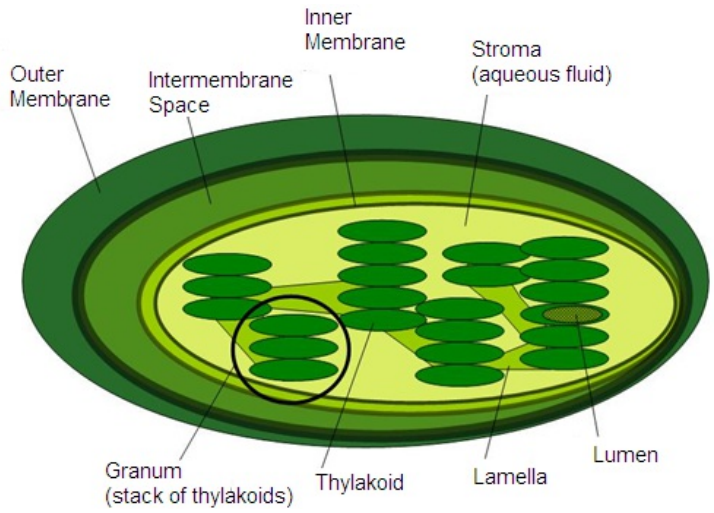
Revision Notes on Photosynthesis in Higher Plants

Chloroplast-The site of photosynthesis:

The most active photosynthetic tissue in higher plants is the mesophyll of leaves. Mesophyll cells have many chloroplasts. Chloroplast is present in all the green parts of plants and leaves. There may be over half a million chloroplasts per square millimetre of leaf surface. In higher plants, the chloroplasts are discoid or lens-shaped. They are usually 4-10*mm* in diameter and 1-3*mm* in thickness.



Chloroplast pigments:

Pigments are the organic molecules that absorb light of specific wavelengths in the visible region due to presence of conjugated double bonds in their structures. The chloroplast pigments are fat soluble and are located in the lipid part of the thylakoid membranes.

(i) **Chlorophylls:** The chlorophylls, the green pigments in chloroplast are of seven types *i.e.*, chlorophyll *a, b, c, d, e*, bacteriochlorophyll and bacterioviridin.

Pigments	Chemical Formula	Distribution
Chlorophyll *a*	$C_{55}H_{72}O_5N_4Mg$	All photosynthetic organisms except photosynthetic bacteria.
Chlorophyll *b*	$C_{55}H_{70}O_6N_4Mg$	Chlorophyta, Euglenophyta and in all higher plants.
Chlorophyll *c*	$C_{35}H_{32}O_5N_4Mg$	Brown algae (Phaeophyta), Diatoms and Pyrrophyta.
Chlorophyll *d*	$C_{54}H_{70}O_6N_4Mg$	Red algae (Rhodophyta).
Chlorophyll *e*	Not fully known	Xanthophyta.
Bacteriochlorophyll	$C_{55}H_{74}O_6N_4Mg$	Purple photosynthetic bacteria.
Chlorobiumchlorophyll (Bacterioviridin)		Green sulphur bacteria.

(ii) **Carotenoids :** The carotenoids are unsaturated polyhydrocarbons being composed of eight isoprene (C_5H_8) units. They are made up of two six-membered rings having a hydrocarbon chain in between. They are sometimes called lipochromes due to their fat soluble nature.

Difference between Photosystem I and Photosystem II

S.No.	Photosystem I	Photosystem II
(1)	PS I lies on the outer surface of the thylakoids	PS II lies on the inner surface of the thylakoid.
(2)	In this system molecular oxygen is not evolved.	As the result of photolysis of water molecular oxygen is evolved.
(3)	Its reaction center is P700.	Its reaction center is P680.
(4)	NADPH is formed in this reaction.	NADPH is not formed in this reaction.
(5)	It participate both in cyclic and noncyclic photophosphorylation.	It participates only in noncyclic photophosphorylation.
(6)	It receives electrons from photosystem II.	It receives electrons from photolytic dissociation of water.
(7)	It is not related with photolysis of water.	It is related with photolysis of water.

Difference between C3 Plants and C4 Plants

S.No.	Characters	C_3 plants	C_4 plants
(1)	CO_2 acceptor	The CO_2 acceptor is Ribulose 1, 5 diphosphate.	The CO_2 acceptor is phosphoenol-pyruvate.
(2)	First stable product	The first stable product is phosphoglyceric acid.	Oxaloacetate is the first stable product.
(3)	Type of chloroplast	All cells participating in photosynthesis have one type of chloroplast.	The chloroplast of parenchymatous bundle sheath is different from that of mesophyll cells. Leaves have 'Kranz' type of anatomy. The bundle sheath chloroplasts lack grana. Mesophyll cells have normal chloroplasts.
(4)	Cycles	Only reductive pentose phosphate cycle is found.	Both C_4-dicarboxylic acid and reductive pentose phosphate cycles are found.
(5)	Optimum temperature	The optimum temperature for the process is 10-25°C.	In C_4 plants, it is 30-45°C.
(6)	Oxygen inhibition	Oxygen present in air (=21% O_2) markedly inhibit the photosynthetic process as compared to an external atmosphere containing no oxygen.	The process of photosynthesis is not inhibited in air as compared to an external atmosphere containing no oxygen.
(7)	PS I and PS II	In each chloroplast, photosystems I and II are present. Thus, the Calvin cycle occurs.	In the chloroplasts of bundle sheath cells, the photosystem II is absent. Therefore, these are dependent to mesophyll chloroplast for the supply of $NADPH + H^+$
(8)	Enzymes	The Calvin cycle enzymes are present in mesophyll chloroplast.	Calvin cycle enzymes are absent in mesophyll chloroplasts. The cycle occurs only in the chloroplasts of sheath cells.
(9)	Compensation point	The CO_2 compensation point is 50-150ppm.	CO_2 compensation point is 0-10ppm.
(10)	Photorespiration	Photorespiration is present and easily detectable.	Photorespiration is present only to a slight degree and difficult to detect.
(11)	Net rate	Net rate of photosynthesis in full sunlight (10,000-12,000 ft.c) is 15-35mg. of CO_2 per dm^2 of leaf area per h.	It is 40-80mg. of CO_2 per dm^2 of leaf area per h. That is photosynthetic rate is quite high. The plants are efficient.
(12)	Saturation intensity	The saturation intensity reached in the range of 100-4000 ft.c.	It is difficult to reach saturation even in full sunlight.

Difference between Photorespiration, Photosynthesis and True Respiration

S.No.	Photorespiration	Photosynthesis	True Respiration
(1)	Occurs in green plants in light.	Occurs in green plants in light.	Occurs in all living organisms in light and dark.
(2)	The primary substrate is glycolate formed from RuBP.	Substrate is CO_2 and H_2O.	Substrates are carbohydrates, fat and proteins.
(3)	Occurs in most of the C_3 plants.	Occurs in all green plants.	Occurs in all living organisms.
(4)	Intracellularly, the process occurs in peroxisomes in association with chloroplasts and mitochondria.	Occurs in chloroplasts.	Occurs in cytosol and mitochondria.
(5)	The process increases with increasing concentration of O_2 and decreasing concentration of CO_2.	The process is inhibited with increasing concentration of O_2.	The process saturates at 2-3% O_2 in the atmosphere and beyond this conc, virtually no increase occurs.
(6)	Hydrogen peroxide is formed during this process.	H_2O_2 is not formed.	H_2O_2 is not formed.
(7)	Phosphorylation does not occur.	Photophosphorylation occurs.	Oxidative phosphorylation occurs.

Important Points:-

(a) **Photosynthetic Materials:** 264 gm of CO_2 and 216 gm of water give rise to 108 gm of water, 192 gm of O_2 and 180 gm of glucose.

(b) **Rubisco:** Rubisco constitutes 16% of chloroplast protein. It is the most abundant protein on this planet.

(c) Actual reduction of CO_2 to carbohydrates is independent of light, i.e., occurs in presence or absence of light, but production of assimilatory powers (ATP and $NADPH_2$) needs light and is light dependent.

(d) **Willmott's bubbler** is used to measure rate of O_2 evolution or rate of photosynthesis.

(e) **T.W. Engelmann** (1882) experimentally verified that in monochromatic lights, photosynthesis is maximum in red light.

(f) Cyclic photophosphorylation is the most effective anaerobic phosphorylation mechanism.

(g) NADP (Nicotinamide adenine dinucleotide phosphate) was earlier called as **TPN** (Triphosphopyridine nucleotide),

(h) In green plants the hydrogen acceptor is NADP, but in bacteria it is NAD.

(i) No Emerson effect is seen in bacteria.

(j) NAD is considered to be the "Universal hydrogen acceptor".

(k) Non-cyclic photophosphorylation or Z-scheme is inhibited by **CMU** and **DCMU**.

(l) As Calvin cycle takes in only one carbon (as CO_2) at a time, so it takes **six turns** of the cycle to produce a net gain of six carbons (i.e., hexose or glucose).

(m) **Cytochromes:** the term was coined by Keilin (1925) though the biochemicals were discovered by Mac Munn (1866).

(n) Intensity of light can be measured by **Luxmeter**.

(o) Isolated chlorophyll 'a' in pure form emits red colour. It is called **fluoresence**.

(p) Phytochrome is a proteinaceous pigment found in low concentrations in most plant organs. Which absorbs red (P_R or P_{660}) and far red (P_{fR} or P_{730}) light.

(q) Anthoxanthins and Anthocyanin pigments are also soluble in water and found in cell sap, due to which white, yellow and orange colour produce in flowers.