B.Sc. II Semester

BBT- 2002

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Photosynthetic Pigments

- Photosynthetic organisms contain light-absorbing molecules called pigments. These photosynthetic pigments absorbs only specific wavelengths of visible light while reflecting others. The set of wavelengths absorbed by a pigment is its absorption spectrum.
- Different photosynthetic organisms have a variety of different pigments, so they can absorb energy from a wide range of wavelengths.
- There are major 3 types of photosynthetic pigments, namely; **Chlorophyll, Carotenoids, and Phycobilins.**

Chlorophyll

- The photosynthetic plants have a primary light-absorbing pigment known as chlorophylls.
- Chlorophyll is a water-insoluble magnesium porphyrin compound.
- It can absorb light at a wavelength below 480 nm and between 550 and 700 nm.
- As white sunlight falls on a chlorophyll layer, the green light with a wavelength between 480 and 550 nm is not absorbed but is reflected which is why plant chlorophylls and whole leaves are green.
- Chlorophyll always occurs bound to proteins.
- It is a green pigment with polycyclic and planar structure.
- Chlorophyll is formed from proto-chlorophyll in the light. Addition of two H-atom to protochlorophyll gives chlorophyll.

$$\text{Protochlorophyll} + 2\text{H} \xrightarrow{light} \text{Chlorophyll}$$

- There are different classes of chlorophylls, major of them are chlorophyll-a (chl-a) and chlorophyll-b (chl-b).
- In plants, the ratio chl-a to chl-b is about three to one. Only chl-a is a constituent of the photosynthetic reaction centers and so it can be regarded as the central photosynthesis pigment. Also, the light energy absorbed by chl-b can be transferred very efficiently to chl-a. In this way chl-b enhances the plant's efficiency for utilizing sunlight energy.
- The basic structure of chlorophyll has tadpole like head with Mg- tetra pyrrole ring and phytol tail.
- The porphyrin head is hydrophilic which consists of 4 pyrrole rings joined by CH bridges. Mg++ is present in the center of the ring as the central atom. Mg++ is

covalently bound with two N-atoms and coordinately bound to the other two atoms of the tetrapyrrole ring.

- A long lipophilic phytol tail of a long branched hydrocarbon chain with one C-C double bond is attached to the ring at C-7 position of 4th pyrrole.
- The chlorophyll-a has –CH3 group and chlorophyll-b has –CHO at C-3 position of 2nd pyrrole ring.

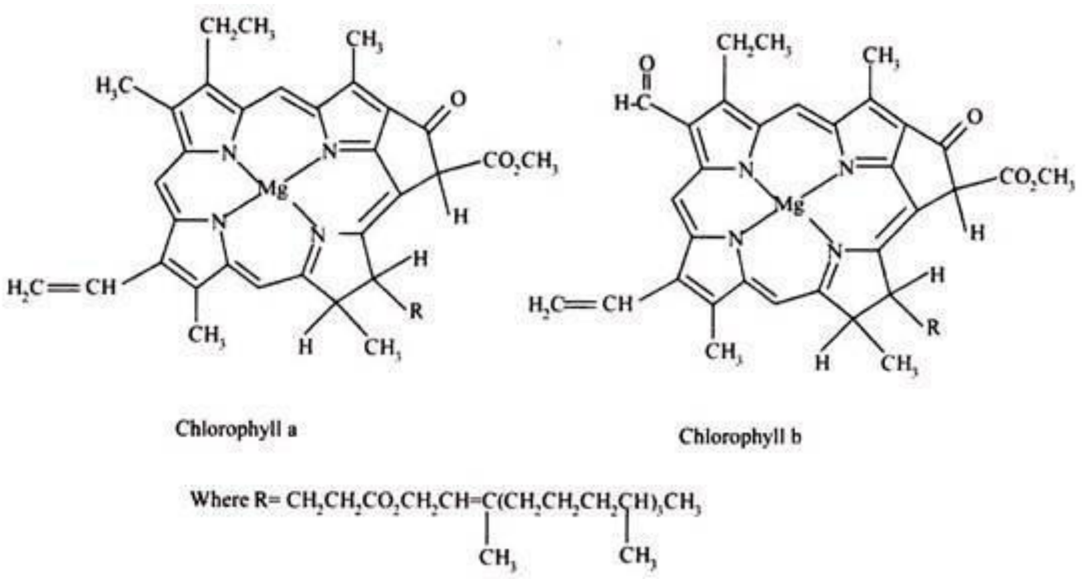


Fig: Molecular structure of Chlorophyll-a and Chlorophyll-b

- The structure of chlorophylls has remained remarkably constant during the course of evolution. Purple bacteria, probably formed more than 3 billion years ago, contain as photosynthetic pigment a bacteriochlorophyll- a, which differs from the chlorophyll-a only by the alteration of one side chain and by the lack of one double bond.
- Chlorophyll molecules are bound to chlorophyll-binding proteins. This binding may cause difference the absorption spectrum of the bound chlorophyll from the absorption spectrum of the free chlorophyll.

Chlorophyll-a

- It is a bluish green colored pigment with molecular formula C55H72O5N4Mg.
- In reflected light chl-a shows blood red color while in transmitted light, it shows blue green light.
- It is an universal pigment in all photosynthetic organism except bacteria.

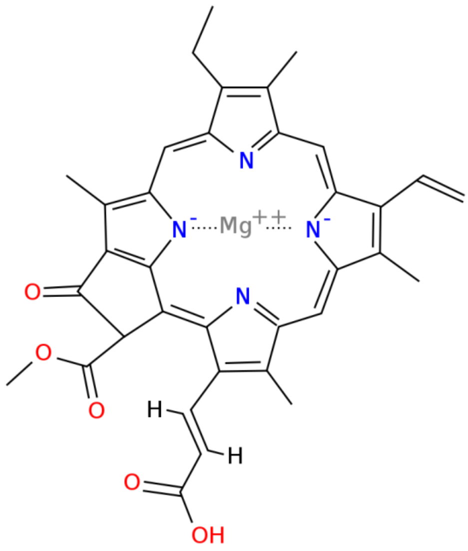
Chlorophyll-b

- It is a yellowish green color pigment with molecular formula C55H70O6N4Mg.
- It appears dull brown in reflected light and yellowish green color in transmitted light.
- Chl-b is absent in green algae, brown algae, red algae, diatoms, etc.

Chlorophyll – c

it helps the organism gather light and passes a quanta of excitation energy through the light harvesting antennae to the photosynthetic reaction centre.

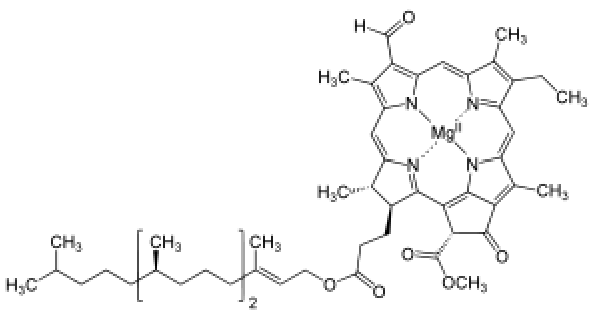
Chlorophyll c is found in certain marine algae, including the photosynthetic Chromista (e.g. diatoms, brown algae) and dinoflagellates. It acts as an accessory pigment, particularly significant in its absorption of light in the 447-452 nm region [Dougherty70]. Chlorophyll c_2 is the most common form of chlorophyll c.



Chlorophyll d

A type of chlorophyll found in marine red algae and cyanobacteria, and absorbs the infrared light of the electromagnetic spectrum. It is the major chlorophyll in cyanobacteria living in an environment depleted in visible light but abundant in infrared light.

Its molecular formula is $C_{54}H_{70}O_6N_4Mg$.



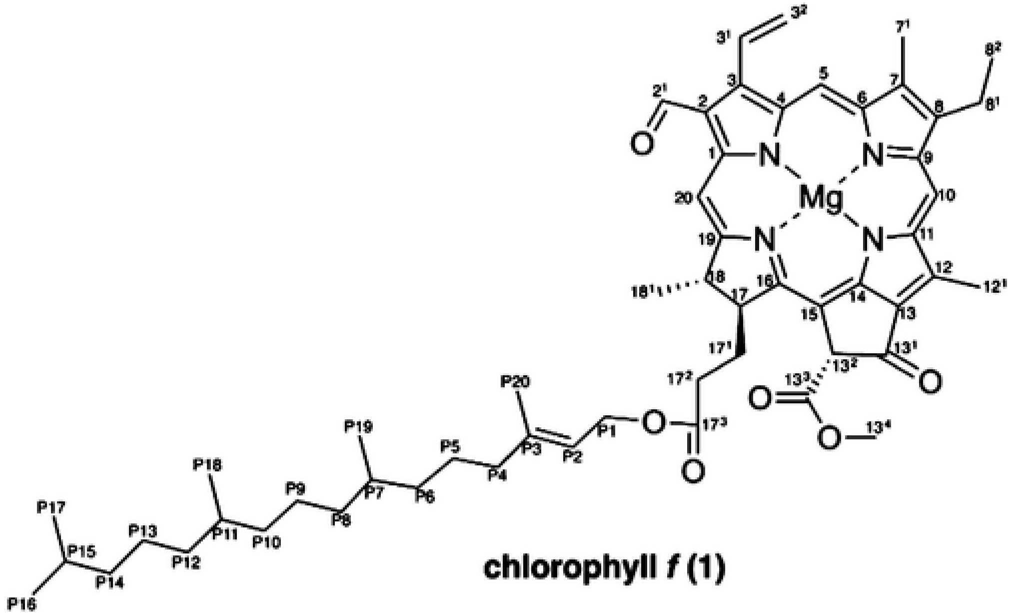
Chlorophyll e

A rare type of chlorophyll isolated from the two algae, *Tribonem bombycinum* and *Vaucheria hamata*.

Chlorophyll f

Discovered in 2010 from **stromatolites in Shark Bay (Australia)**, chlorophyll f is a form of chlorophyll that enables a subset of cyanobacteria to photosynthesize in far-red light

it is assigned the structure [2-formyl]-chlorophyll *a* ($C_{55}H_{70}O_6N_4Mg$).



chlorophyll *f* (1)

Carotenoids

- They are secondary light-absorbing pigments or accessory pigments occurring in the thylakoid membranes.
- They may be yellow, red, or purple colored pigments. The yellow colored carotenoids are lutein while red-orange is β-carotene
- The carotenoid pigments absorb light at wavelengths which are not absorbed by the chlorophylls so they are supplementary light receptors.
- There are 2 types of carotenoids; carotenes and xanthophylls.
- Carotene is in orange color while xanthophylls are yellow in color.
- These accessory pigments protect the chlorophyll against photo-oxidation and then transfer light energy to chlorophylls.
- It also helps in preventing photodynamic damage.
- Also, carotenoids are able to express themselves in mature leaves even if chlorophyll begins to disintegrate.

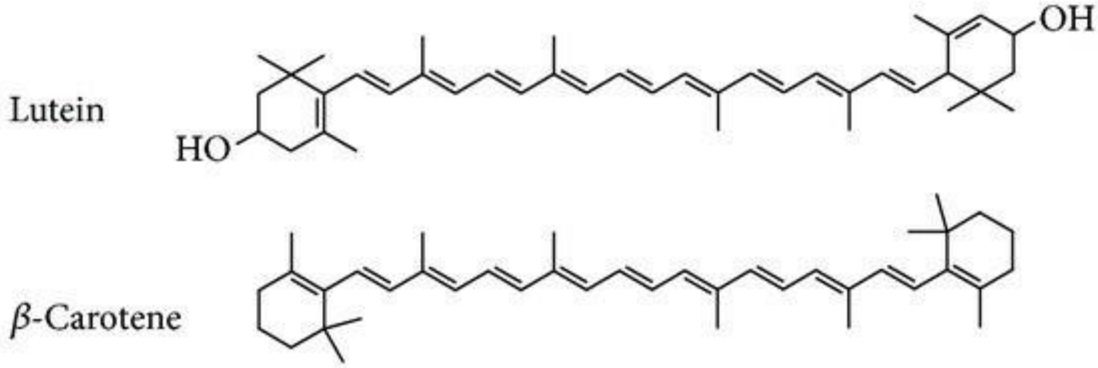


Fig: Molecular structure of carotenoids

Phycobilins

- These are open chain tetra pyrroles which lacks Mg++ and the pytol tail.
- Green algae and red algae posses phycobilins such as phycoerythrobilin and phycocyanobilin respectively as their light-harvesting pigments.
- Phycobilins are covalently linked to specific binding proteins, forming phycobiliproteins, which associate to form highly ordered complexes called phycobilisomes that constitute the primary light-harvesting structures in the microorganisms like green algae and red algae.

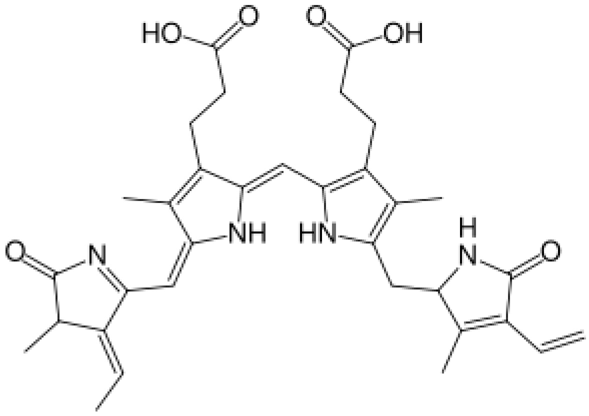


Fig: Molecular structure of phycoerythrobilin

Table: Types of pigments and their distribution

SN	Photosynthetic pigments	Distribution
	Chlorophylls	
	Chlorophyll-a	All photosynthetic plants except bacteria
	Chlorophyll-b	Higher plants and Green algae
	Chlorophyll-c	Brown algae and Diatoms
	Chlorophyll-d	Some red algae
	Bacteriochlorophyll-a	Purple and green bacteria
	Bacteriochlorophyll-b	Purple bacteria
	Chlorobium chlorophyll-a	Green Sulphur bacteria
1.	Chlorobium chlorophyll-b	Green Sulphur bacteria
	Carotenoids	
	Carotenes	Algae and Higher plants
2.	Xanthophylls	Algae and Higher plants
	Phycobilins	
	Phycoerythrobilin	BGA and Red algae
3.	Phycocyanobilin	BGA and Red algae