

The Photosynthesis Process

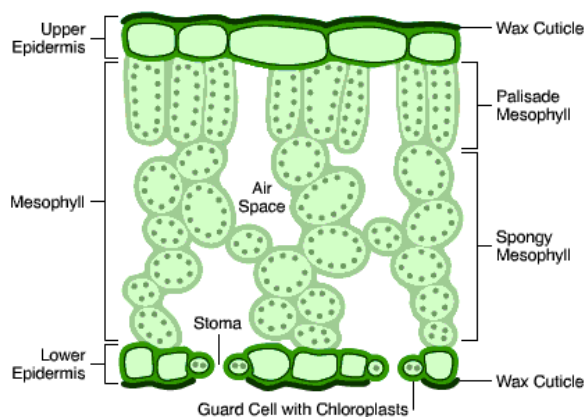
By: Tyler Erb

Photosynthesis is the process of converting light energy into chemical energy. Not all wavelengths of light can be used in the process of photosynthesis. For plants green wavelengths are reflected, giving the plant its green color and thus aren't used. The most effective wavelengths for plant photosynthesis are red and violet-blue. The wavelengths of light are converted into sugars and organic compound. The products are the result of a series of chemical reactions that is summarized by the equation:



Leaf Structure

In plants, virtually all photosynthesis occurs in the leaf. The leaf is made up of four major parts: the upper and lower epidermis, vascular bundles, stomas and mesophyll. The upper and lower epidermises serve as protection for the leaf. The lower epidermis has openings called stomas, allowing for the exchange of carbon dioxide and oxygen that are needed for photosynthesis. The vascular bundles are essentially veins for the plant and transport water and nutrients. The mesophyll cells are where the chloroplasts are located and ultimately where photosynthesis occurs.



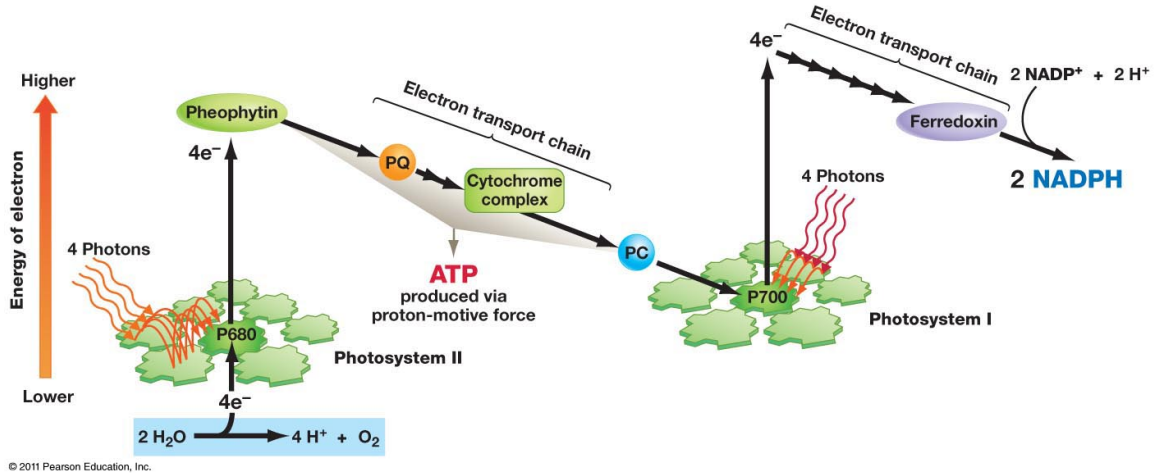
Leaf structure

Image from http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/plants/plants1.shtml

Light Reactions

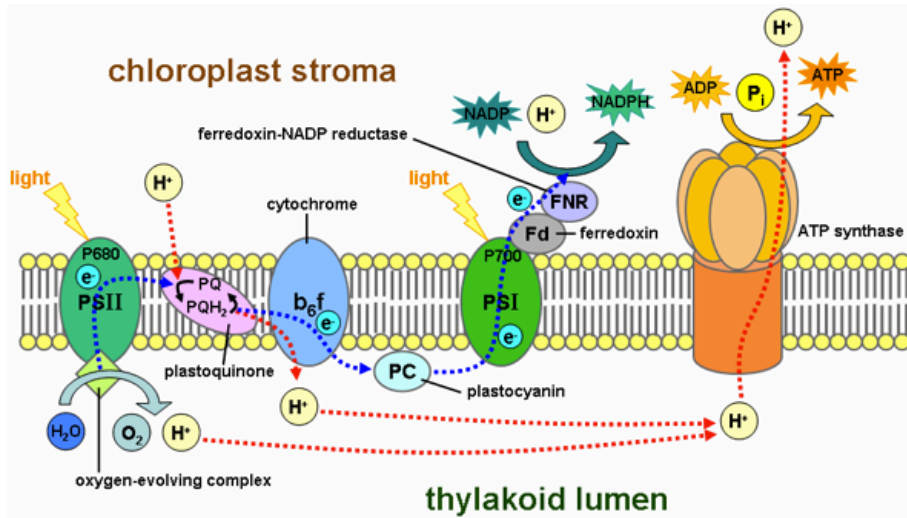
In the Z scheme, chlorophyll absorbs one photon from light and loses one electron. This occurs in photosystem II, containing chlorophyll P680, with the presence of water and carbon dioxide. The electron then passes through an electron transport chain, which is a series of compounds that act as electron donors and acceptors occurring via redox reactions. From the passing of the electron through

the transport chain, energy is created which allows for the chemiosmosis synthesis of adenosine triphosphate. The electron continues to photosystem I, containing chlorophyll P700, where light is again added to “excite” the electron. The electron is then transferred to phylloquinone and again to ferredoxin. The ferredoxin then transports the electron to **NADP** resulting in the reduction of **NADP** to **NADPH**.



Z scheme showing the path of an electron and varying energy levels
 Image from <http://www.uic.edu/classes/bios/bios100/lectures/ps01.htm>

Phosphorylation of adenosine diphosphate accompanies the Z scheme. Light energy is again changed to chemical energy, but this time through a process called photophosphorylation. The enzyme **ATP synthase** uses hydrogen ions that are products of the Z scheme process. These hydrogen ions provide the energy needed to convert adenosine diphosphate to adenosine triphosphate.



Process of Phosphorylation shown with Z scheme
 Image from <http://biology.clc.uc.edu/courses/bio104/photosyn.htm>

Dark Reactions

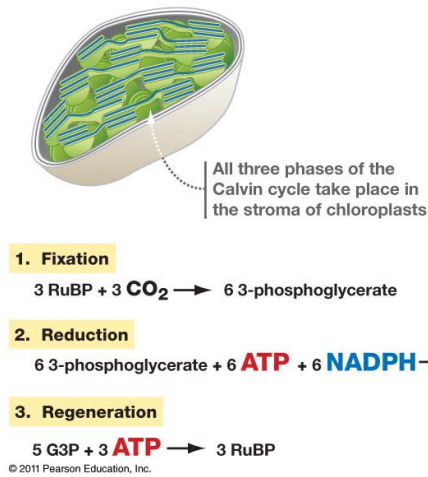
In addition to the processes that require light, there is an equally important process that occurs without the presence of light called the Calvin cycle. Although the process doesn't require light directly, the inputs needed for this process come from the light reactions. Since the light reactions cannot occur without light, the Calvin cycle will not be able to generate the inputs needed to continue and often is stopped with the light reactions when the sun goes down. The Calvin cycle process can be broken down into three steps: fixation, reduction, and regeneration.

During fixation, CO_2 , an enzyme called ribulose biphosphate carboxylase (**RuBisCo**), and ribulose biphosphate (**RuBP**) are present. The enzyme **RuBisCo** catalyzes a reaction between CO_2 and **RuBP**, so that for every one molecule of CO_2 reacting with one molecule of **RuBP** two molecules of 3-phosphoglyceric acid (3-PGA) are formed. This process "fixes" CO_2 from an inorganic form to an organic form and thus is called fixation.

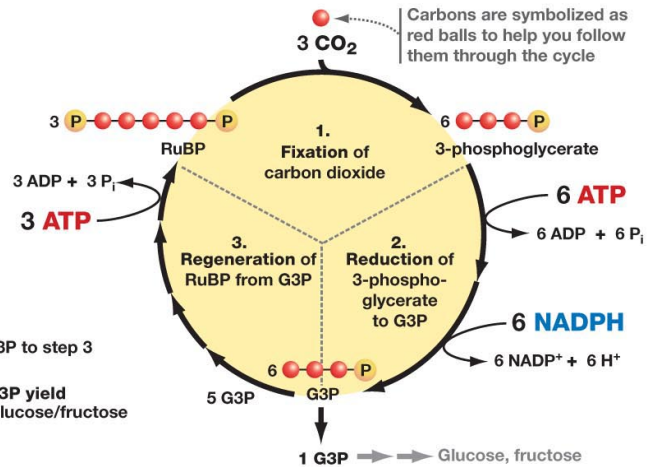
After fixation occurs, the process of reduction begins. **ATP** and **NADPH** convert 3-PGA into glyceraldehyde 3-phosphate (G3P), which is used to produce sugars and other compounds. This reaction requires 3-PGA to gain electrons, making it a reduction process. The reduction process requires six molecules of **ATP** and six molecules of **NADPH** to convert six molecules of 3-PGA into six molecules of G3P. The molecules of **ATP** release energy through the loss of the phosphate and converts back to ADP. The molecules of **NADPH** release both energy and a hydrogen atom, which converts back to **NADP⁺**. Both the ADP and **NADP⁺** return to the light reaction to be reenergized and used again.

During the final stage, regeneration, one of the G3P molecules exits the Calvin cycle and enters the cytoplasm to be used by the plant in the formation of other compounds. Due to this removal of a G3P it takes three full cycles to produce the five needed G3P molecules. These five G3P molecules are used to regenerate **RuBP**, allowing for the cycle to prepare for more CO_2 to be fixed.

(a) The Calvin cycle has three phases.



(b) The reaction occurs in a cycle.



Calvin cycle phases and cycle diagram
 Image from <http://www.uic.edu/classes/bios/bios100/lectures/ps01.htm>

Conclusion

Photosynthesis starts in the leaf with the intake of light and CO_2 through the stomas of the leaf. The energized particles then undergo processes in the light reaction. These processes lead to the creation of ATP from the phosphorylation of ADP . ATP and NADPH are also created from the Z scheme process. The ATP goes onto be used by the plant in various processes as the source of energy. The NADPH continues on to the Calvin cycle, also known as the dark reaction. The Calvin cycle converts RuBP via the RuBisCo enzyme and CO_2 to 3-PGA. This is then converted into G3P and the ATP and NADPH are used for energy and hydrogen and returned to their lower energy state, ADP and NADP^+ . The ADP and NADP^+ are returned to the light processes to be reenergized and the cycle continues. One for every six G3P produced are used elsewhere in the plant for creating other essential compounds, while the remaining five are used to regenerate RuBP to be used in the cycle again.