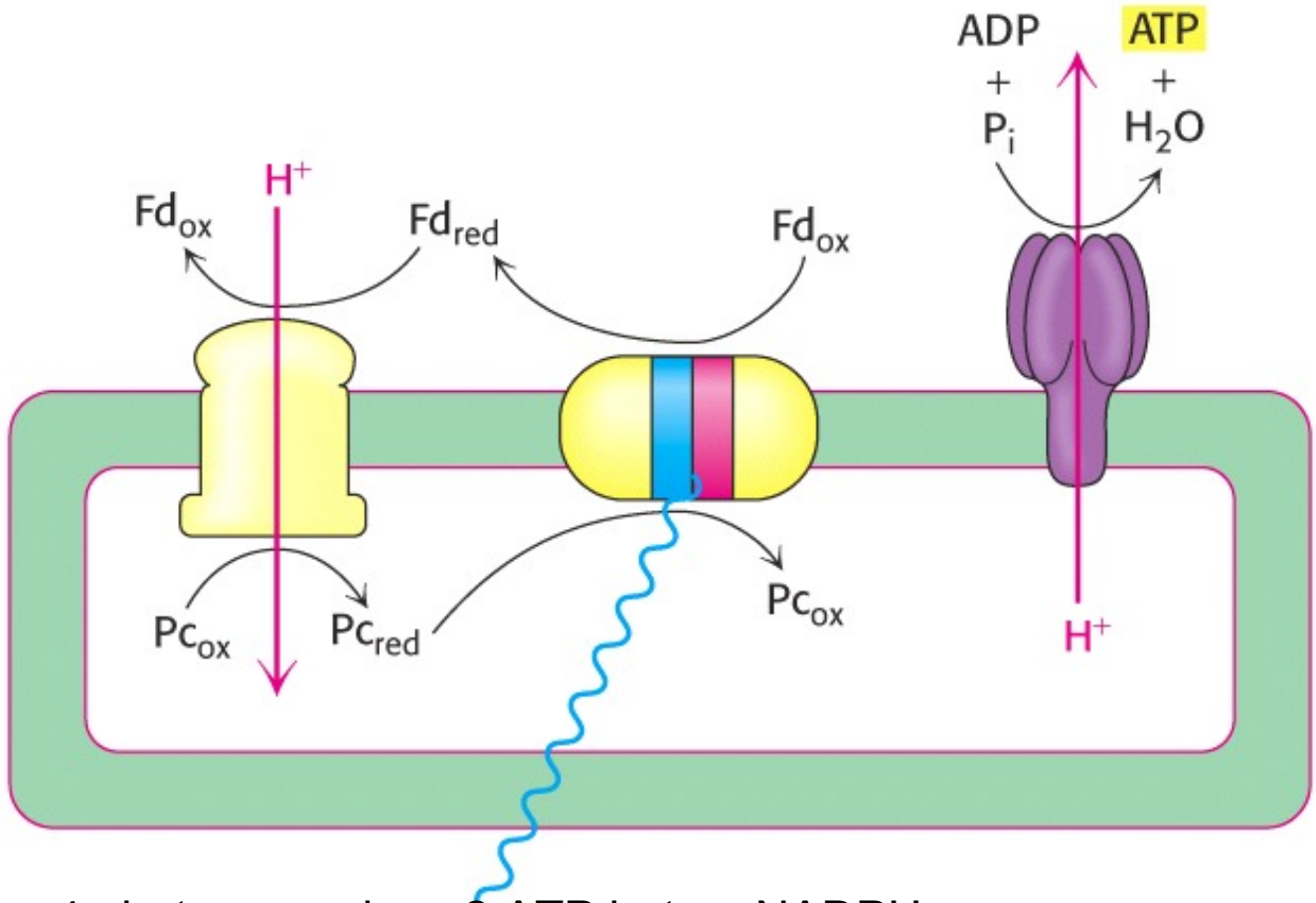




$2\ H_2O + 2\ NADP^+ + 10H^+ \rightarrow O_2 + 2NADPH + 12\ H^+$

- Absorption of 8 photons
- Yields 1 mol oxygen
- 2 mol NADPH
- 3 ATP;
- 12 protons flow through ATP synthase
- There are 12 subunits for one full rotation and yield 3 ATP

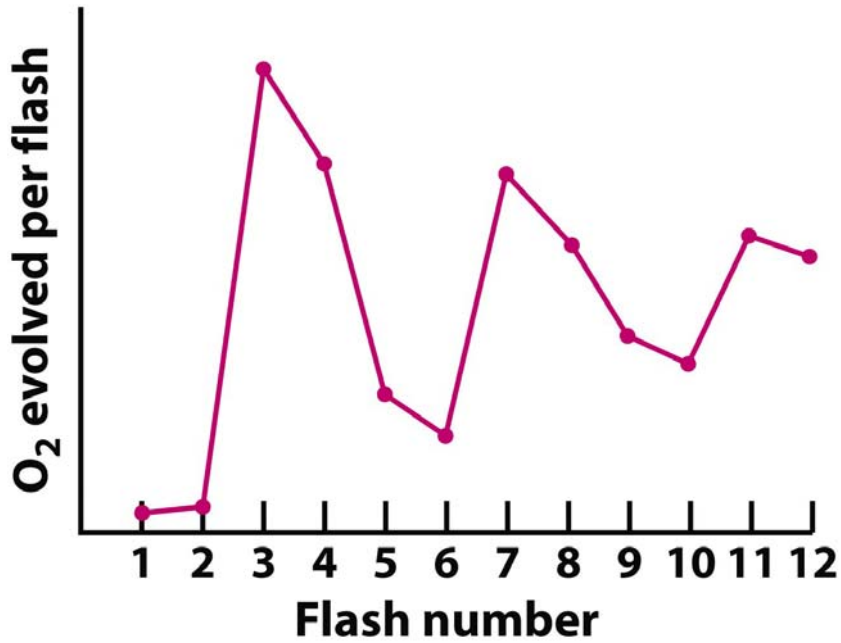
Cyclic Photophosphorylation



4 photons produce 2 ATP but no NADPH

Electron flow water to oxygen

- Oxygen evolving complex
- Mn dependent complex
- in Thylakoid lumen
- transitions with flashes



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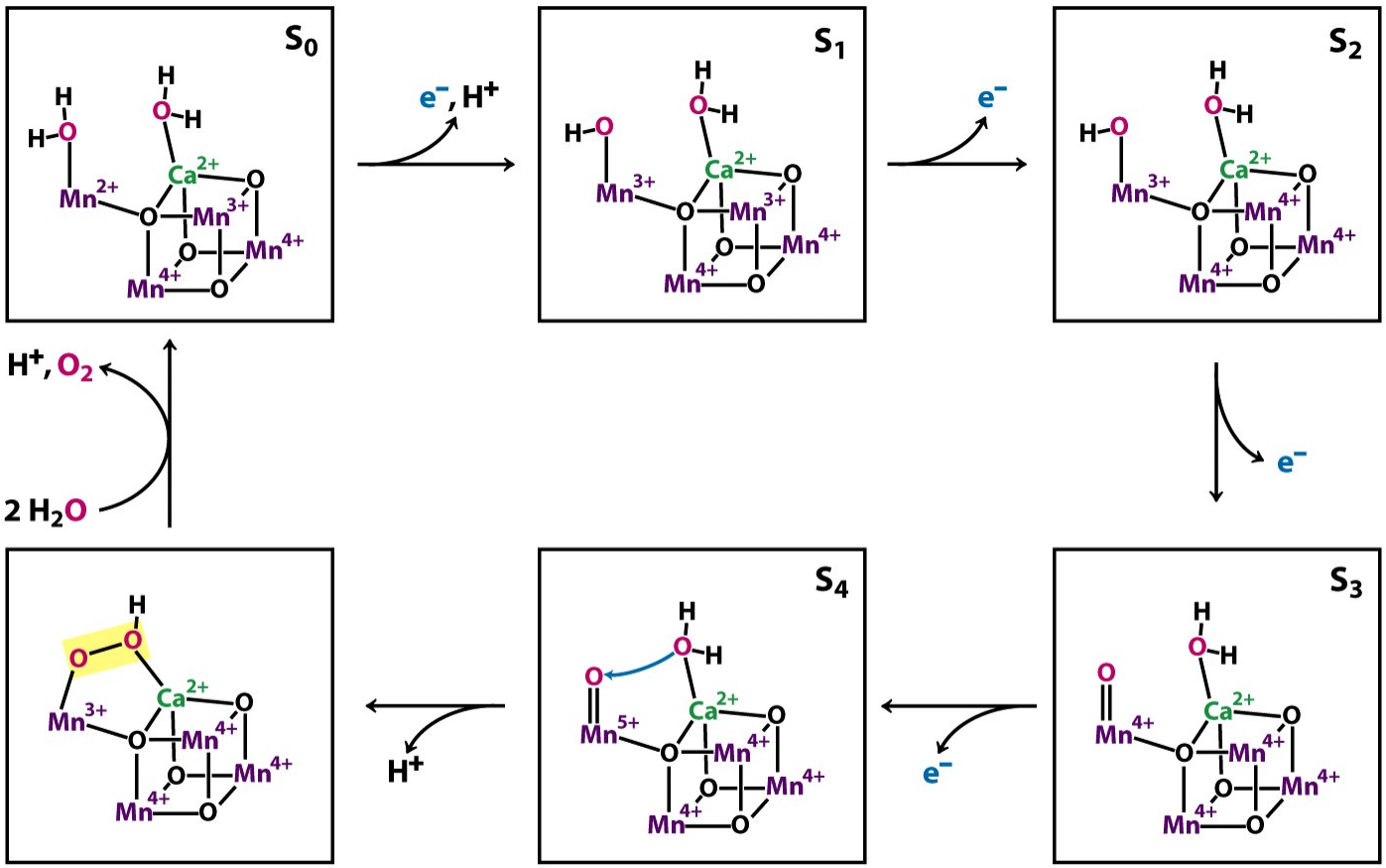
Oxygen evolution



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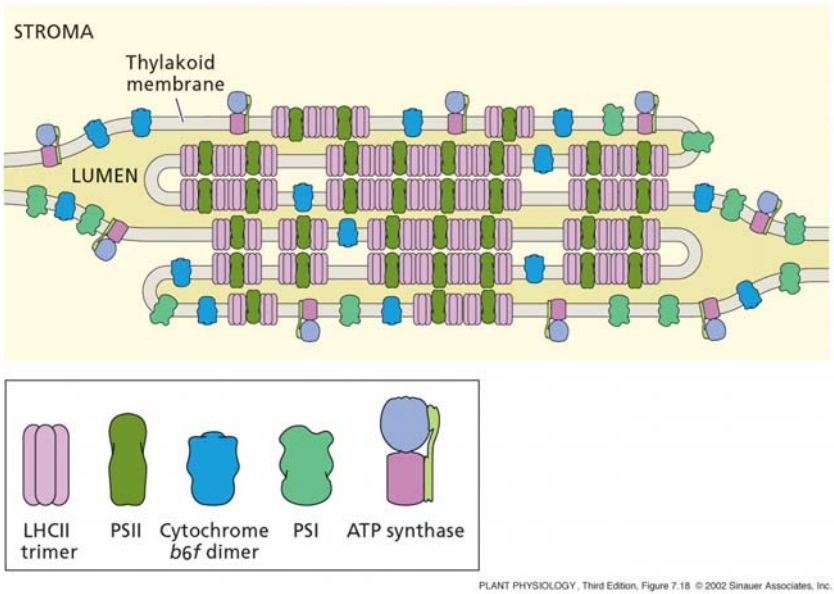
Location of protein complexes



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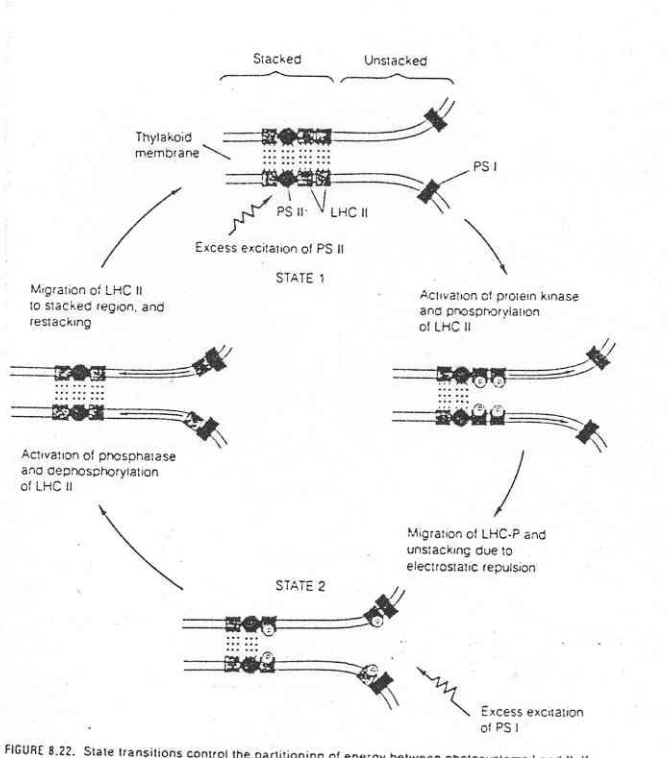
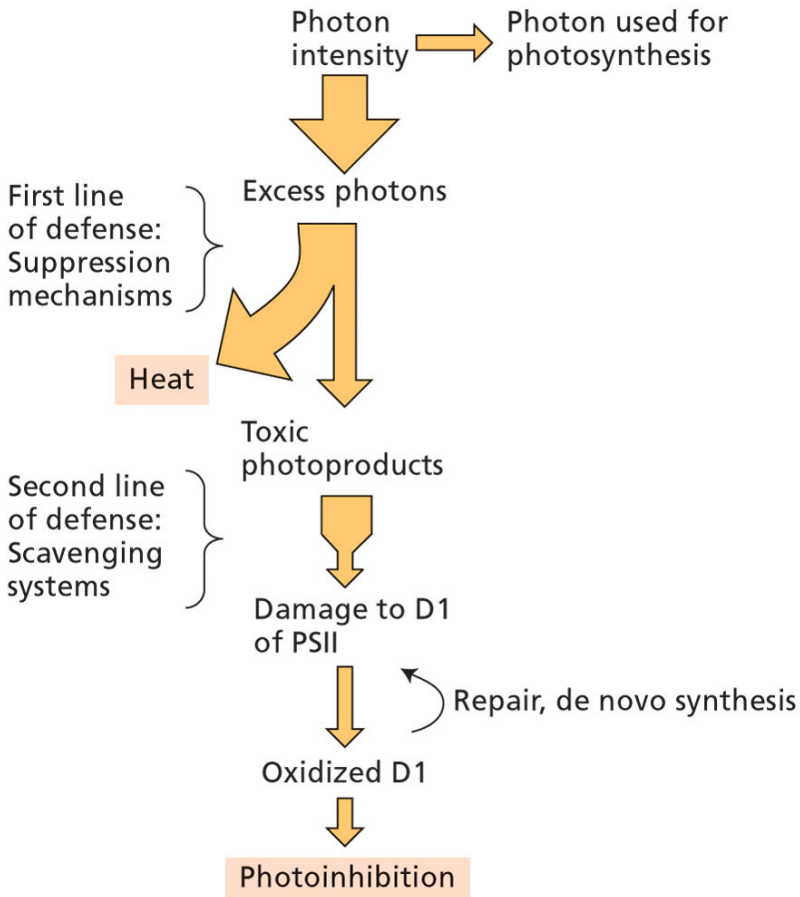


FIGURE 8.22. State transitions control the partitioning of energy between

Photoinhibition and excess light energy



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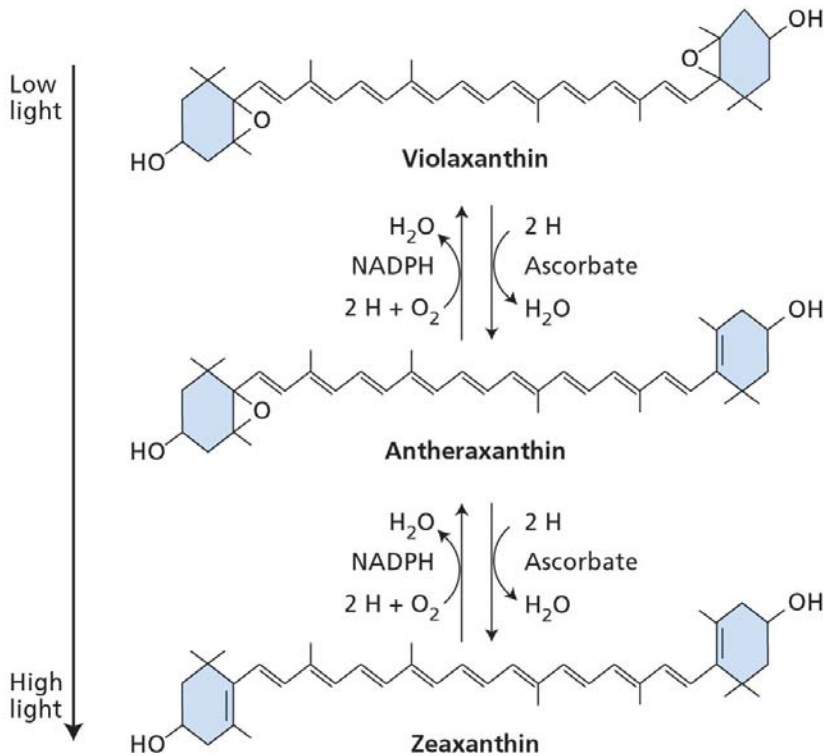

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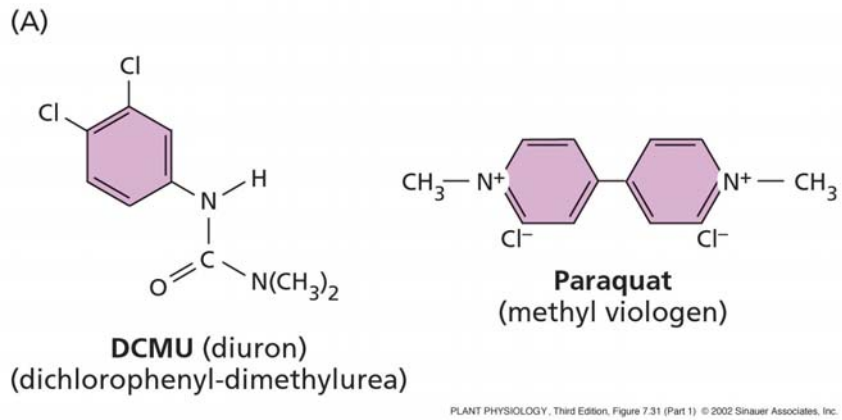
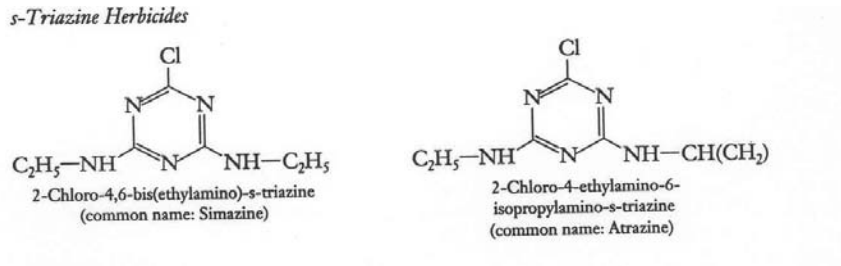
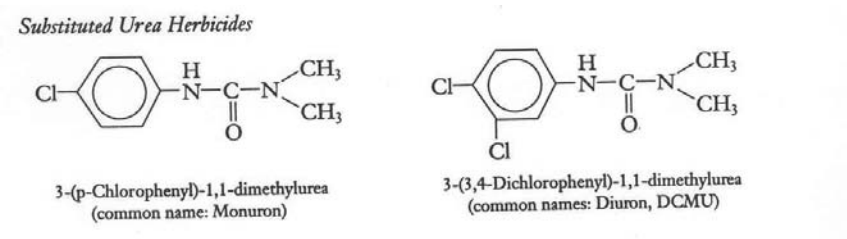
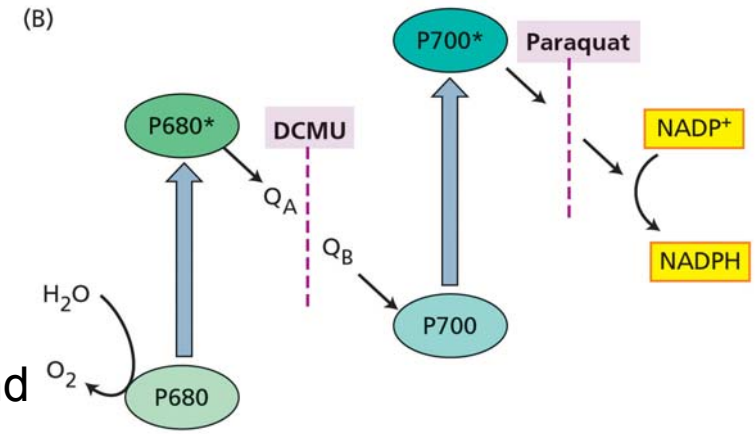
Herbicides









Diruron and atrazine: PS II inhibitiors, bind
To D1 sub-unit block formation of QH_2.