

Lecture Series 10  
Photosynthesis: Energy  
from the Sun

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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

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Photosynthesis In General

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

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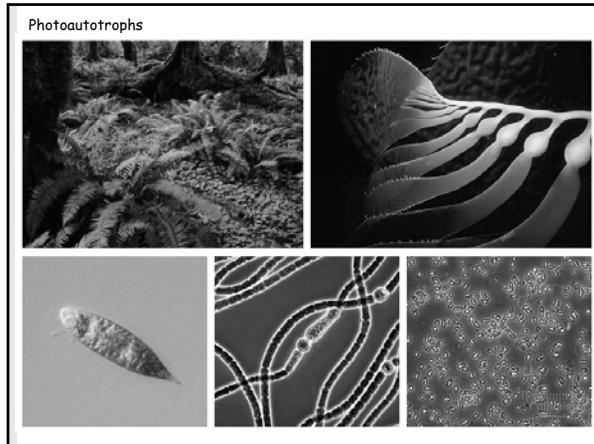
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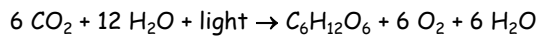
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## A. Identifying Photosynthetic Reactants and Products

- 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  $CO_2$ .

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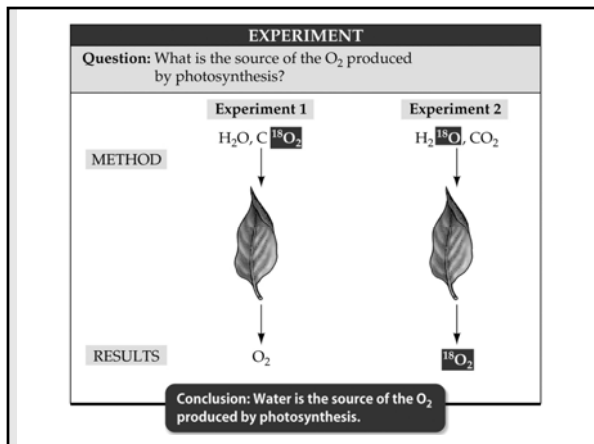
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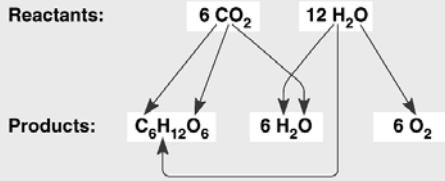
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Tracking atoms through photosynthesis



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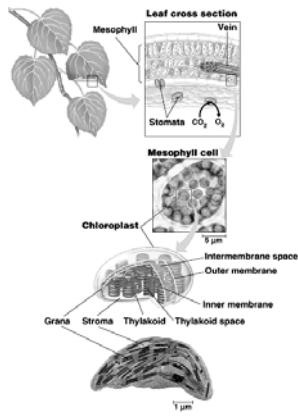
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Focusing in on the location of photosynthesis in a plant



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## B. The Two Pathways of Photosynthesis: An Overview

- In the light reactions of photosynthesis, electron flow and photophosphorylation produce ATP and reduce  $\text{NADP}^+$  to  $\text{NADPH} + \text{H}^+$ .
- ATP and  $\text{NADPH} + \text{H}^+$  are needed for the reactions that fix and reduce  $\text{CO}_2$  in the Calvin-Benson cycle, forming sugars. These are sometimes erroneously referred to as the dark reactions.

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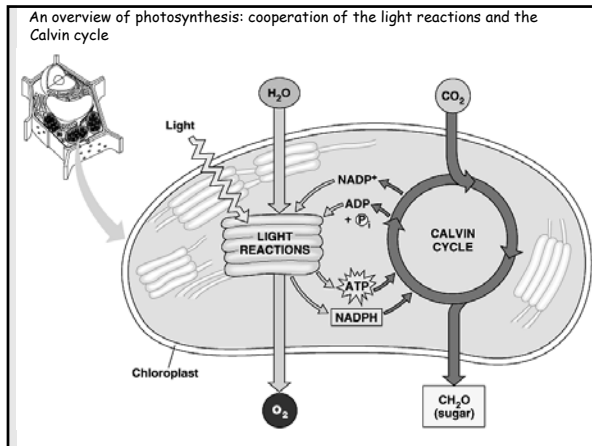
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### C. Properties of Light and Pigments

- 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.

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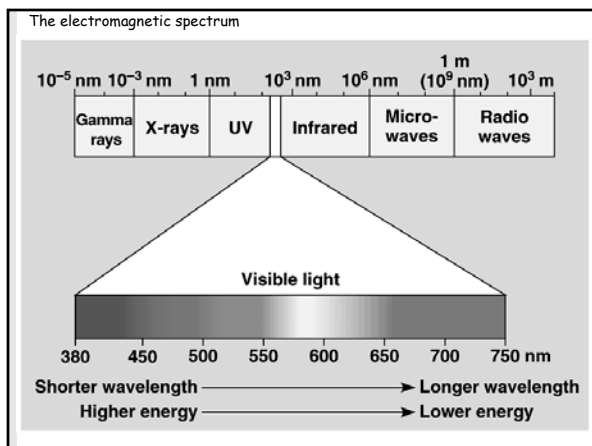
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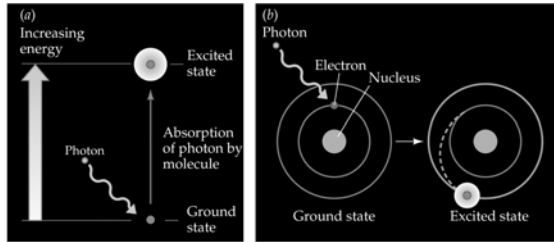
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### Exciting a Molecule



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### 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.

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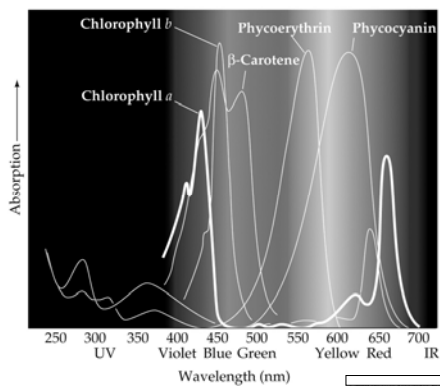
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### Absorption Spectra



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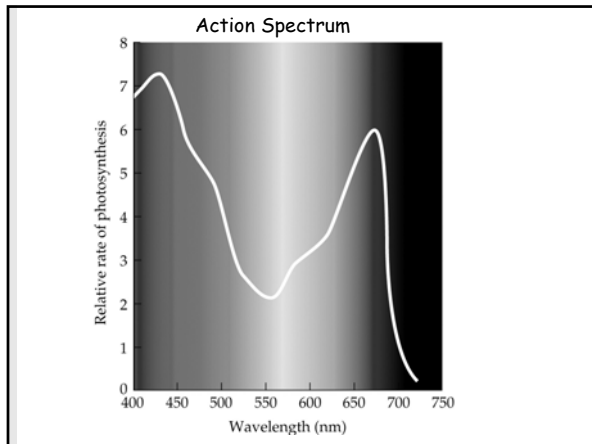
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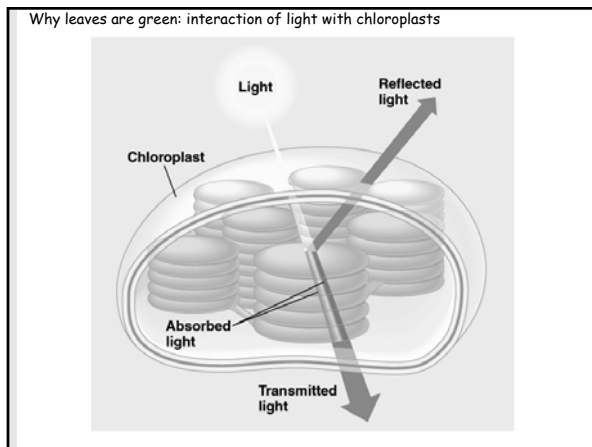
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### C. Properties of Light and Pigments

- 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.

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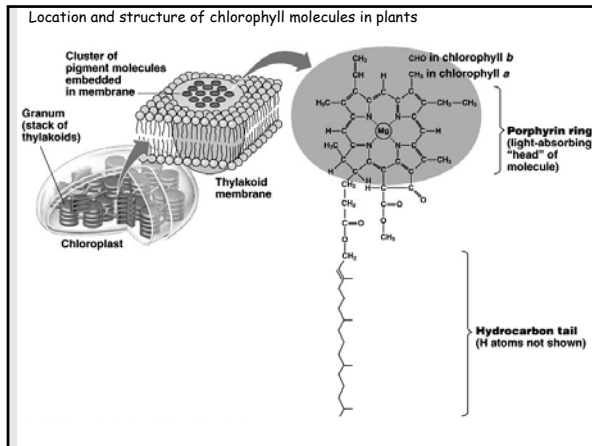
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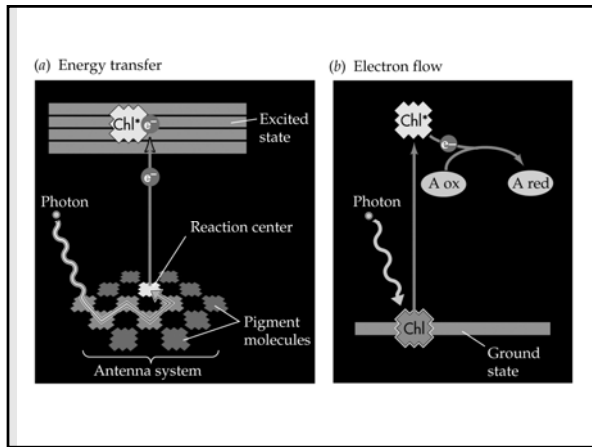
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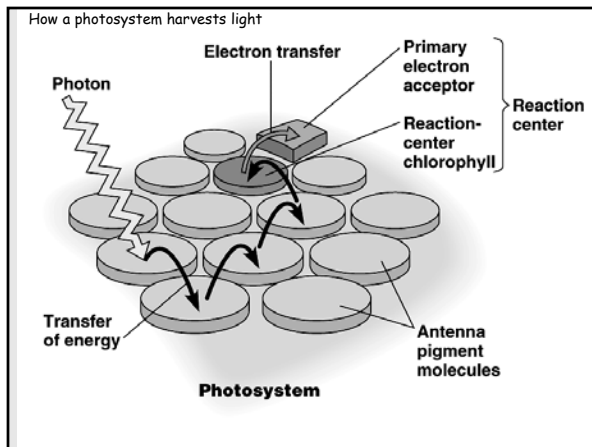
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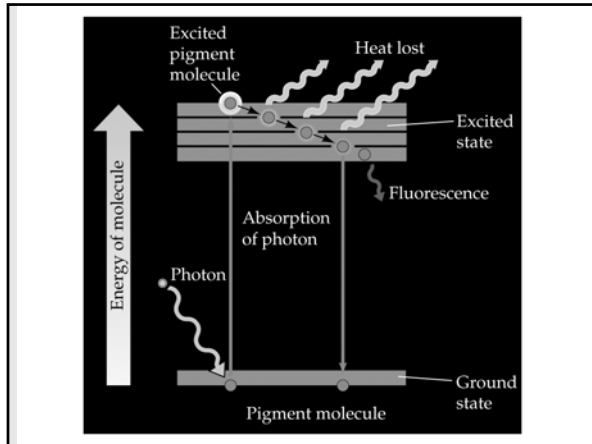
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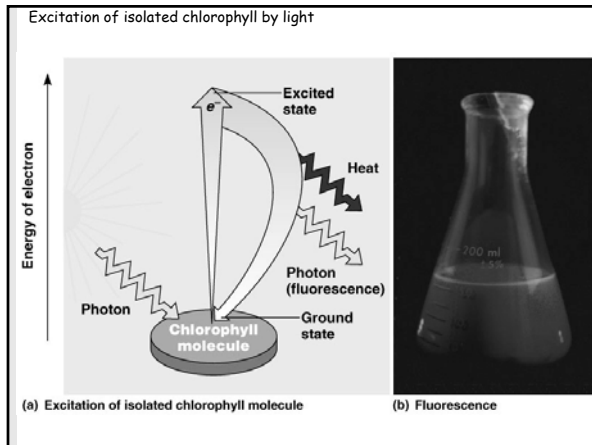
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### D. Electron Flow, Photophosphorylation, and Reductions

- 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  $NADPH + H^+$ .

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## 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.

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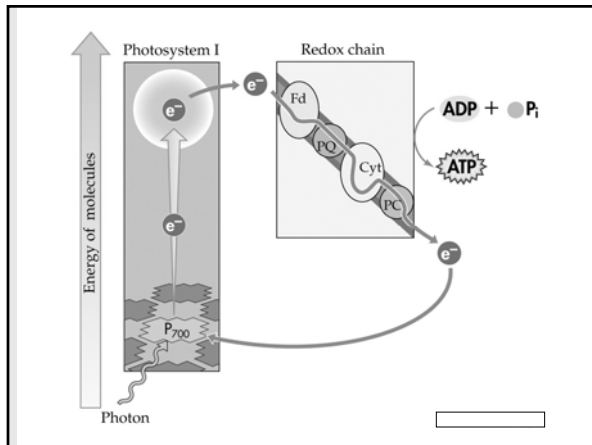
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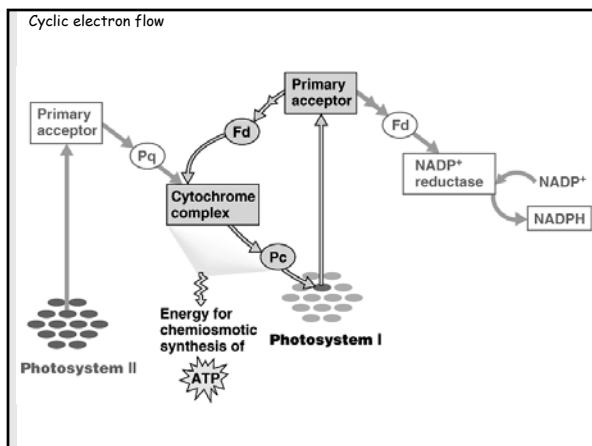
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## D. Electron Flow, Photophosphorylation, and Reductions

- 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  $P_i$ .

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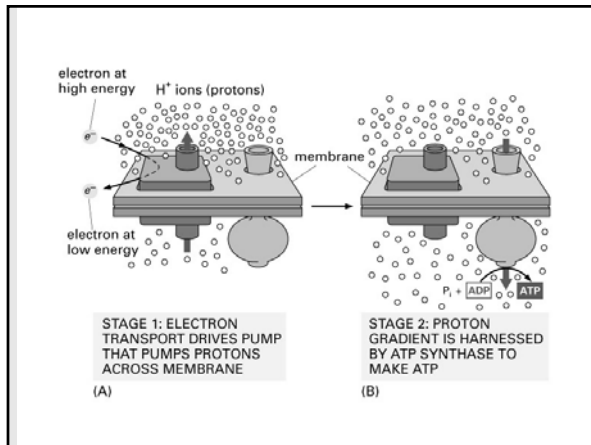
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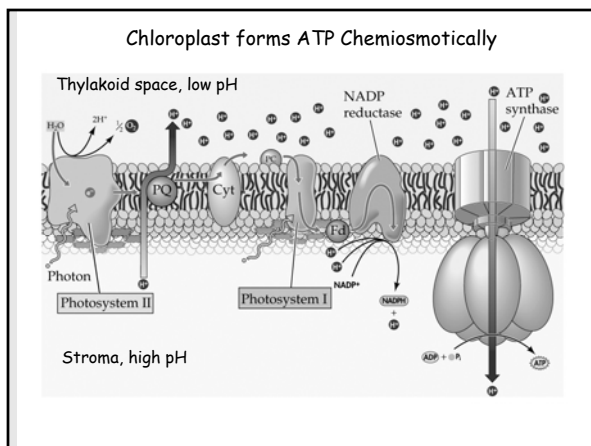
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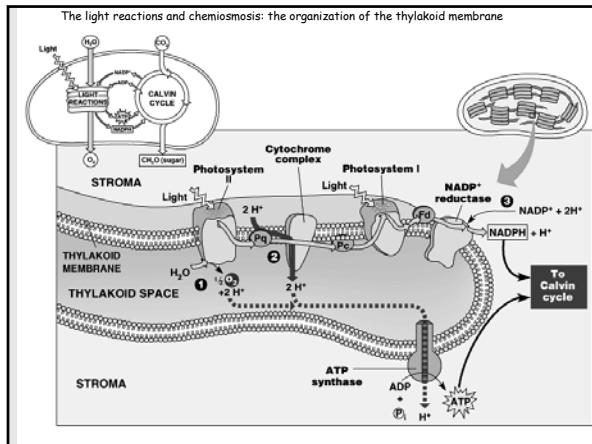
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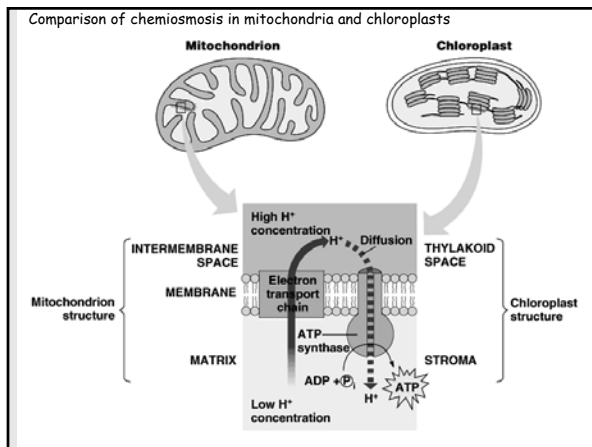
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### D. Electron Flow, Photophosphorylation, and Reductions

- 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.

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## E. Making Sugar from CO<sub>2</sub>: The Calvin-Benson Cycle

- The Calvin-Benson cycle makes sugar from CO<sub>2</sub>. This pathway was elucidated through use of radioactive tracers.

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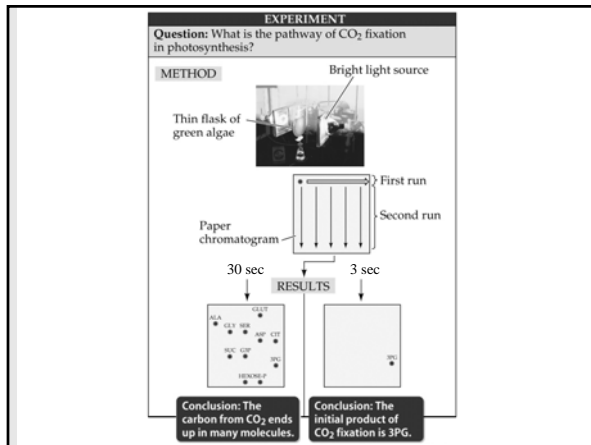
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## E. Making Sugar from CO<sub>2</sub>: The Calvin-Benson Cycle

- The Calvin-Benson cycle has three phases:
- Fixation of CO<sub>2</sub>
- Reduction (and carbohydrate production)
- Regeneration of RuBP.
- RuBP is the initial CO<sub>2</sub> acceptor, 3PG is the first stable product of CO<sub>2</sub> fixation. Rubisco catalyzes the reaction of CO<sub>2</sub> and RuBP to form 3PG.

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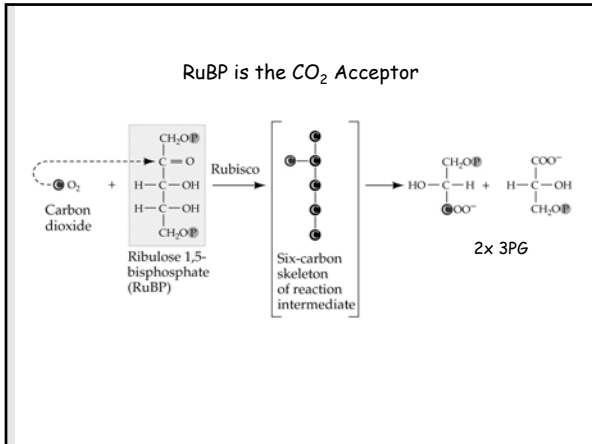
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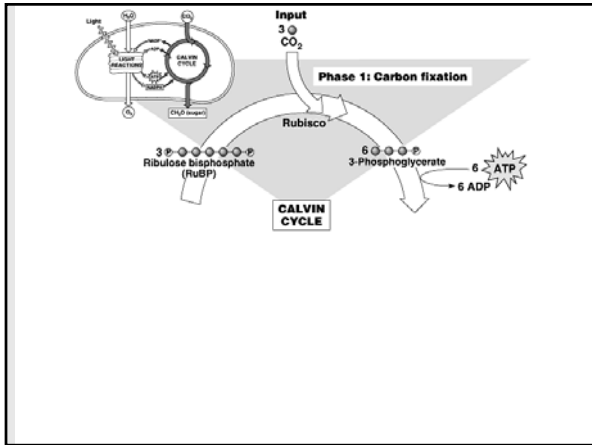
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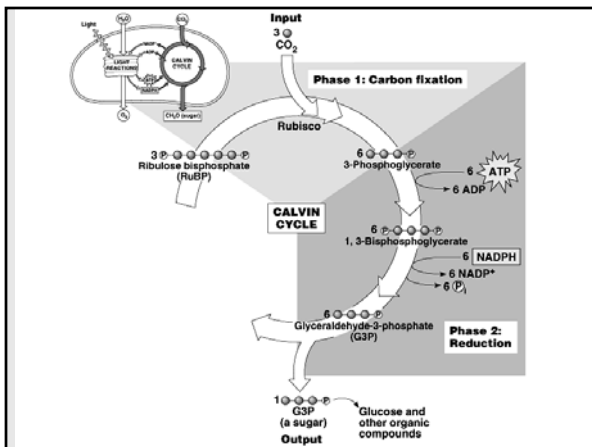
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