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Learning Programs for Biology Education

Branches on the Tree of Life: Plants

Study Guide

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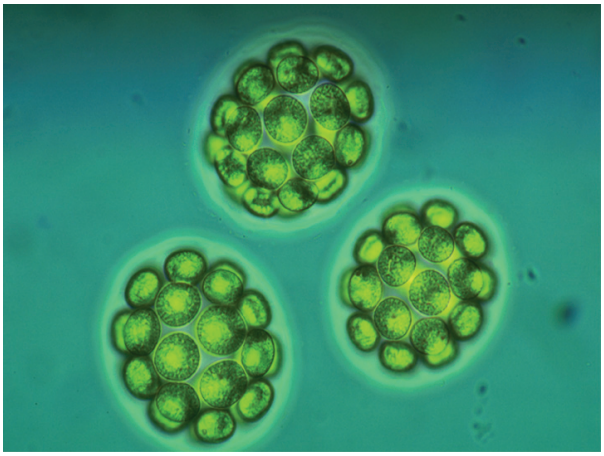
Supplement to Video Program

Capturing Energy

For over three billion years photosynthesis has tapped into the constantly available energy of light, converting this energy into the chemical bond energy that holds together the molecules of life.

Colonies of green protists provided the evolutionary stepping-stones to the first simple plants, around half a billion years back.

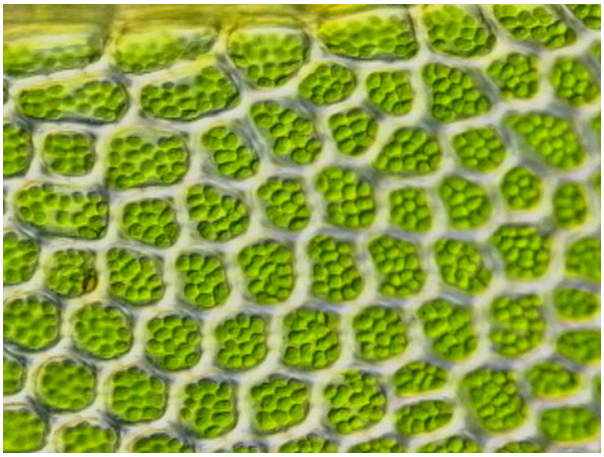


Water-splitting photosynthesis evolved around two billion years ago in organisms resembling today's cyanobacteria. By one million years back, cells with nuclei had developed symbiotic relationships with cyanobacteria symbionts.

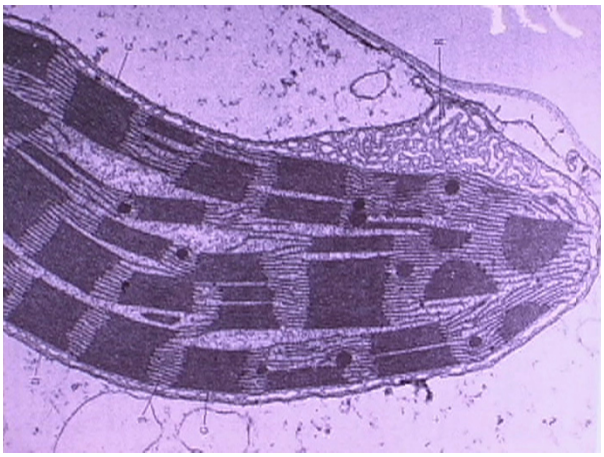
The photosynthetic symbionts eventually evolved into chloroplasts and the waters of planet Earth became populated with nucleated cells that carried out photosynthesis.

The Chloroplast

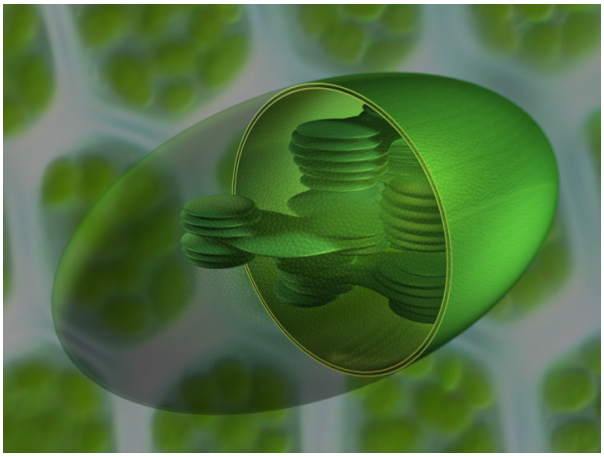
In plant cells, chloroplasts are usually jelly-bean-shaped green organelles where light energy is converted to the chemical bond energy of energy-carrier molecules, and oxygen is released as a waste product.



The structure of chloroplasts was mysterious until the first electron microscopes revealed their inner structure.

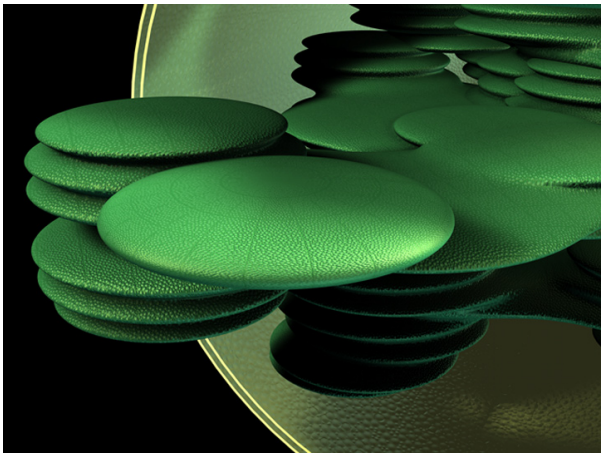


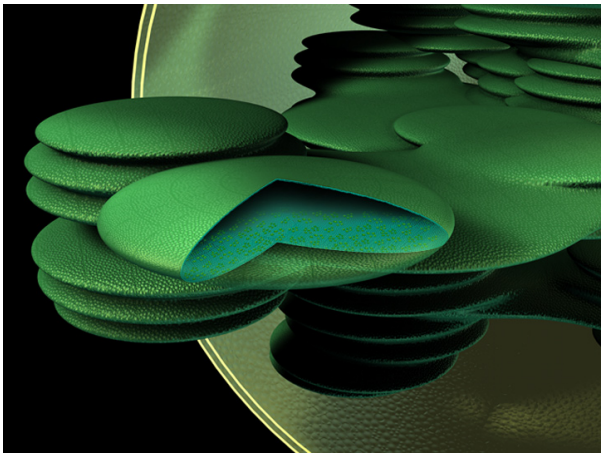
Chloroplasts have a double membrane (an inner membrane and an outer membrane) surrounding stacks hollow discs called thylakoids.

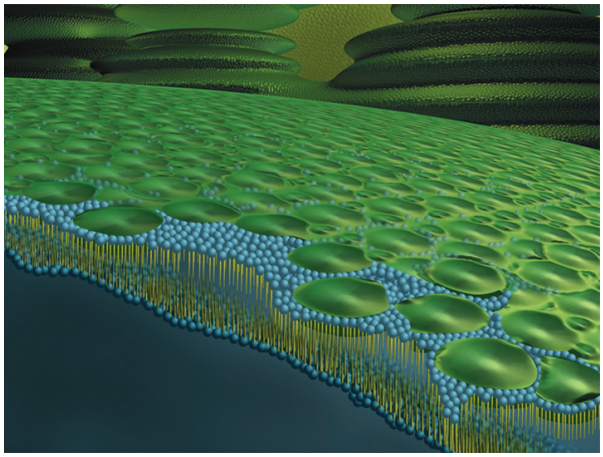


The thylakoid membrane is a carpet of chlorophyll molecules.

The space in which the thylakoids reside is called the stroma.

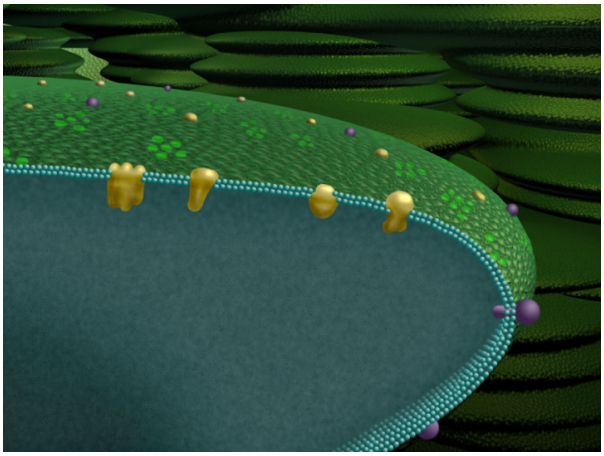




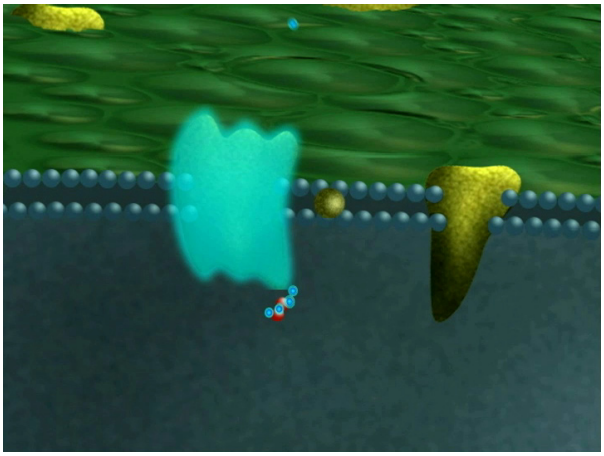


Splitting Water

Energy from sunlight is trapped by chlorophyll molecules that energize electrons.

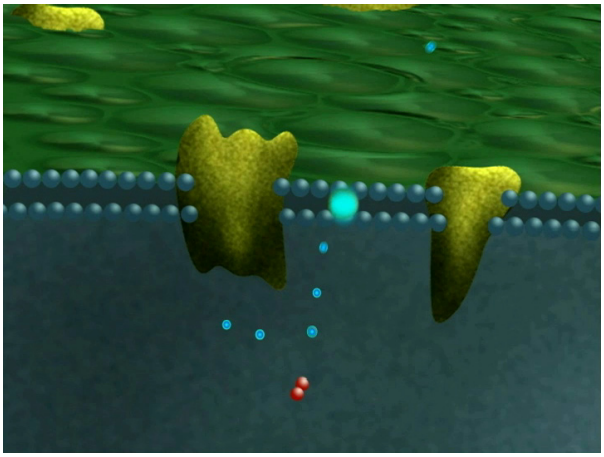


The electrons are transported through proteins embedded in the thylakoid membrane; the energy is used to pump hydrogen ions (protons) into the thylakoid space.



The source of hydrogen is water, split through reactions occurring on the thylakoid discs.

When the water molecules are stripped of their hydrogens, the remaining oxygen atoms bond to form O2 gas – oxygen.



The Energy of Life

The exit flow of protons from the thylakoid space is through ATP synthase, an enzyme that couples a phosphate group to an ADP to make ATP, life's universal energy carrier.

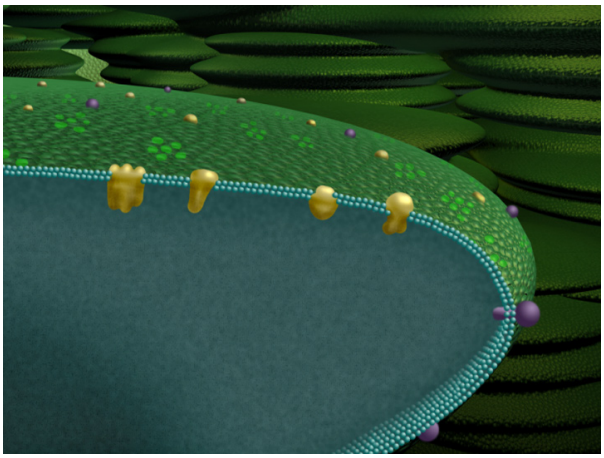
With input of electron energy from another cluster of chlorophylls, another energy carrier, NADPH is generated. The reactions producing ATP and NADPH are referred to as *the light dependent reactions.*

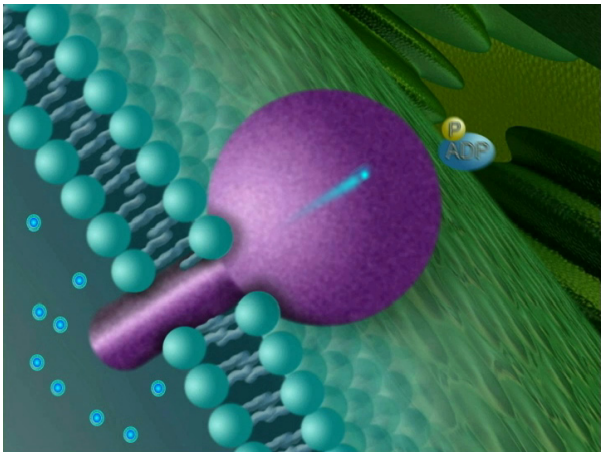
In the stroma (the space surrounding the thylakoid discs) carbon from carbon dioxide feeds a cycle of reactions driven by ATP and NADPH.

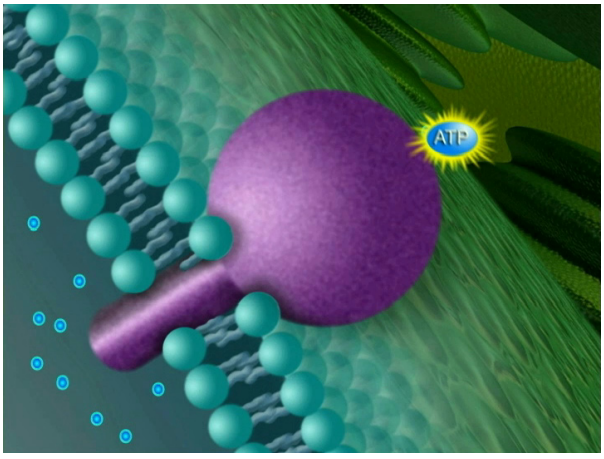
The three carbon compound Phosphogyceraldehyde (pGAL) is one of the products. pGAL molecules can be combined to form the simple sugar glucose, a basic cell fuel.

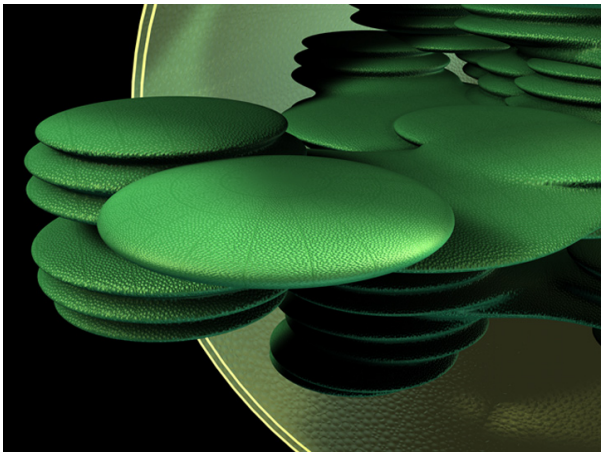
These reactions occur day or night and so are called *the light independent reactions* of photosynthesis.

Other important building blocks are also synthesized in the chloroplast such as amino acids, nucleic acids, fatty acids, all vital to life.









Plants on the Tree of Life

Mosses and Liverworts

Liverworts, with low growing flattened plant bodies, are almost always found in contact with water or wet soil. Liverworts produce male and female gametes to generate offspring that carry a combination of their parent's genetic variations.

Mosses are an adaptable and diverse group, easily collected for study. Look for fruiting bodies with elaborate devices for spore dispersal. Sexual exchange of gametes occurs in water provided by rain drops.

Ferns and Horsetails

This ancient line of plants reproduces by air borne spores. In ferns, the spores are produced on the underside of the fronds. In horsetails, the spores are produced in a cone-like catkin.

Gymnosperms

Gymnosperms produce "naked seeds" (as compared to flowering plants, where the seed develops within an ovary). Also, in this group, sperm travels to egg through air-born pollen. One group, the conifers, are dominant plants today, producing forests that spread through the temperate and subarctic regions of the world.

Angiosperms

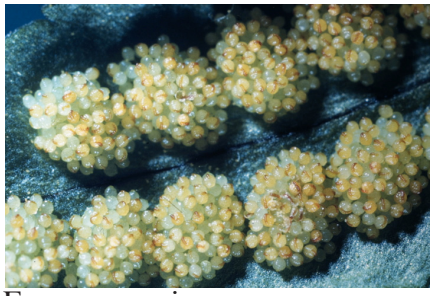
Angiosperms, the flowering plants, have developed the most elaborate sexual exchanges and seed dispersal strategies, abilities that have produced an amazing diversity of plants, ranging from the Arctic to the equator.


Star moss


Moss cells


Liverwort with gemmi cups


Hanging fern


Fern sporangia


Horsetails


First year cone section


Male cones dropping pollen


Fallen mature (female) pine cones


Cactus spines


Bleeding hearts


Bee pollinating

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