

Lecture Series 13
Photosynthesis: Energy
from the Sun

Photosynthesis: Energy from the Sun

- A. Identifying Photosynthetic Reactants and Products
- B. The Two Pathways of Photosynthesis: An Overview
- C. Properties of Light and Pigments

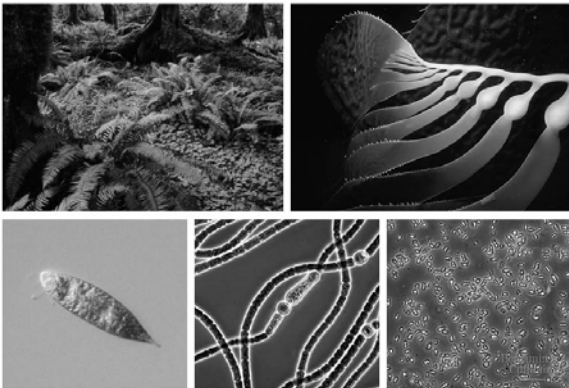
Photosynthesis: Energy from the Sun

- D. Electron Flow, Photophosphorylations, and Reductions
- E. Making Sugar from CO₂: The Calvin–Benson Cycle
- F. Photorespiration and Its Evolutionary Consequences

Photosynthesis In General

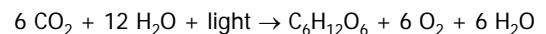
- Life on Earth depends on the absorption of light energy from the sun.
- In plants, photosynthesis takes place in chloroplasts.

Photoautotrophs

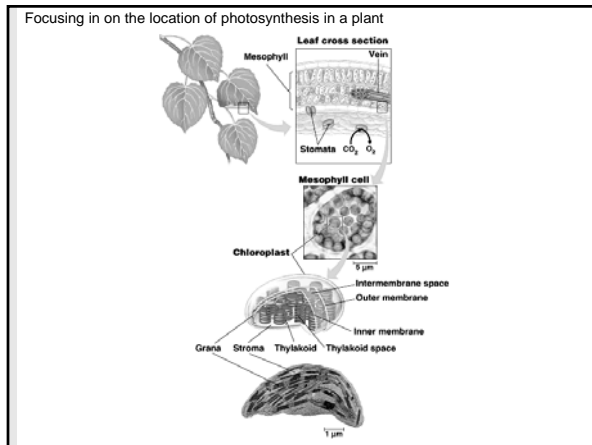
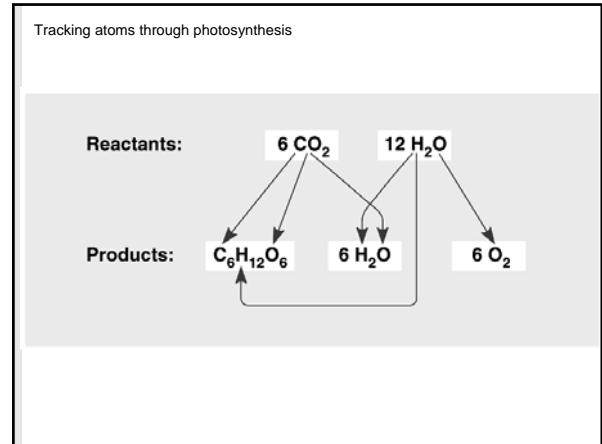
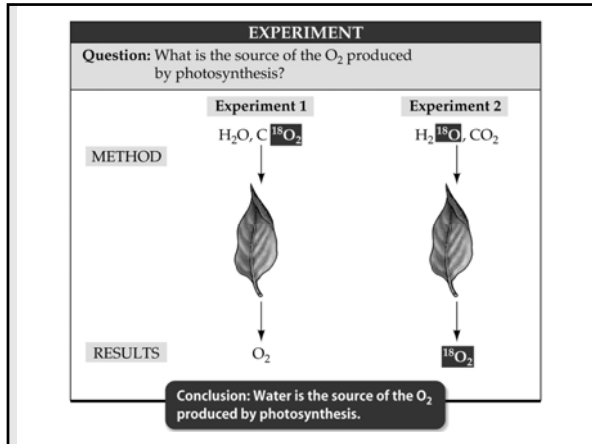


A. Identifying Photosynthetic Reactants and Products

- Photosynthesizing plants take in CO₂, water, and light energy, producing O₂ and carbohydrate. The overall reaction is

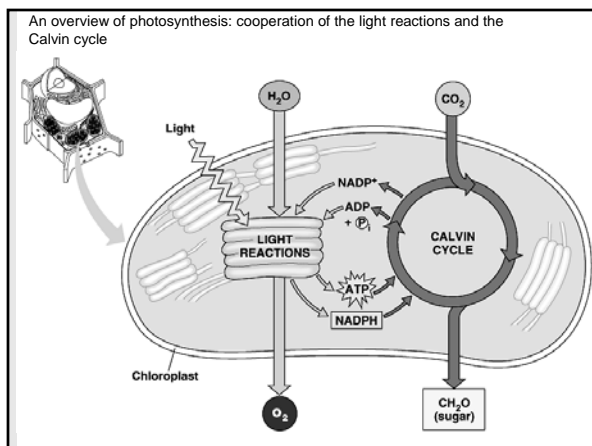


- The oxygen atoms in O₂ come from water, not from CO₂.



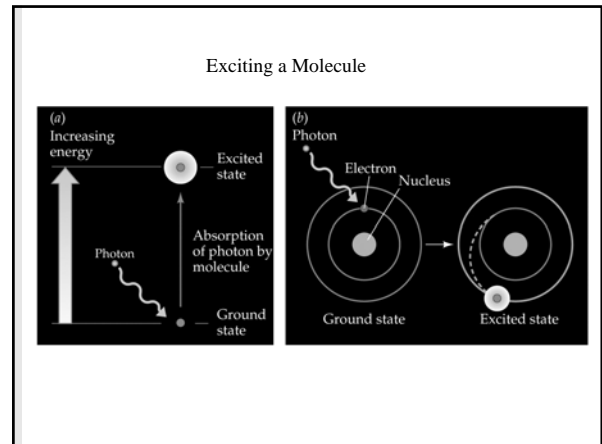
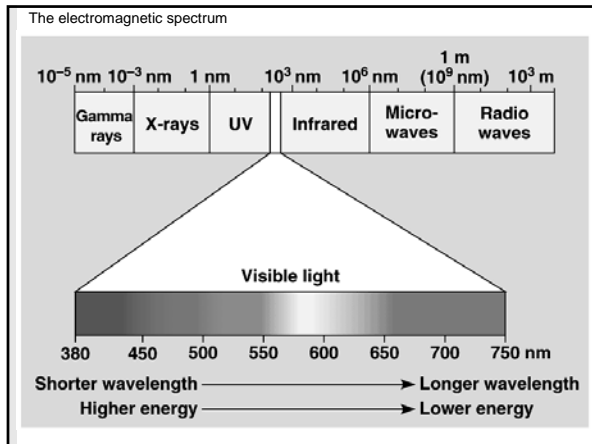
B. The Two Pathways of Photosynthesis: An Overview

- In the light reactions of photosynthesis, electron flow and photophosphorylation produce ATP and reduce $NADP^+$ to $NADPH + H^+$.
- ATP and $NADPH + H^+$ 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.



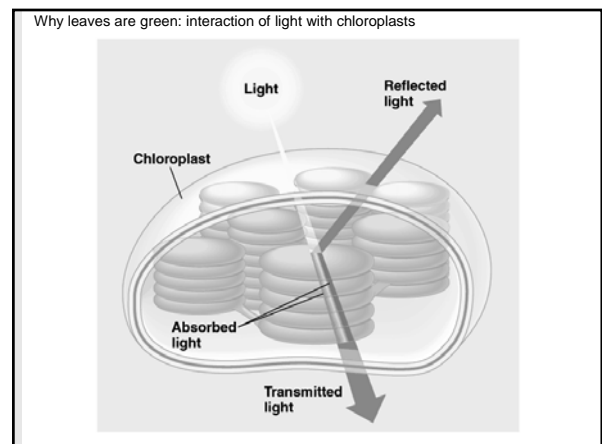
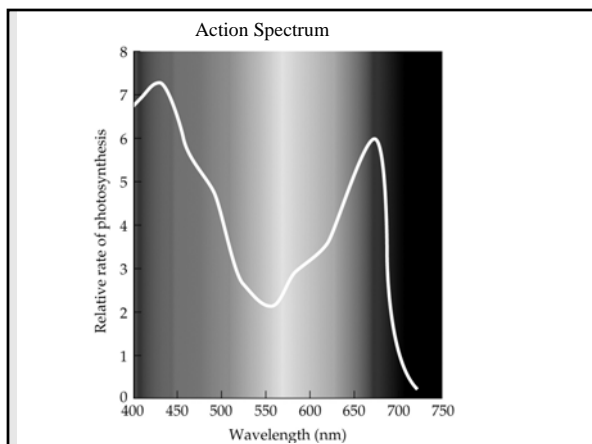
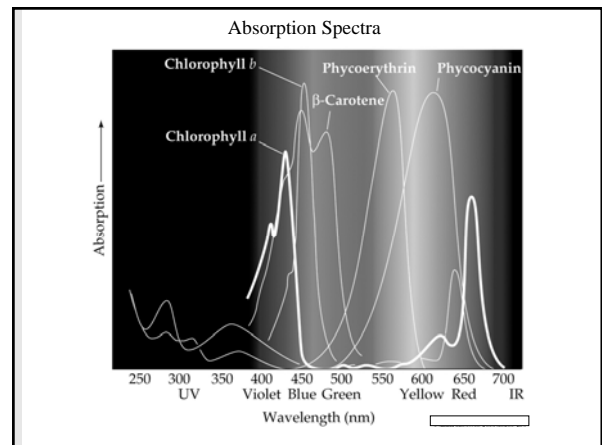
C. Properties of Light and Pigments

- 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.



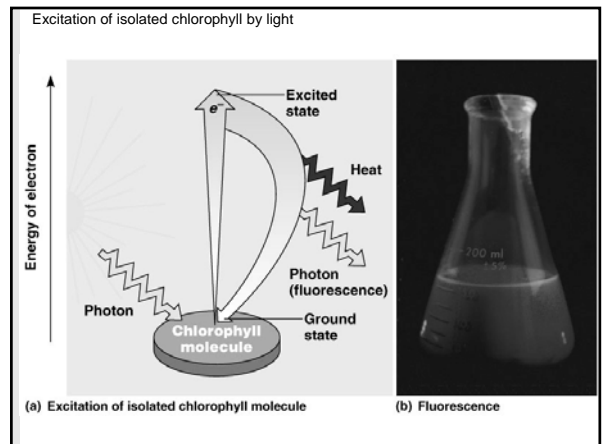
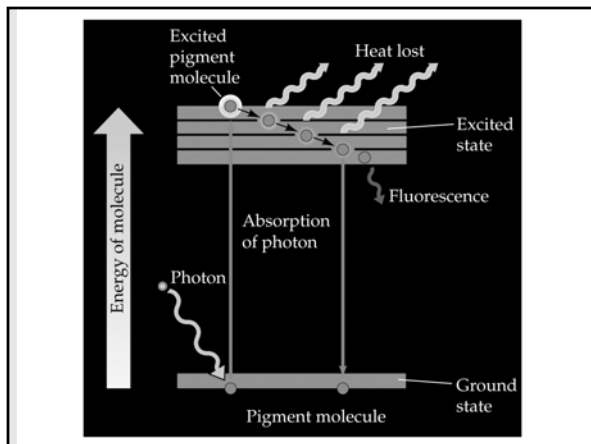
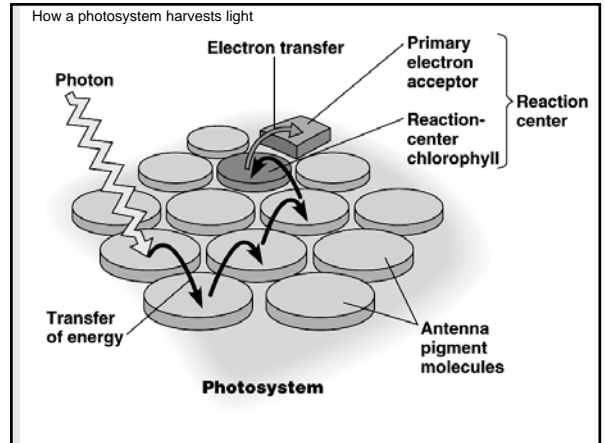
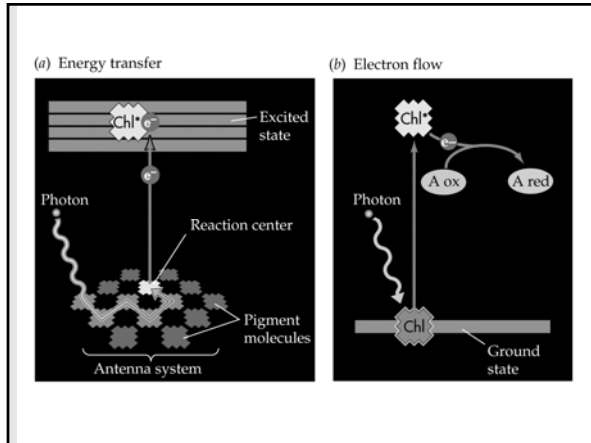
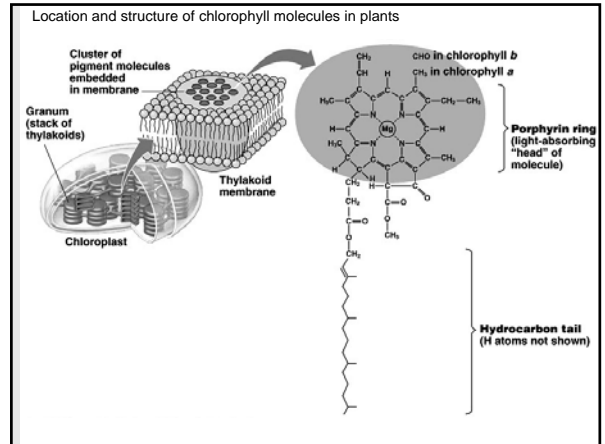
C. Properties of Light and Pigments

- 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.



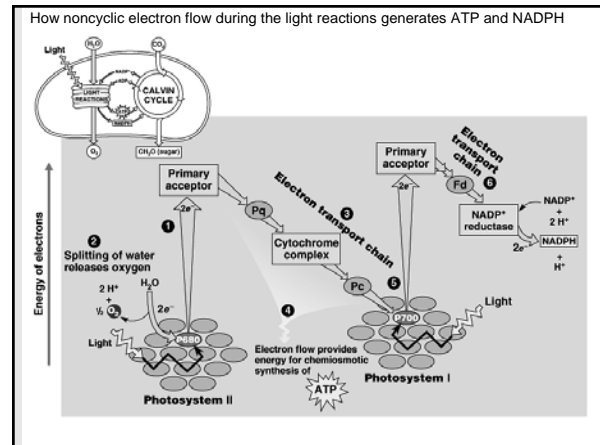
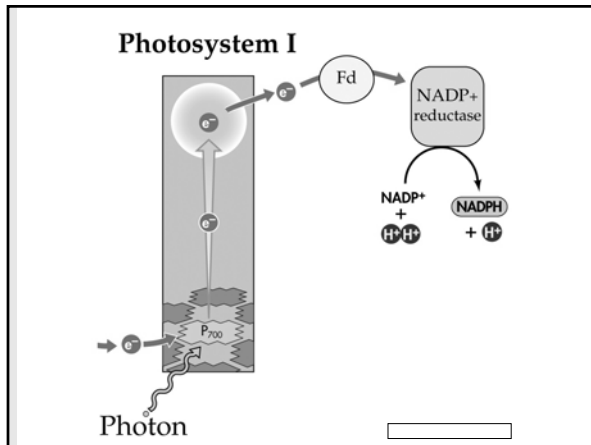
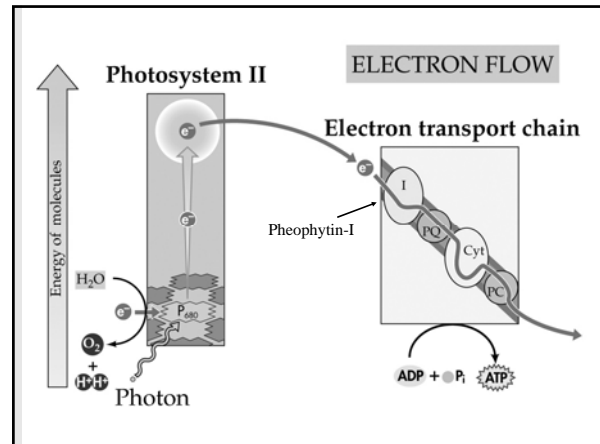
C. Properties of Light and Pigments

- 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.



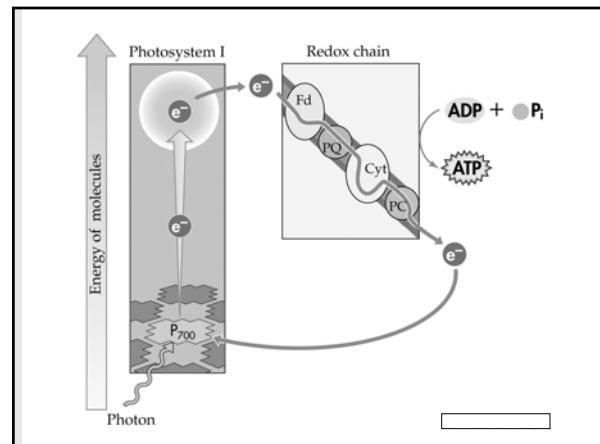
D. Electron Flow, Photophosphorylation, and Reductions

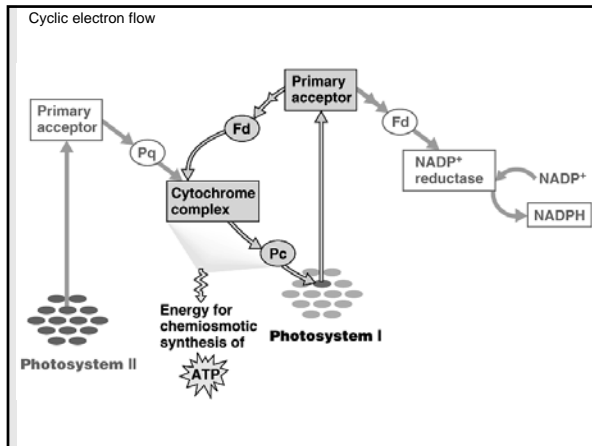
- Noncyclic electron flow uses two photosystems.
- Photosystem II uses P_{680} chlorophyll, from which light-excited electrons pass to a redox chain that drives chemiosmotic ATP production. Light-driven water oxidation releases O_2 , passing electrons to P_{680} chlorophyll.
- Photosystem I passes electrons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



D. Electron Flow, Photophosphorylation, and Reductions

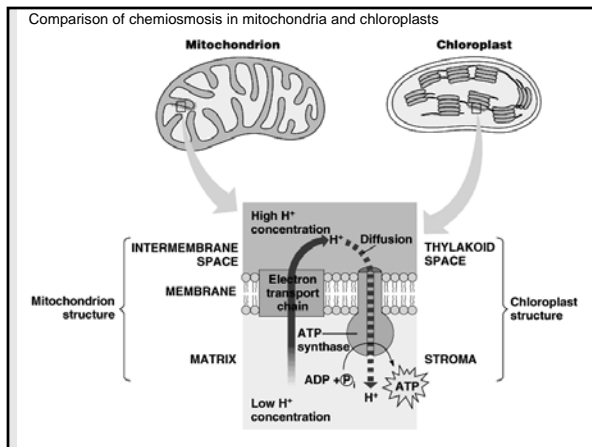
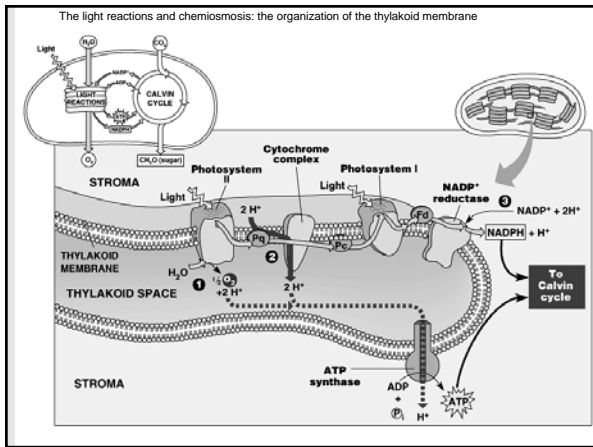
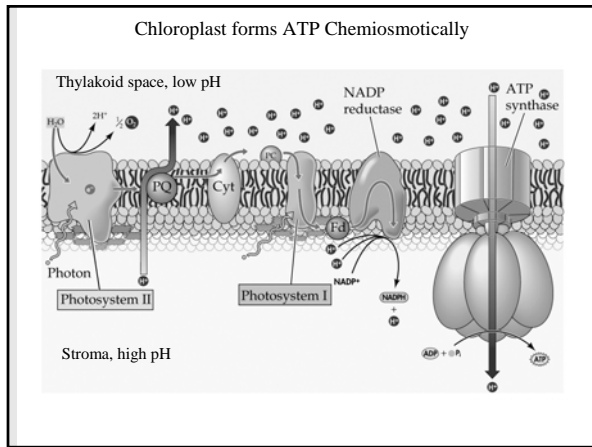
- Cyclic electron flow uses P_{700} chlorophyll producing **only** ATP. Its operation maintains the proper balance of ATP and $NADPH + H^+$ in the chloroplast.





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 .

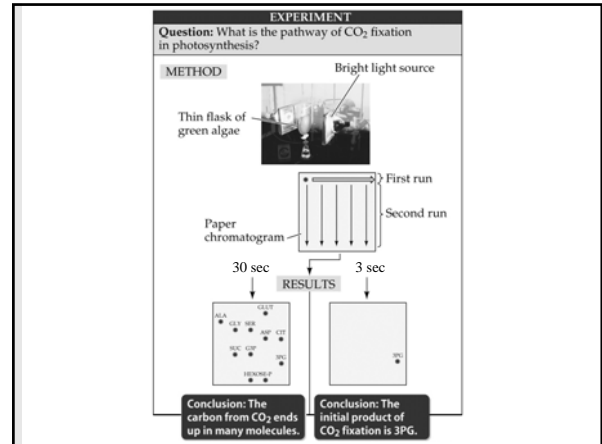


D. Electron Flow, Photophosphorylation, and Reductions

- 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.

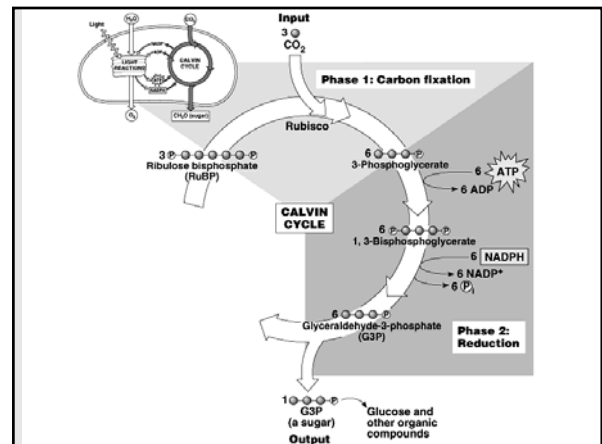
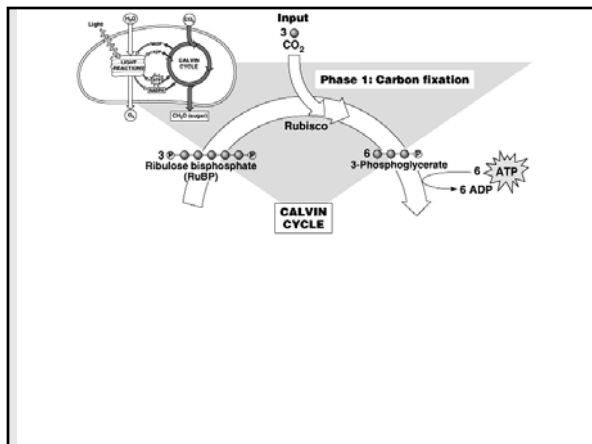
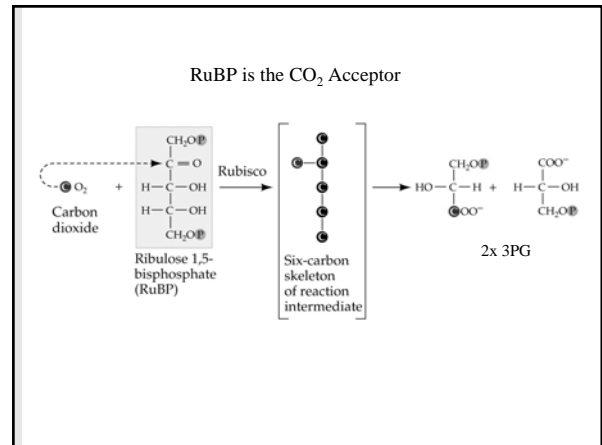
E. Making Sugar from CO₂: The Calvin–Benson Cycle

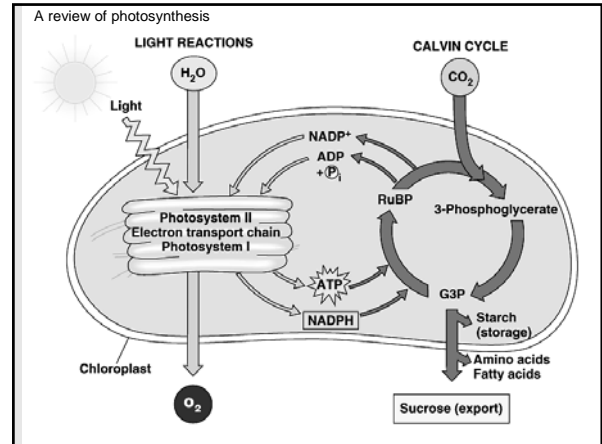
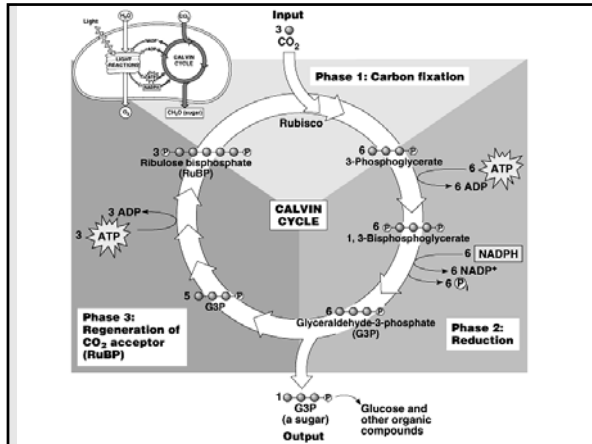
- The Calvin–Benson cycle makes sugar from CO₂. This pathway was elucidated through use of radioactive tracers.



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

- 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.



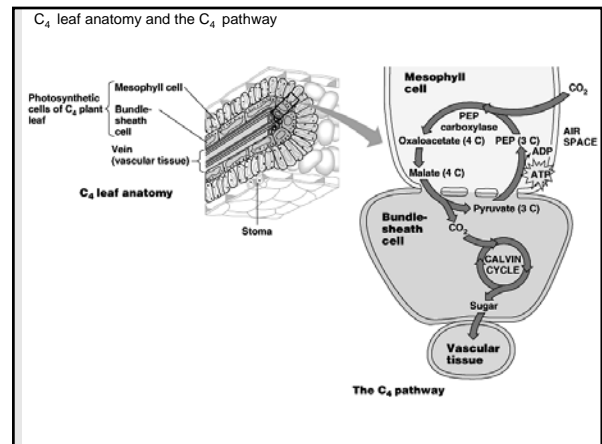
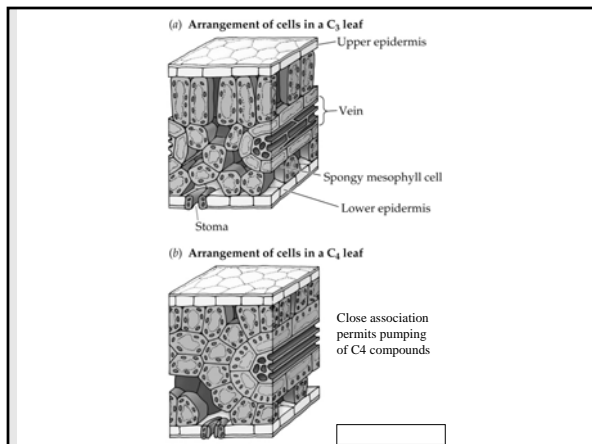


F. Photorespiration and Its Evolutionary Consequences

- Rubisco catalyzes a reaction between O₂ and RuBP in addition to that of CO₂ and RuBP.
- Photorespiration significantly reduces photosynthesis efficiency.
- Reactions that constitute photorespiration are distributed over chloroplast, peroxisome, and mitochondria organelles.

F. Photorespiration and Its Evolutionary Consequences

- At high temperatures and low CO₂ concentrations, the oxygenase function of rubisco is favored.
- C₄ plants bypass photorespiration. PEP carboxylase in mesophyll chloroplasts initially fixes CO₂ in four-carbon acids, which diffuse into bundle sheath cells, where their decarboxylation produces locally high concentrations of CO₂.



F. Photorespiration and Its Evolutionary Consequences

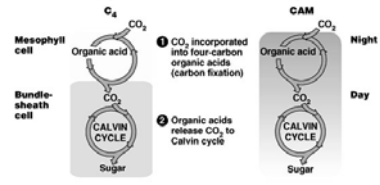
- CAM (crassulacean acid metabolism) plants operate much like C_4 plants, but their initial CO_2 fixation by PEP carboxylase is temporally separated from the Calvin-Benson cycle, rather than spatially separated.

C_4 and CAM photosynthesis compared



Sugarcane

Pineapple



(a) Spatial separation of steps

(b) Temporal separation of steps