## Photosynthesis

In order to understand the basis of photosynthesis, it is first necessary to be familiar with the molecule that is responsible for supplying energy for cellular processes. Adenosine triphosphate, ATP, is energy-carrying due to its third ("tri") phosphate group, and is converted to ADP, adenosine diphosphate, in order to release the terminal phosphate group and release energy.

$$\textbf{ATP} \rightarrow \textbf{ADP} + \textbf{P}_i + \textbf{energy}$$

ATP is produced in the process of cellular respiration, but photosynthesis is essentially the reverse of this. Whereas respiration involves the breakdown of simple carbohydrates to produce energy and inorganic waste products, photosynthesis requires an energy input in order to allow plants and other photosynthetic organisms to store organic carbohydrates from inorganic reactants. The overall equation is:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Photosynthesis is broken down into two main components, the light-dependent reactions and the dark reactions or Calvin Cycle.

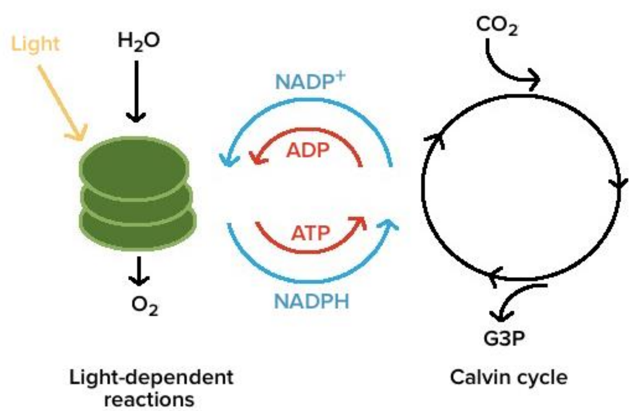
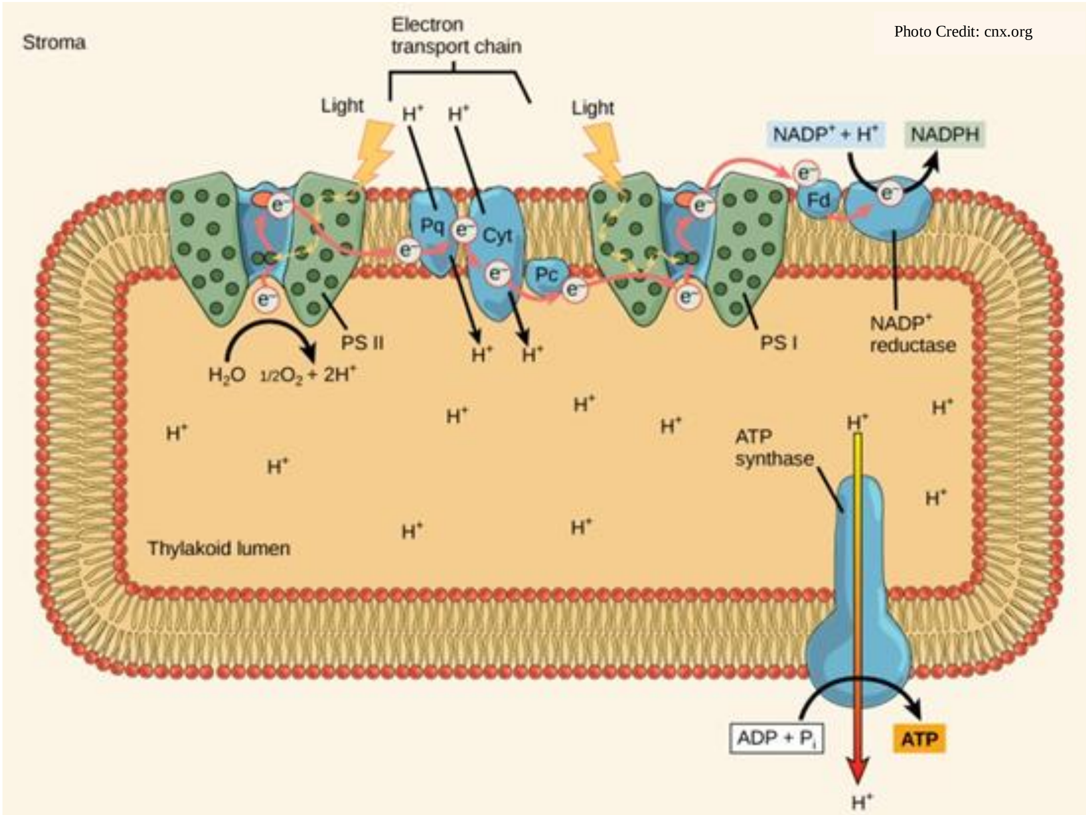


Photo Credit: Khan Academy

### I. The Light-Dependent Reactions

Autotrophic organisms that rely on photosynthesis employ the chloroplast organelle for this purpose. Within the chloroplasts are membranous stacks of grana that collectively form the thylakoids. There are pigment molecules embedded in the thylakoid membrane that absorb specific frequencies of light and convert this to usable energy.

Chlorophyll is the main photosynthetic pigment, absorbing predominately in the 400-500 nm and 600-700 nm range of visible light. Green light (within the 500-600 nm region) is not absorbed but is instead reflected, causing the green appearance of plant matter.




The chemical structure of pigment molecules allows them to convert solar energy into chemical energy in the form of energetic molecules of ATP and NADPH by transferring "excited" electrons.

Two photosystems prompt a series of redox reactions (remember "LEO goes GER," where loss of electrons indicates oxidation and gain of electrons is reduction). Photosystem II uses sunlight to oxidize water and transfer its electrons in an electron transport chain via the cytochrome complex to Photosystem I, which ultimately reduces $NADP^+$ to NADPH.

The $H^+$ ions that were removed from H2O accumulate in the lumen (center) of thylakoid. These will allow for reduction of $NADP^+$, and are intrinsically exploited to lower the lumen pH, allowing for the opening of the ion channel of the ATP synthase enzyme that harnesses the passive diffusion of H+ into the stroma to generate ATP from ADP and inorganic phosphate ($P_i$).

**II. The Light-Independent Reactions (aka The Calvin Cycle)**

Carbon fixation is the term used to describe the generation of organic molecules (carbohydrates) from inorganic ($CO_2$). This is a process that requires considerable energy input, and it is for this reason that the Calvin Cycle must follow the energy-producing light reactions. After $CO_2$ combines with a five-carbon molecule known as RuBP, two three-carbon 3-PGAs are formed and reduced using the ATP and NADPH from the light reactions.

NADPH donates electrons and $H^+$ to form two G3P sugar molecules which are precursors to glucose, the primary monosaccharide that forms the starches for structural storage of carbohydrates in a plant. In all, for each three $CO_2$ molecules that enter the cycle, one G3P will contribute to the formation of glucose. Because glucose is a six-carbon molecule, however, a single glucose requires a total of six $CO_2$s for completion.

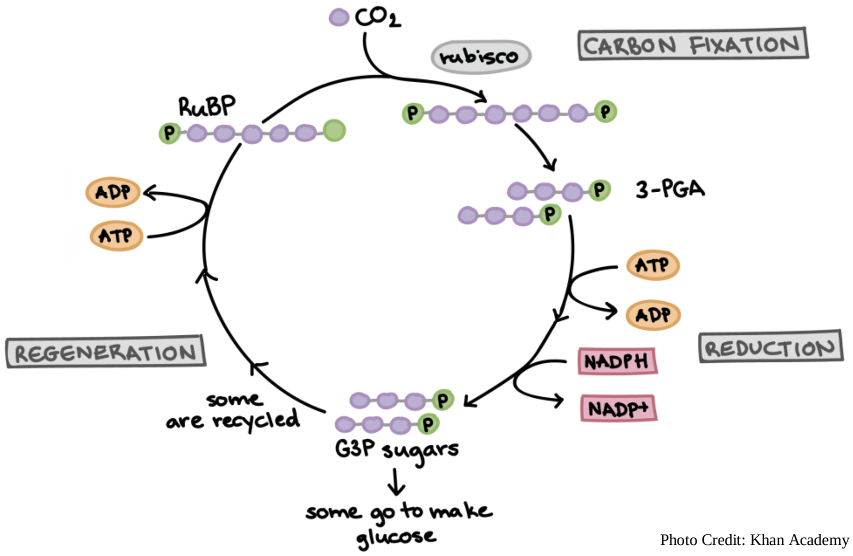



Photo Credit: Khan Academy