Photosynthesis Background

All life is based on the element ***carbon***. Carbon is the major chemical constituent of most organic matter, from fossil fuels to the complex molecules (DNA and RNA) that control genetic reproduction in organisms.

Ecosystems gain most of their carbon dioxide from the atmosphere. A number of autotrophic organisms have specialized mechanisms that allow for absorption of this gas into their cells. With the addition of water and energy from solar radiation, these organisms use **photosynthesis** to chemically convert the carbon dioxide to carbon-based sugar molecules. These molecules can then be chemically modified by these organisms through the metabolic addition of other elements to produce more complex compounds like proteins, cellulose, and amino acids. Some of the organic matter produced in plants is passed down to heterotrophic animals through consumption.

Carbon is released from ecosystems as carbon dioxide gas by the process of **respiration**. Respiration takes place in both plants and animals and involves the breakdown of carbon-based organic molecules into carbon dioxide gas and some other compound by-products. The detritus food chain (decomposers) contains a number of organisms whose primary ecological role is the decomposition of organic matter into its abiotic components.

Pidwirny, M. (2006). "The Carbon Cycle". *Fundamentals of Physical Geography, 2nd Edition*. 1/4/09. http://www.physicalgeography.net/fundamentals/9r.html

Carbon is the backbone of the organic world. It is found in most everything and almost everywhere. The chemical composition of carbon makes it a very durable and flexible element. Carbon can bond in many ways because of the presence of four bonding electrons; it can form single, double, and triple bonds that can bond with many other atoms as well as with carbon itself. Carbon compounds can exist in linear or ring forms. Because of its design, most of our fuels, such as coal, oil, and natural gas, are carbon based. Coal, oil, and natural gas are collectively known as fossil fuels.

Carbon, in various forms and combinations, moves between the atmosphere, soil, the ocean, and many living things, as seen in the Carbon Cycle. It is also found in dead organisms and fossil fuels. It exists primarily as a gas, carbon dioxide (CO_2), in the atmosphere and as the solid organic form in living and dead organisms. Atmospheric carbon is constantly recycled. Many organisms release carbon, in the form of CO_2, as a waste by-product, which is quickly absorbed mostly by green plants and algae creating oxygen in the process.

Organisms, like green plants and algae containing chlorophyll, use photosynthesis to store the sun's energy in the bonds of carbohydrates (compounds containing carbon, hydrogen, and oxygen) for future use, both by the organisms themselves and by other organisms. One such energy usage and transformation occurs in the process of photosynthesis.

Photosynthesis is the process of converting light energy to chemical energy and storing it in the bonds of sugar. A simplified version of this reaction is:

$$CO_2 + H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} [CH_2O] + O_2$$

Carbon dioxide + water + light energy + chlorophyll yields carbohydrate + oxygen

This process occurs in plants and some algae (Kingdom Protista). Plants need only light energy, CO_2, and H_2O to make sugar. The process of photosynthesis takes place in the chloroplasts, specifically using chlorophyll, the green pigment involved in photosynthesis.

Photosynthesis takes place primarily in plant leaves, and little to none occurs in stems, etc. The parts of a typical leaf include the **upper and lower** epidermis, the mesophyll, the **vascular bundle(s)** (veins), and the stomates. The upper and lower epidermal cells do not have chloroplasts, thus photosynthesis does not occur there. They serve primarily as protection for the rest of the leaf. The stomates are holes which occur primarily in the lower epidermis and are for air exchange: they let CO_2 in and O_2 out. ttp://biology.clc.uc.edu/Courses/bio104/photosyn.htm)

There are two parts to photosynthesis: light dependent and light independent. In the light dependent phase, light as energy is taken and converted to chemical energy. This first process requires direct energy of light to make energy carrier molecules that are used in the second process called light independent. Oxygen, removed from water, is released back into the atmosphere as a waste product, whereas the hydrogen and released energy are used to combine with NADP+ to form NADPH. The light independent phase can occur with or without light and combines water with carbon dioxide to form a carbohydrate. Water is used in both phases, but carbon is “fixed” (used) only in the light independent phase. Therefore, “in the light dependent processes light strikes chlorophyll in such a way as to excite electrons to a higher energy state. In a series of reactions the energy is converted (along an electron transport process) into ATP and NADPH. Water is split in the process, releasing oxygen as a by-product of the reaction. The ATP and NADPH are used to make C-C bonds in the Light Independent Process” (http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookPS.html).

Light independent process is also called the Calvin Cycle. The energy stored in ATP and NADPH in the light dependent reactions will now be used in the Calvin cycle. This cycle continually produces and uses a five-carbon sugar called ribulose disphosphate (RuDP), also called ribulose biphosphate (RuBP). The cycle begins when a carbon dioxide molecule bonds with a RuDP molecule. The resulting molecule, which has six carbon atoms, splits into two three-carbon atoms. These three-carbon molecules are called phosphoglycerates (PGA). The PGA molecules undergo additional reactions, outlined below, which allows for the regeneration of the RuDP molecule and the production of a three-carbon molecule called glyceraldehyde phosphate (PGAL). Notice how the NADPH molecule produced during noncyclical electron flow is necessary for the Calvin cycle. (http://kvhs.nbed.nb.ca/gallant/biology/calvin_cycle.jpg)

After many turns of the Calvin cycle, PGAL molecules can be bonded together to form glucose (which can be used as food) or other more complex sugars like sucrose. In addition, PGAL can also be used in the formation of lipids and proteins. (Information for Calvin Cycle found primarily in library.thinkquest.org/.../calvin_cycle)