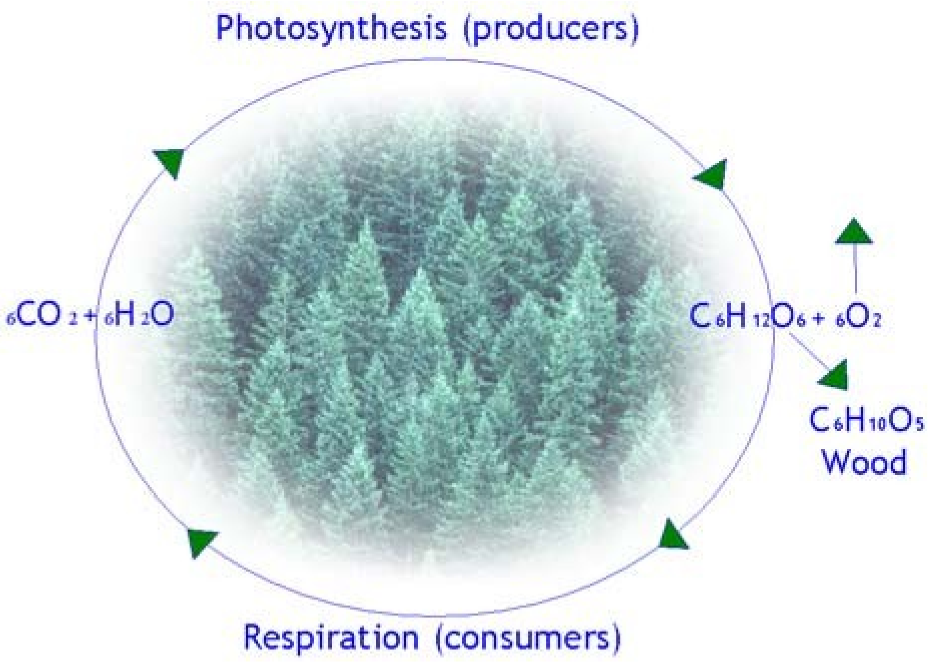
PHOTOSYNTHESIS

The oxygen rich atmosphere of the Earth is the work of the plants. It is a by-product of photosynthesis, the biological use of the Sun's energy to make molecules (chemical energy). Since plants and photosynthetic bacteria lie at the base of the food pyramid, all life on Earth is ultimately solar-powered.

Photosynthesis produces all of the oxygen in the atmosphere. The fundamental task of photosynthesis is to make it possible for cells to convert carbon dioxide and water into carbohydrates with energy absorbed from the sun. In green plants, chlorophyll molecules collect light energy and funnel it to a reaction center.



Respiration is the reverse of photosynthesis. In respiration, glucose is consumed, with energy, water and carbon dioxide produced. We breath in the oxygen produced by healthy growing tree and we breath out (respire) carbon dioxide and water.

A chemical can be part of a living thing at one moment and part of the non-living environment a moment later. Chemicals move in and out of living organisms and are used again and again. Some of the carbon atoms forming a protein molecule in your arm may have once been a part of a chicken liver, the hide of a dinosaur, or even a limestone formation. The kinds and amounts of chemicals in an ecosystem regulate the activities of the plants and thus the animals in that system. Maybe you have some atoms from Einstein or a redwood tree.

Origins

Algae were photosynthesizing at least 3,5billion years ago, when the continents were newly formed and ungreened. These organisms were the first *autotrophs*: 'self feeders', making their own molecules from little more than light, water and carbon in the air.

About 60 billion tons of carbon are plucked every year from the carbon dioxide in the atmosphere and are turned into energy-rich biomass. Some of this we eat, burn, arrange into houses and tables, feed to the livestock, pulp into paper, spin into cloth. Much of it falls, is broken down by micro-organisms, and is released back into the atmosphere as volatile carbon compounds. Over geological time, some will be buried, compressed into coal, or decomposed into oil or gas.

Chloroplast: solar power center in plant cells
Photosynthesis depends on molecules that interact with light, absorbing some of its energy and channeling it into chemical processes with almost 100 percent efficiency. While mammalian cells have fuel-burning factories in the form of mitochondria, the solar power centers in the cells of plant leaves are compartments called **chloroplasts**. The process conducted herein is broadly speaking, the reverse of glucose metabolism.

The chloroplast takes carbon dioxide (CO_2) and water (H_2O), and from them constructs the sugar. 'Burning' glucose is an energetically downhill process, so it follows that the manufacture of glucose in photosynthesis is uphill. This is why the plant needs the energy of light rays to do it. Yet the plant uses this energy not just to create glucose for weaving into the cellulose walls of its cells, but also -and just as important- for making ATP molecules to drive the cells' chemistry.

2 subprocesses
There are several similarities between the processes of aerobic metabolism and photosynthesis. Both consist of two distinct subprocesses with separate evolutionary origins: a linear sequence of reactions coupled to a cyclic sequence that regenerates the molecules they both need. The bridge between glycolysis and the citric acid cycle is the electron ferrying NAD molecule; the two sub-processes of photosynthesis are bridged by the cycling of an almost identical molecule NADPhosphate.

Subprocess 1
In the first part of photosynthesis, light is used to (1) convert NADP to an electron carrier (NADPH) and (2) to transform ADP to ATP. This is effectively a charging-up process that primes the chloroplast for glucose synthesis.

The first process takes place at the surface of a folded membrane inside the chloroplast, called the *thylakoid membrane*. This is studded with clusters of molecules called '*photosystems*' in which light-absorbing molecules called photopigments initiate light-powered reactions. At the heart of the photosystems –the photosynthetic reaction center- is a molecule called ***chlorophyll*** which absorbs red and blue light strongly, and is thus responsible for the green color of leaves.

Water release
When chlorophyll receives light energy, it becomes 'excited' (starts vibrating) and loses one of the outer electrons. The free electron is passed on to an enzyme which -once it has received two electrons from 'shaken' chlorophylls- can transform a positively charged ion of NADP to NADPH. The electron-deficient chlorophylls are then replenished with electrons plucked from water molecules in another light-powered reaction. The water is broken into two-atom oxygen molecules, which the plant releases through openings in the leaf surface. The electron taken from water is passed to chlorophyll along molecules embedded in the thylakoid membrane.

From ADP to ATP
Each transfer step is a downhill process that releases energy, some of which is tapped to pump hydrogen ions into the inner space of the thylakoid membrane. This imbalance is then harnessed as an energy source by ATP synthase molecules lodged in the membrane, which perform their windmilling conversion of ADP to ATP.
"The energy moves in a wavelike motion along all the pathways in the system at once (<-> from one molecule to another), a quantum effect that ensures that the energy

takes the most efficient route, arriving at its destination almost instantaneously”.*

Subprocess 2

In the second part of photosynthesis, ATP and NADPH turn carbon dioxide (CO_2) into sugar, in the Calvin-Benson cycle. The two ingredients are released in the *stroma*, the fluid outside the thylakoid membrane. Here they drive the reactions of the cycle. These processes are called the 'dark reactions' because they do not require light directly.

References:
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