Photosynthesis

Much of this information is taken from:

http://www.rsc.org/Education/Teachers/Resources/cfb/Photosynthesis.htm

The importance of photosynthesis

Photosynthesis converts the energy of sunlight to the chemical energy that is used in living systems. The glucose that is formed in photosynthesis can ultimately be converted to any other organic molecule found in living things. All the food we eat and all the fossil fuels we use as a source of energy or chemicals have made use of the energy carried by sunlight to form them. In addition, the oxygen that is found in the atmosphere has come from photosynthesis. Earth's original atmosphere was a reducing atmosphere that contained no oxygen.

Green plants, algae and some bacteria use the energy from sunlight to produce glucose from carbon dioxide and water. Oxygen is also formed. The photosynthetic process may be summarised by the balanced chemical equation:

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Energy from the Sun}} C_6H_{12}O_6 + 6O_2$$

Leaves and leaf structure

Most plants have leaves as their organs of photosynthesis. A leaf may be viewed as a solar collector crammed full of photosynthetic cells. The raw materials of photosynthesis, water and carbon dioxide, enter the cells of the leaf, and the products of photosynthesis, glucose and oxygen, leave the leaf.

Land plants have evolved specialised structures known as guard cells to allow gases to enter and leave the leaf. Carbon dioxide cannot pass through the protective waxy layer covering the leaf (cuticle), but it can enter the leaf through a stoma (plural: stomata), flanked by two guard cells. Likewise, oxygen produced during photosynthesis can only pass out of the leaf through the opened stomata.

Unfortunately for the plant, a great deal of water can also be lost. Cottonwood trees, for example, will lose about 450 dm^3 of water per hour during hot desert days.

Guard cells are designed to open the stomata to allow carbon dioxide to enter during photosynthesis. They close to conserve water when it stops, for example at night, or when the plant begins to wilt due to excessive water loss.

The structure of the chloroplast and photosynthetic membranes

The thylakoid is the structural unit of photosynthesis. Only eukaryotes have chloroplasts with a surrounding double membrane. Thylakoids are piled like pancakes in stacks known as grana. The space between the grana is the stroma.

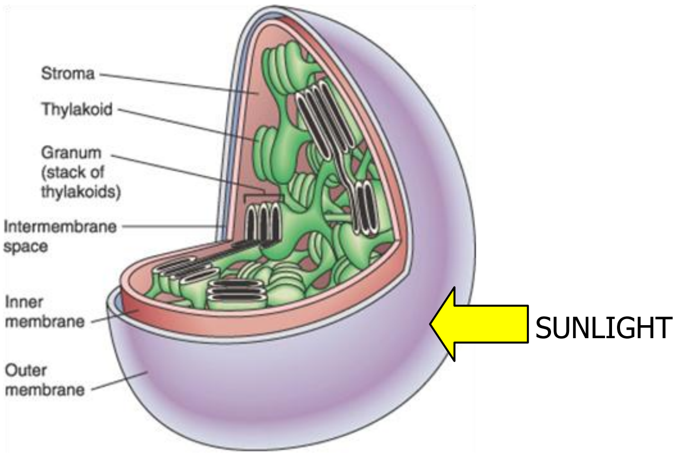

Figure Structure of a chloroplast.

Chlorophyll

The conversion of usable sunlight energy into chemical energy is associated with the action of the chlorophyll. Chlorophyll is a mixture of pigments. Several modifications of chlorophyll occur, all have *chlorophyll a*. Accessory pigments absorb energy that chlorophyll a does not absorb. Accessory pigments include chlorophyll b, xanthophylls, and carotenoids (such as beta-carotene). Chlorophyll a absorbs its energy from the violet-blue and reddish orange-red wavelengths, and little from the intermediate (green-yellow-orange) wavelengths.

PPT

More information about the role of chlorophyll can be found in:

Farms, sensors and satellites

The chemical reactions involved in photosynthesis include:

- condensation reactions - responsible for water molecules splitting out;
- oxidation/reduction (redox) reactions involving electron transfer.

Photosynthesis is a two stage process

- The light dependent reactions, a series of reactions which occur in the grana, require the direct energy of light to make energy-carrier molecules that are used in the second process. They result in the splitting of water molecules and the transfer of energy to ATP and reduced NADP (nicotinamide adenine dinucleotide phosphate).
- The light-independent reactions happen in the stroma of the chloroplasts. Here, ATP and NADPH (products of the light-dependent reactions) are used to make carbohydrates from carbon dioxide (reduction). GALP (glyceraldehyde 3-phosphate, a 3-carbon molecule) is formed in the Calvin Cycle.

The light-dependent reactions

When light energy is absorbed by a chlorophyll molecule its electrons gain energy, are 'excited' and move to higher energy levels in the molecule. This is called photoexcitation. Sufficient energy ionises the molecule, releasing the electron. Chlorophyll is oxidized and has a positive charge. This is called photoactivation or photoionisation.

Each chlorophyll molecule is associated with an electron acceptor and an electron donor. These molecules make up the core of a photosystem. Two electrons from photoionised chlorophyll are transferred to the electron acceptor. The positively charged chlorophyll ion then takes a pair of electrons from a neighbouring electron donor such as water.

An electron transfer system (a series of chemical reactions) carries the two electrons to and fro across the thylakoid membrane. The energy to drive these processes comes from two photosystems:

- Photosystem II (PSII) and
- Photosystem I (PSI).

PSII occurs *before* PSI. It was the second to be discovered and hence named second.

The energy changes accompanying the two sets of changes make a Z shape when drawn out. This is why the electron transfer process is sometimes called the Z scheme. Key to the scheme is that sufficient energy is released during electron transfer to enable ATP to be made from ADP and phosphate.

A condensation reaction leads to phosphorylation.