

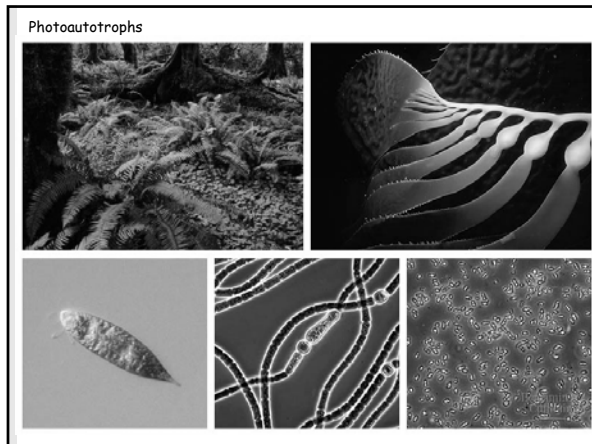
Lecture Series 10
Photosynthesis: Energy
from the Sun

Reading Assignments

- Review Chapter 3
Energy, Catalysis, & Biosynthesis
- Read Chapter 13
How Cells obtain Energy from Food
- Read Chapter 14
Energy Generation in Mitochondria &
Chloroplasts

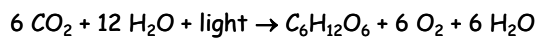
Photosynthesis In General

- Life on Earth depends on the absorption
of light energy from the sun.
- In plants, photosynthesis takes place in
chloroplasts.

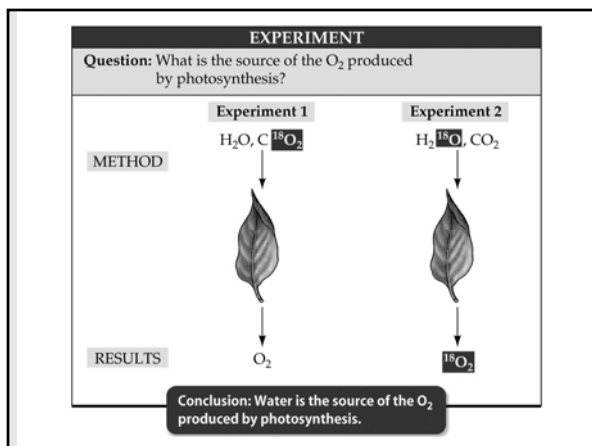


A. Identifying Photosynthetic Reactants and Products

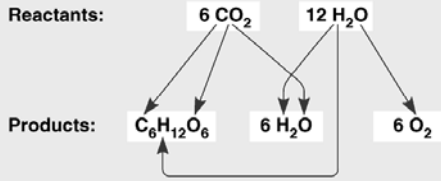
- Photosynthesizing plants take in CO_2 , water, and light energy, producing O_2 and carbohydrate. The overall reaction is



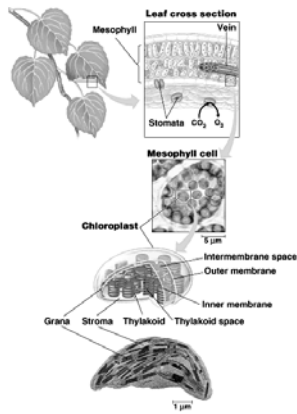
- The oxygen atoms in O_2 come from water, not from CO_2 .



Tracking atoms through photosynthesis

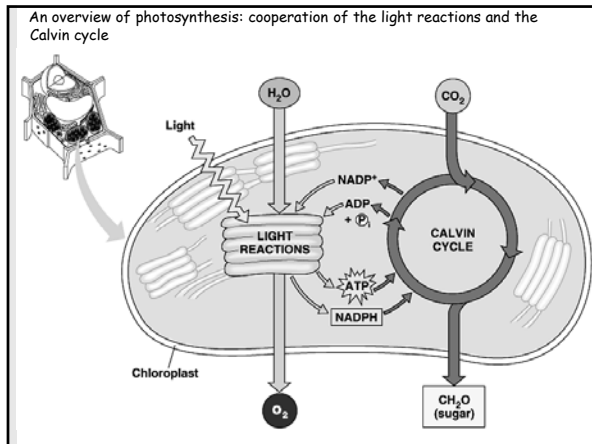


Focusing in on the location of photosynthesis in a plant



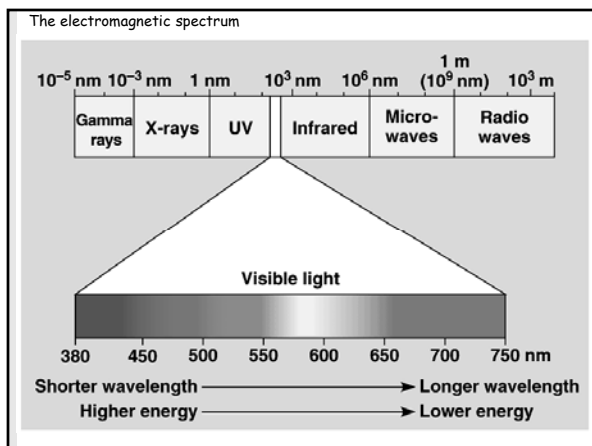
B. The Two Pathways of Photosynthesis: An Overview

- In the light reactions of photosynthesis, electron flow and photophosphorylation produce ATP and reduce NADP^+ to $\text{NADPH} + \text{H}^+$.
- ATP and $\text{NADPH} + \text{H}^+$ are needed for the reactions that fix and reduce CO_2 in the Calvin-Benson cycle, forming sugars. These are sometimes erroneously referred to as the dark reactions.

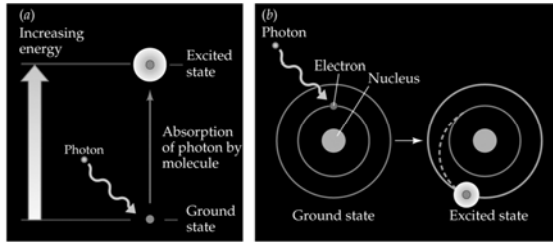


C. Properties of Light and Pigments

- Light energy comes in packets called photons, but it also has wavelike properties.
- Pigments absorb light in the visible spectrum.
- Absorption of a photon puts a pigment molecule in an excited state with more energy than its ground state.



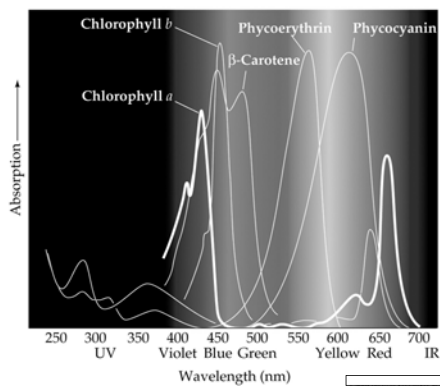
Exciting a Molecule

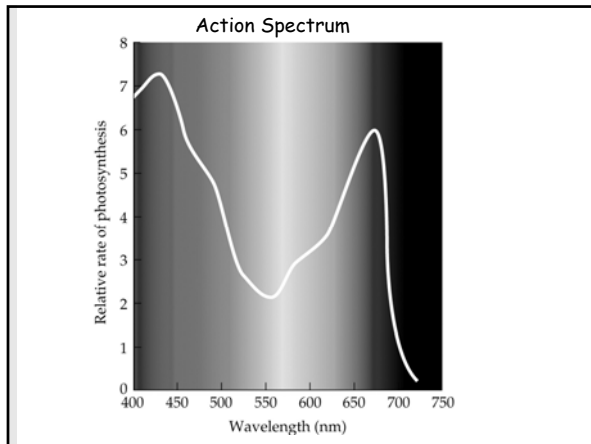


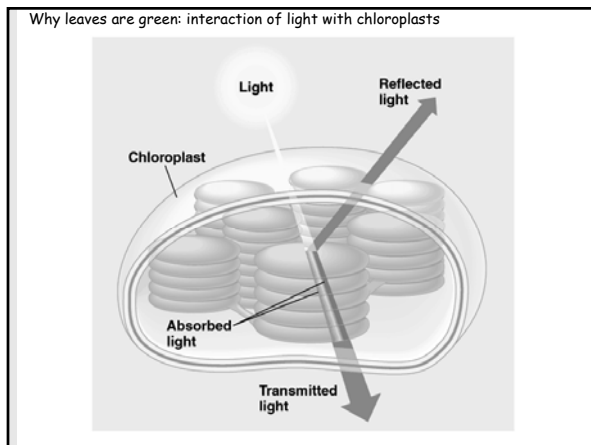
C. Properties of Light and Pigments

- Each compound has a characteristic absorption spectrum which reveals the biological effectiveness of different wavelengths of light.
- An action spectrum plots the overall biological effectiveness of different wavelengths for an organism.

Absorption Spectra

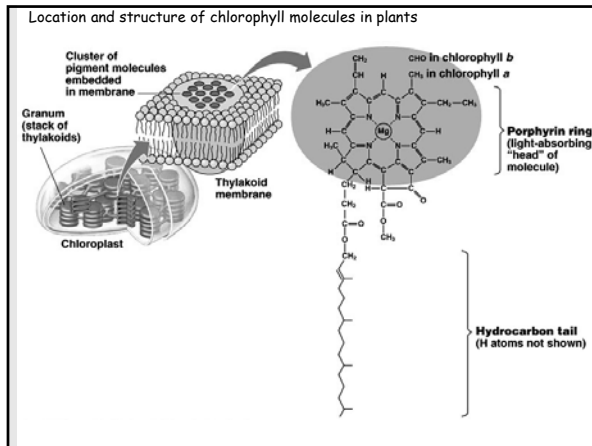


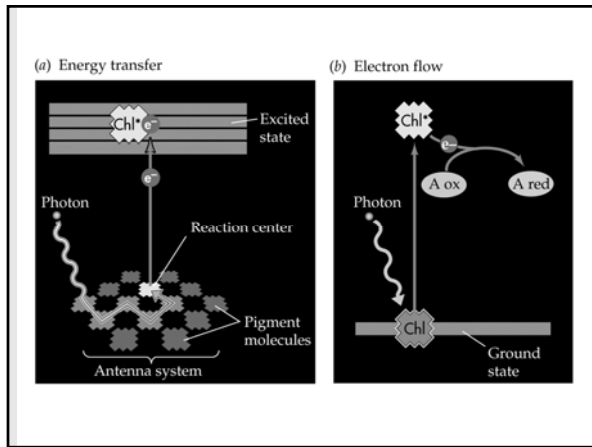


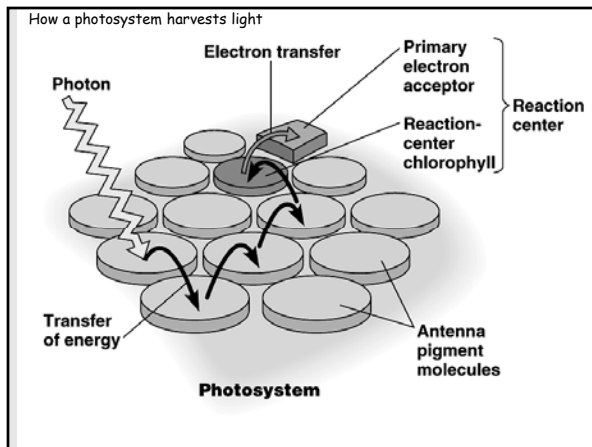


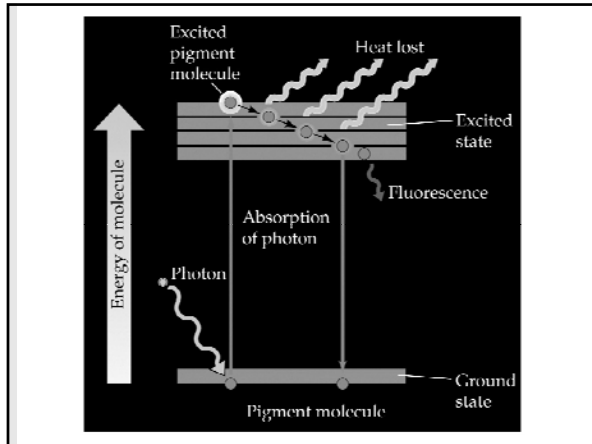
C. Properties of Light and Pigments

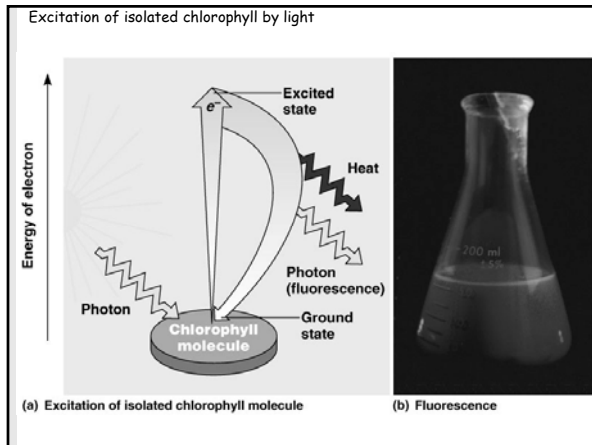
- Chlorophylls and accessory pigments form antenna systems for absorption of light energy.
- An excited pigment molecule may lose its energy by fluorescence, or by transferring it to another pigment molecule.





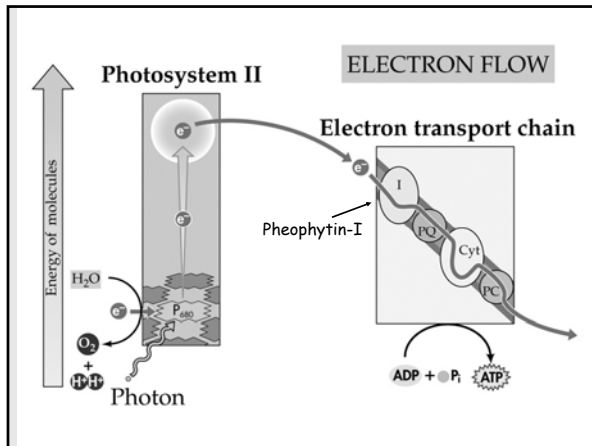


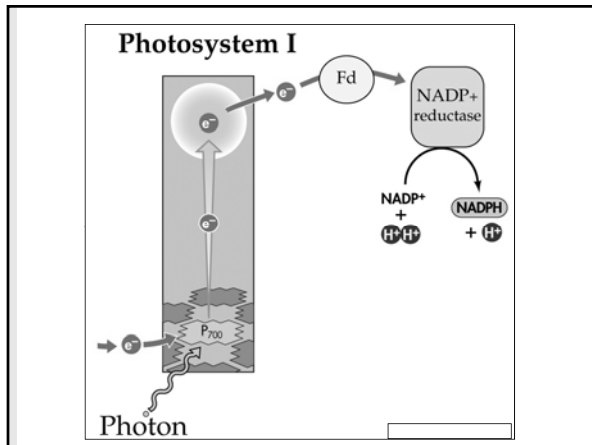


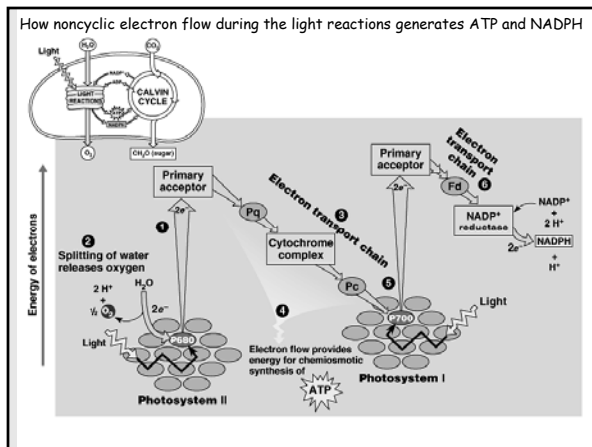


D. Electron Flow, Photophosphorylation, and Reductions

- Noncyclic electron flow uses two photosystems.
- Photosystem II uses P_{680} chlorophyll, from which light-excited electrons pass to a redox chain that drives chemiosmotic ATP production. Light-driven water oxidation releases O_2 , passing electrons to P_{680} chlorophyll.
- Photosystem I passes electrons from P_{700} chlorophyll to another redox chain and then to $NADP^+$, forming $NADPH + H^+$.

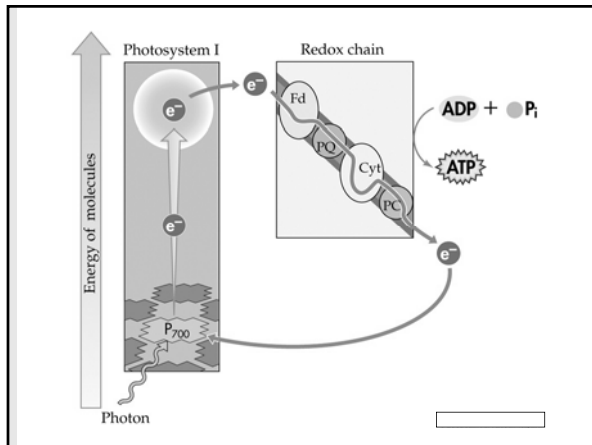


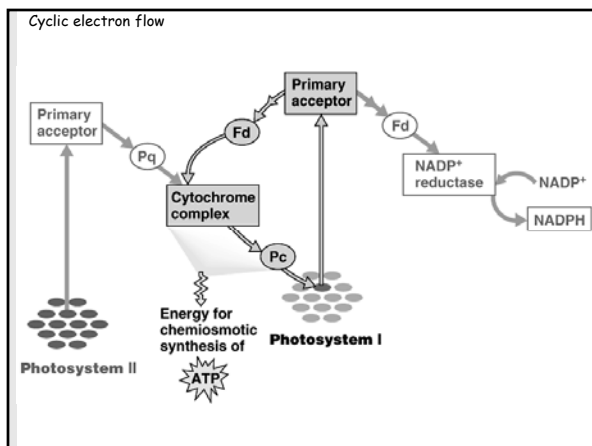




D. Electron Flow, Photophosphorylation, and Reductions

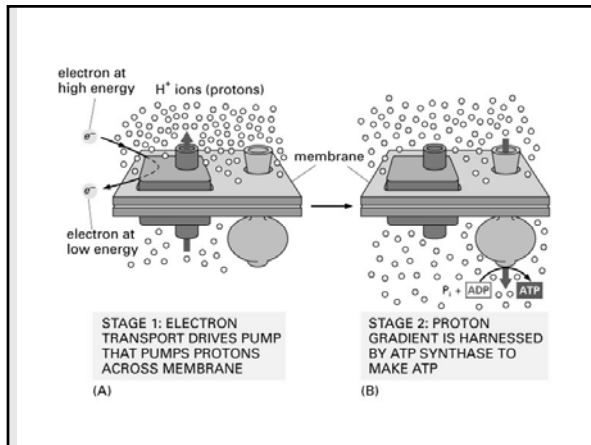
- Cyclic electron flow uses P_{700} chlorophyll producing **only** ATP. Its operation maintains the proper balance of ATP and $NADPH + H^+$ in the chloroplast.

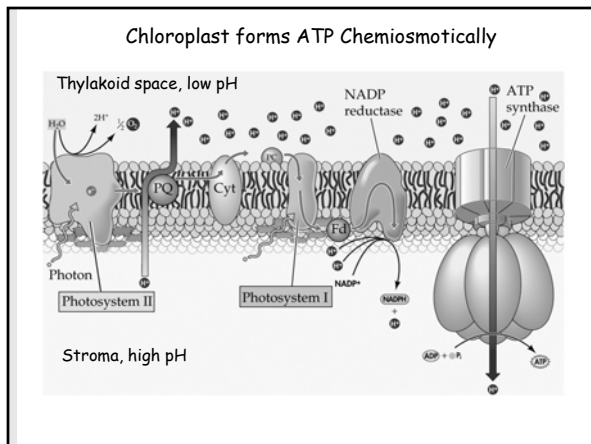


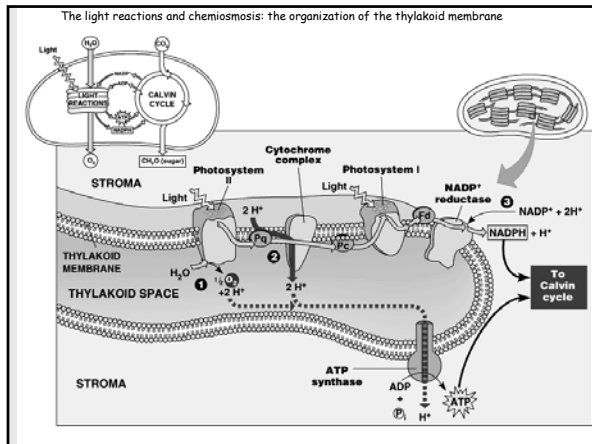


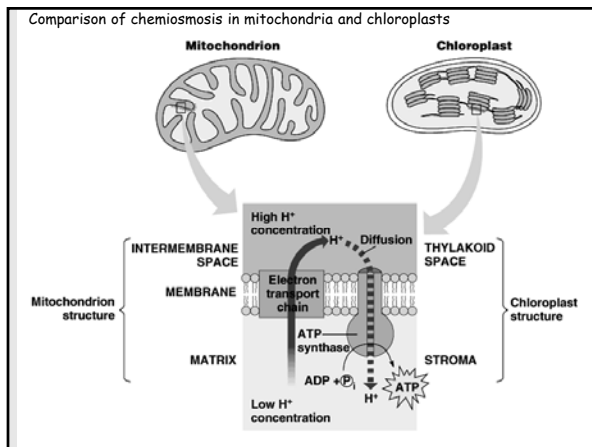
D. Electron Flow, Photophosphorylation, and Reductions

- Chemiosmosis is the source of ATP in photophosphorylation.
- Electron transport pumps protons from stroma into thylakoids, establishing a proton-motive force.
- Proton diffusion to stroma via ATP synthase channels drives ATP formation from ADP and P_i .







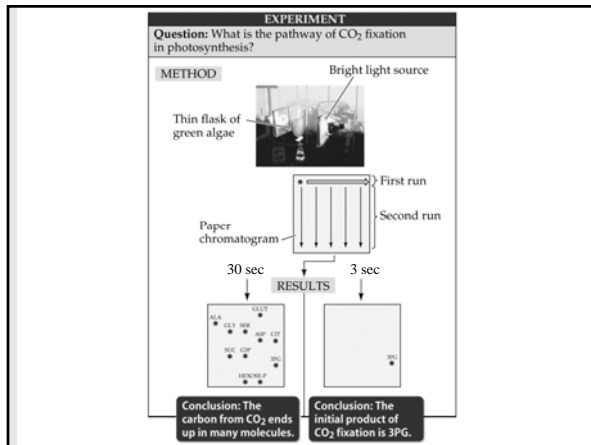


D. Electron Flow, Photophosphorylation, and Reductions

- Photosynthesis probably originated in anaerobic bacteria that used H_2S as a source of electrons instead of H_2O .
- Oxygen production by bacteria was important in eukaryote evolution.

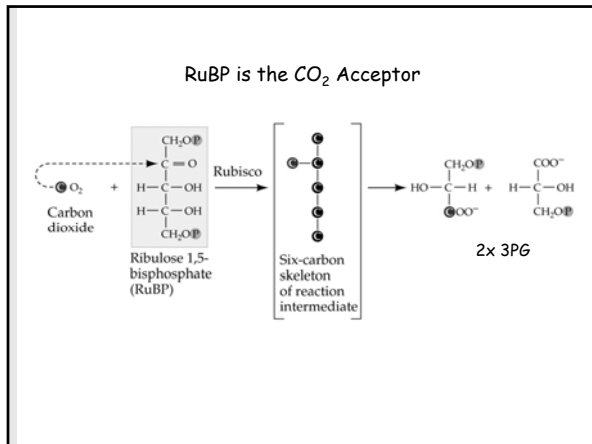
E. Making Sugar from CO₂: The Calvin-Benson Cycle

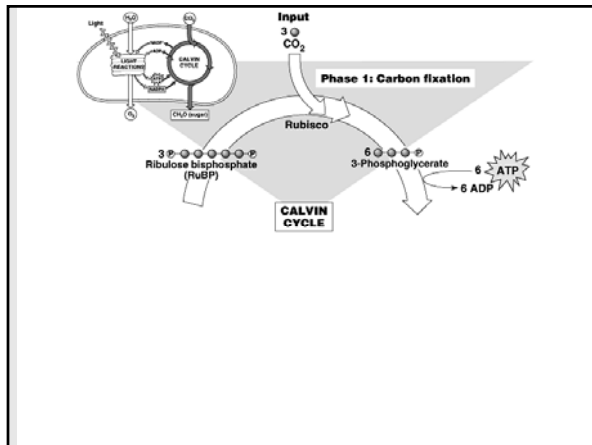
- The Calvin-Benson cycle makes sugar from CO₂. This pathway was elucidated through use of radioactive tracers.

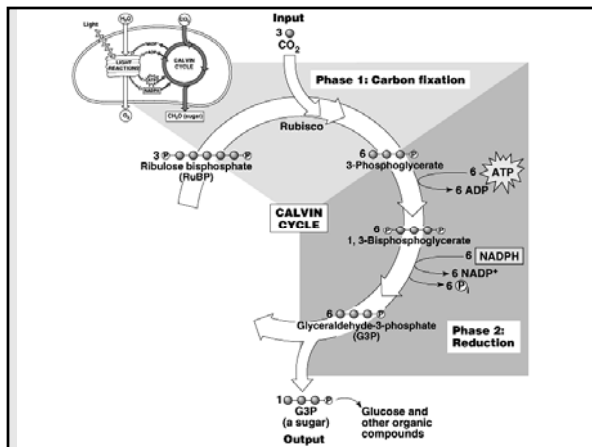


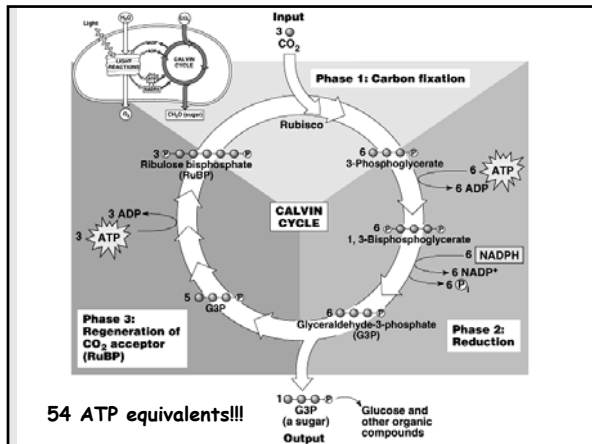
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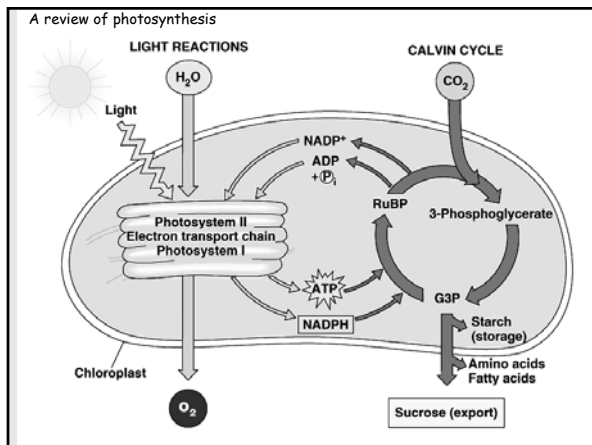
- The Calvin-Benson cycle has three phases:
- Fixation of CO₂
- Reduction (and carbohydrate production)
- Regeneration of RuBP.
- RuBP is the initial CO₂ acceptor, 3PG is the first stable product of CO₂ fixation. Rubisco catalyzes the reaction of CO₂ and RuBP to form 3PG.









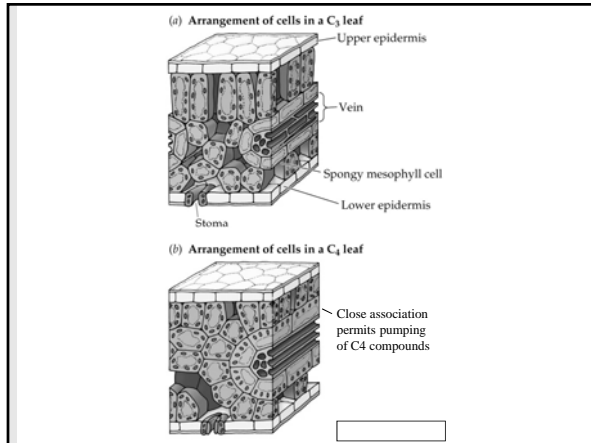


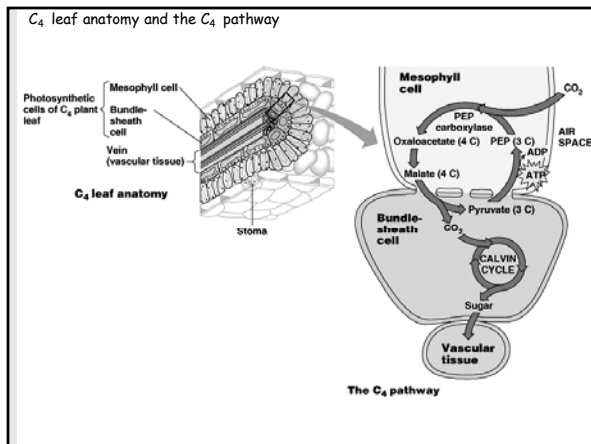
F. Photorespiration and Its Consequences

- Rubisco catalyzes a reaction between O₂ and RuBP (forming phosphoglycolate + 3PG) in addition to the usual route of CO₂ and RuBP.
- Photorespiration byproducts are processed by chloroplasts, peroxisomes, and mitochondria.
- Photorespiration significantly reduces photosynthesis efficiency.

F. Photorespiration and Its Consequences

- Higher temperatures and dryer climates increase the effects of photorespiration; the oxygenase function of rubisco is then favored.
- C_4 plants bypass photorespiration. PEP carboxylase in mesophyll chloroplasts initially fixes CO_2 in four-carbon acids, which diffuse into bundle sheath cells, where their decarboxylation produces locally high concentrations of CO_2 .





F. Photorespiration and Its Consequences

- Higher temperatures and dryer climates increase the effects of photorespiration; the oxygenase function of rubisco is then favored.
- CAM (crassulacean acid metabolism) plants operate much like C_4 plants, but their initial CO_2 fixation by PEP carboxylase is temporally separated from the Calvin-Benson cycle, rather than spatially separated.

