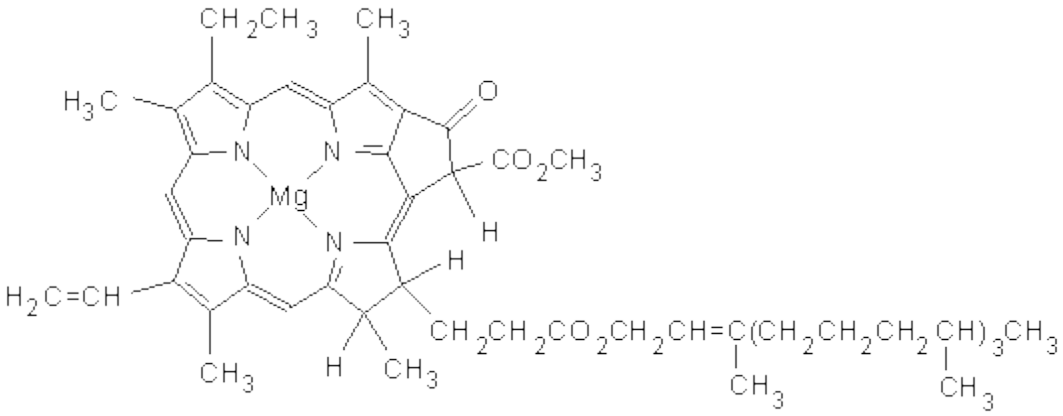
Learn About ...

CHLOROPHYLL

Many important natural substances are chelates. In chelates a central metal ion is bonded to a large organic molecule, a molecule composed of carbon, hydrogen, and other elements such as oxygen and nitrogen. One such chelate is chlorophyll, the green pigment of plants. In chlorophyll the central ion is magnesium, and the large organic molecule is a porphyrin. The porphyrin contains four nitrogen atoms that form bonds to magnesium in a square planar arrangement. There are several forms of chlorophyll. The structure of one form, chlorophyll *a*, is shown.



(As you can see from the molecular structure, the "chloro" in chlorophyll does not mean that it contains the element chlorine. The chloro portion of the word is from the Greek *chloros*, which means yellowish green. The name of the element chlorine comes from the same source. Chlorine is a yellowish green gas.)

Chlorophyll is one of the most important chelates in nature. It is capable of channeling the energy of sunlight into chemical energy through the process of photosynthesis. In photosynthesis, the energy absorbed by chlorophyll transforms carbon dioxide and water into carbohydrates and oxygen.

$$CO_2 + H_2O \longrightarrow (CH_2O) + O_2$$

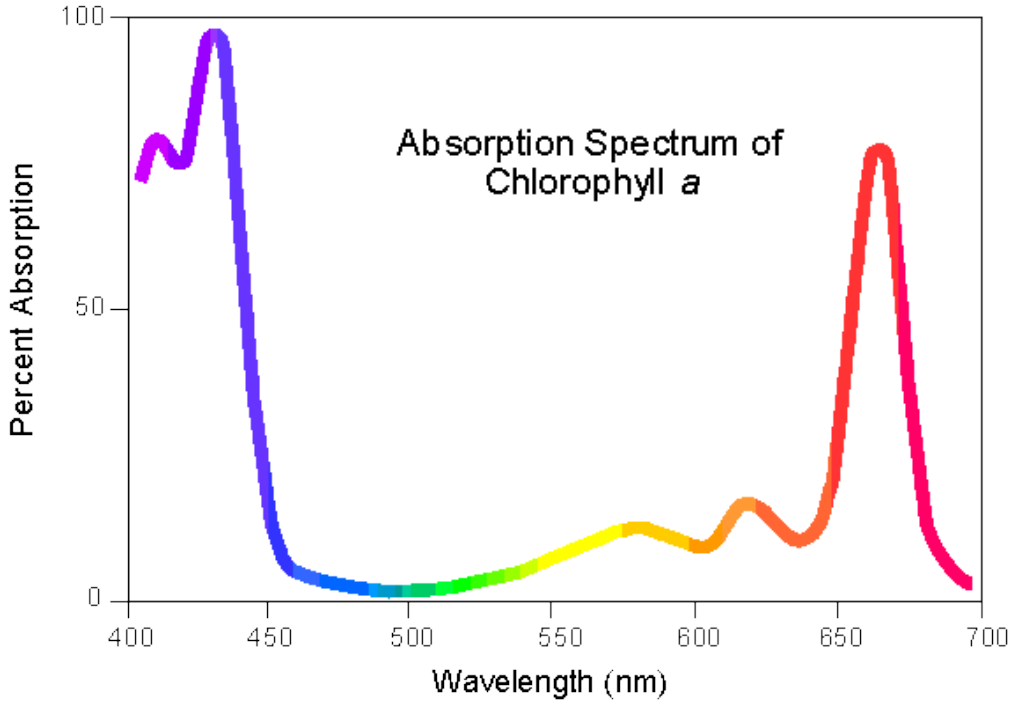
(In this equation, (CH_2O) is the empirical formula of carbohydrates.) The chemical energy stored by photosynthesis in carbohydrates drives biochemical reactions in nearly all living organisms.

In the photosynthetic reaction, carbon dioxide is reduced by water; in other words, electrons are transferred from water to carbon dioxide. Chlorophyll assists this transfer. When chlorophyll absorbs light energy, an electron in chlorophyll is excited from a lower energy state to a higher energy state. In this higher energy state, this electron is more readily transferred to another molecule. This starts a chain of electron-transfer steps, which ends with an electron transferred to carbon dioxide. Meanwhile, the chlorophyll which gave up an electron can accept an electron from another molecule. This is the end of a process which starts with the removal of an electron from water. Thus, chlorophyll is at the center of the photosynthetic oxidation-reduction reaction between carbon dioxide and water.

Other molecules with structures similar to that of chlorophyll play important roles in other biochemical electron-transfer (oxidation-reduction) reactions. Heme consists of a porphyrin similar to that in chlorophyll and an iron(II) ion in the center of the porphyrin. Heme is bright red. In the red blood cells of vertebrates, heme is bound to proteins forming hemoglobin. Hemoglobin combines with oxygen in the lungs, gills, or other respiratory surfaces and releases it in the tissues. In muscle cells, myoglobin, the name given to hemoglobin in muscles, stores oxygen as an electron source for energy-releasing oxidation-reduction reactions.

Another relative of chlorophyll is vitamin B_{12}. Vitamin B_{12} contains a cobalt ion at the center of the porphyrin. Like heme, vitamin B_{12} is bright red. It is essential to digestion and nutritional absorption in animals. The exact way it functions is not known. Because vitamin B_{12} is not produced by higher plants, a strictly vegetarian diet can lead to vitamin B_{12} deficiency. However, it is produced by molds and bacteria which grow on most foods.

The intense color of chlorophyll suggests that it may be useful as a commercial pigment. In fact, chlorophyll *a* is a green dye (Natural Green 3) used in soaps and cosmetics. The absorption spectrum of chlorophyll (below) shows that it absorbs strongly in the red and blue-violet regions of the visible spectrum. Because it absorbs red and blue-violet light, the light it reflects and transmits appears green. Commercial pigments with structures similar to chlorophyll have been produced in a range of colors. Some of these have slightly modified porphyrins, such as having hydrogen atoms replaced with chlorine atoms. Others have different metal ions. For example, one bright blue pigment has a copper(I) ion at the center of the porphyrin and is used primarily in coloring fabrics.


Absorption Spectrum of
Chlorophyll a
Percent Absorption
100
50
0
400
450
500
550
600
650
700
Wavelength (nm)