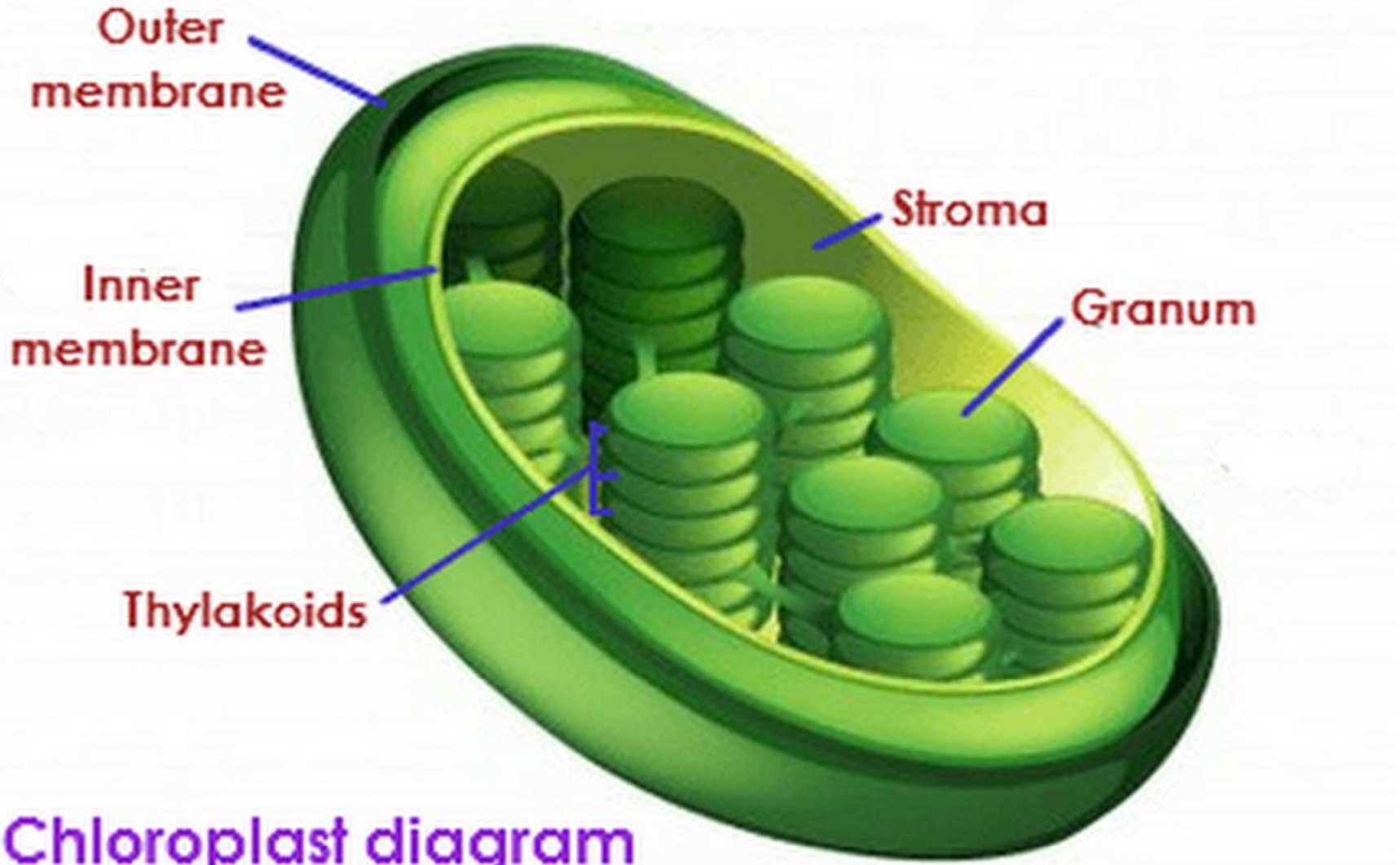
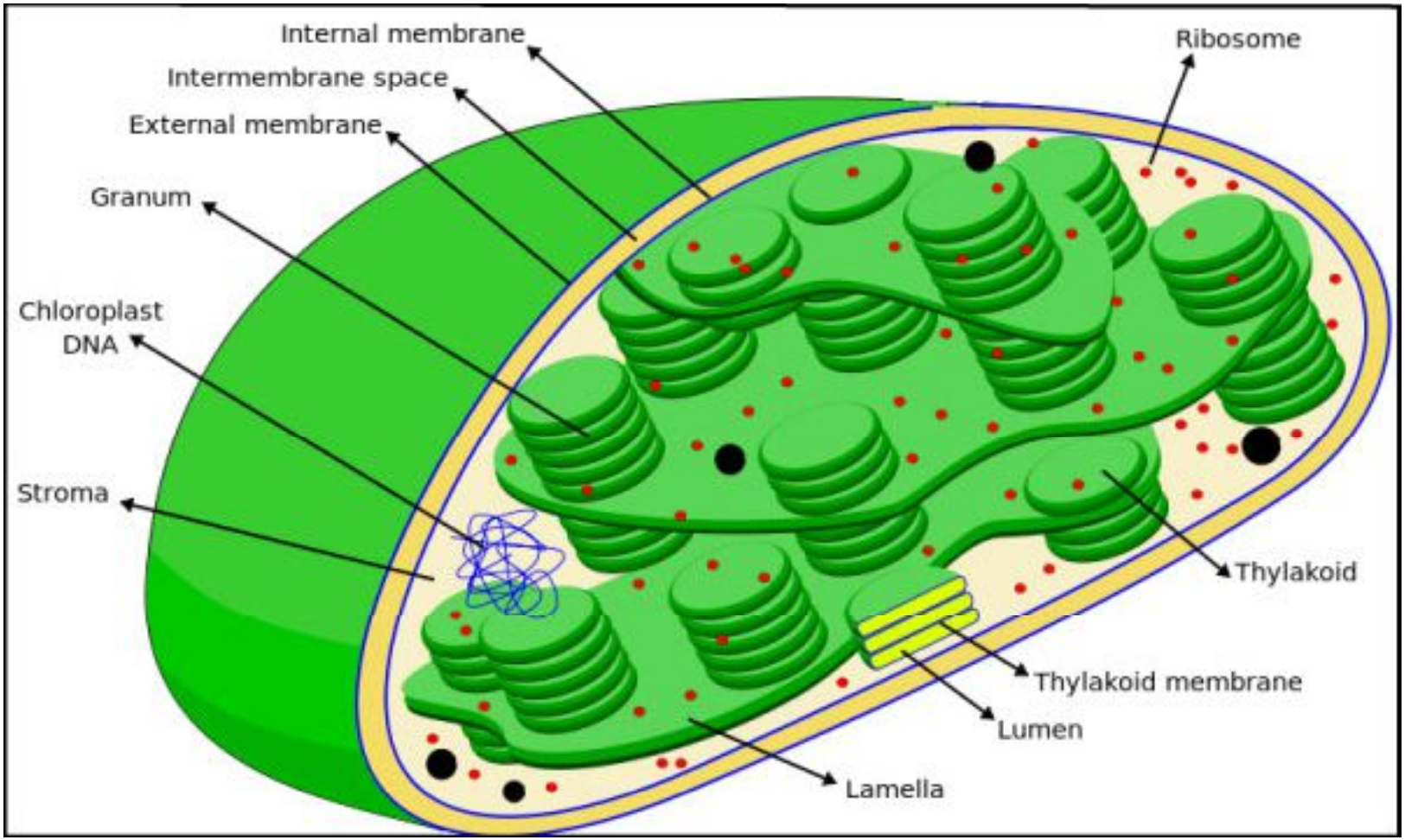
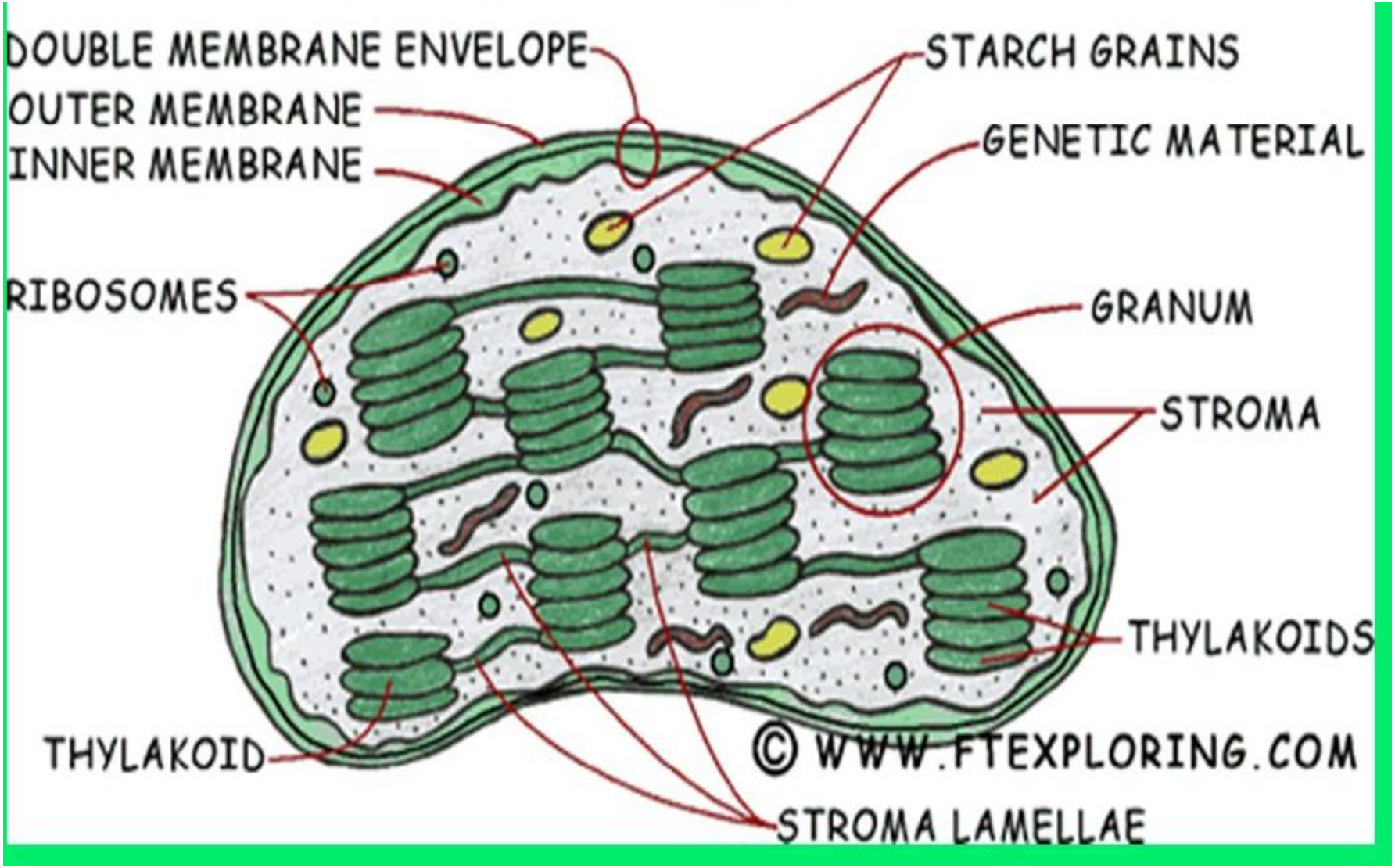


Chloroplast diagram


Internal membrane
Intermembrane space
External membrane
Granum
Chloroplast DNA
Stroma
Ribosome
Thylakoid
Thylakoid membrane
Lumen
Lamella

- First observed by Anton Von Leeuwenhoek in 17th century.
- Small green bodies present in the cytoplasm of higher plants and green algae.
- size – 2-4 x 5-10 micrometer
- Average no. of chloroplasts per cell – 50-60
- ellipsoidal or disc shaped
-

3 main components: The envelope, The stroma, The Thylakoids



THE ENVELOPE (membrane)

- It is made up of two membranes – outer and inner
- It is 50 ansgtrom in thickness and made of lipoproteins.
- The inner membrane is in contunity with the thylakoids and is yellow in colour due to the presence of carotenoids and it lacks chlorophyll.
- It is selectively permeable.
- The outer membrane is smooth and freely permeable to small molecules.

THE STROMA / MATRIX

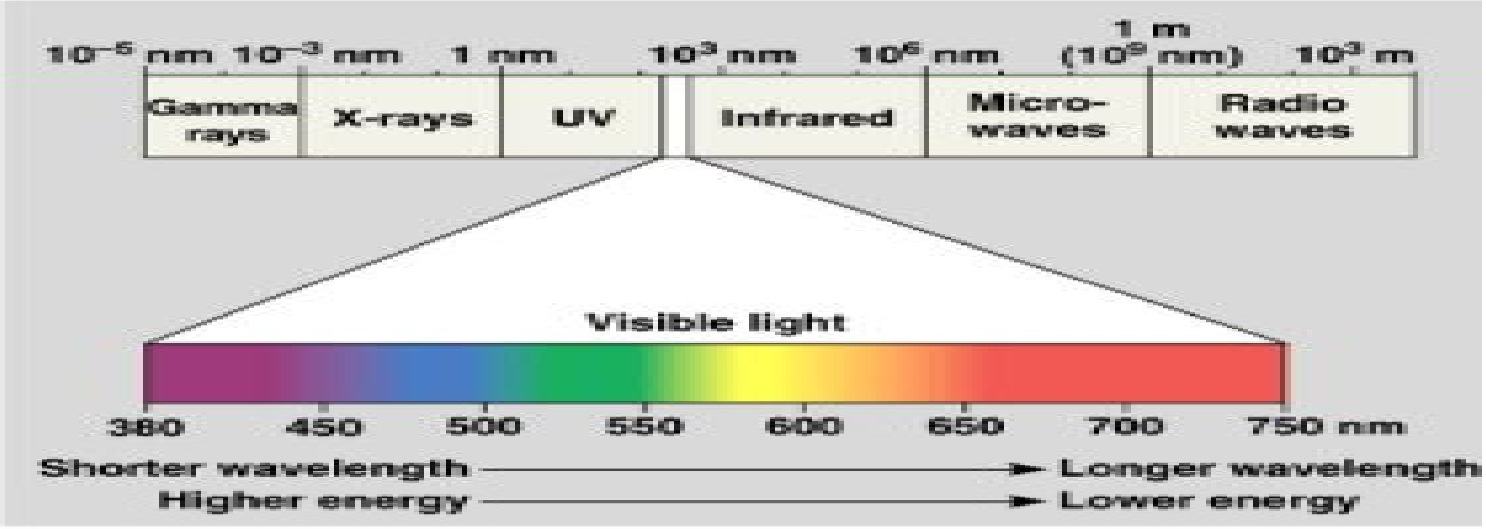
- The inner membrane surrounds a large, central, aqueous ground substance called the stroma.
- It is colloidal in nature.
- 50% of chloroplast proteins are present in the stroma and it also contains ribosomes, enzymes, DNA and RNA.

THE THYLAKOIDS

- These consist of flattened vesicles arranged as a membraneous network.
- They may be stacked (10-100) like a pile of coins, forming grana or they may be unstacked called stroma thylakoids.
- About 40-60 grana in a chloroplast.
- They contain about 505 of proteins and all the components essential for photosynthesis.
- The stroma thylakoids and the grana thylakoids are inter connected by tubules.
- The memrane connecting one granum with the other is called as stroma lamellae.
- Chlorophylls, carotenoid and a reaction center are assembled in thylakoids forming two photosystems (I & II).

PHOTOSYNTHETIC PIGMENTS

They are colored organic molecules in a biological system which absorb light energy in the visible range of electromagnetic spectrum and convert it into chemical energy.



TYPES

Water soluble

- **PHYCOCYANIN (blue)**
- **PHYCOERYTHRIN (red)**

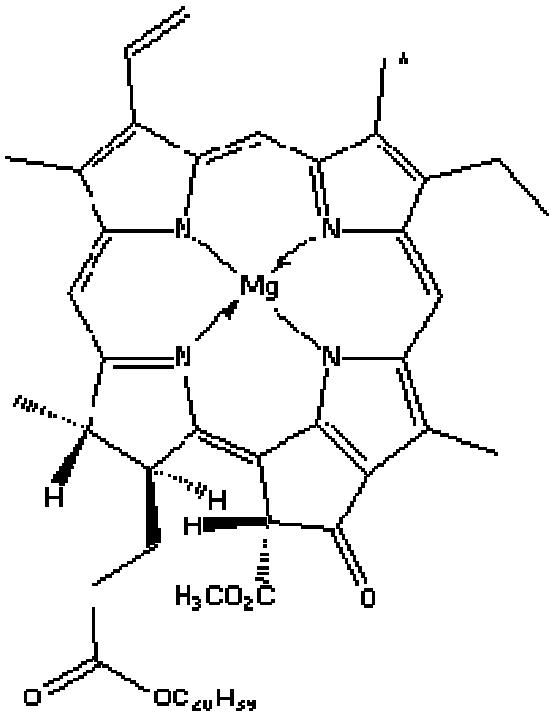
Organic solvent soluble

- **CHLOROPHYLLS (green)**
- **CAROTENOIDS (orange)**

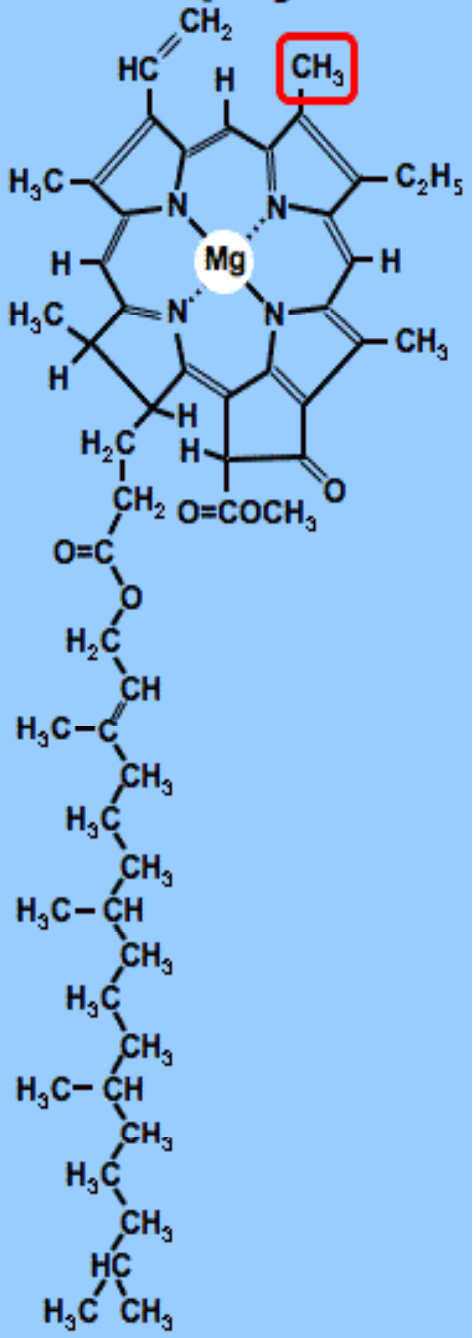
CHLOROPHYLLS

- Green pigments found in all photosynthetic organisms.
- A molecule of chlorophyll consists of a head and a tail.
- Head is made of tetrapyrrole rings and one isopentyl carbon ring arranged in cyclic form.
- Non ionic Mg atom is found in the center of the ring.
- Two molecules of pyrrole rings are linked to Mg with two covalent bonds and the rest two with co ordinate bonds.

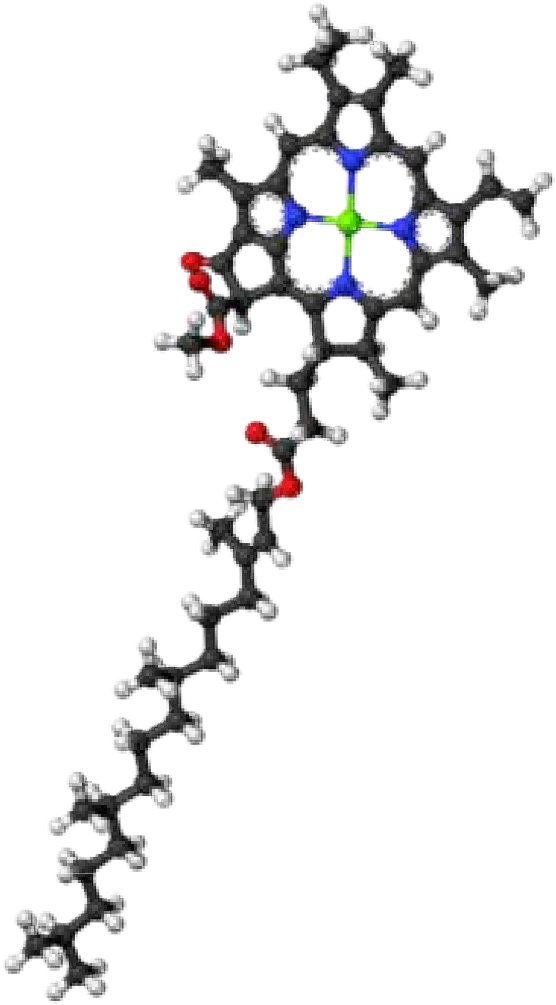
- In addition, a 5^{th} isocyclic ring is also present which contains only carbon atoms.
- This porphyrin skeleton bears an alcohol component with 20 carbon atoms known as PHYTOL tail which is bounded to the 7^{th} carbon of porphyrin head.
- Phytol tail is hydrophobic and has one double bond.
- Chlorophyll molecule looks like a spatula.



Chlorophyll a



$C_{55}H_{72}O_5N_4Mg$



TYPES

Chlorophyll – a, b, c, d, e, f
Bacterio chlorophyll – a, b, c, d, e

The basic structures of all chlorophyll molecules are the same. They vary in their chains attached to the pyrrole rings.

a- all
B- algae
C- diatoms, brown algae
d – red algae

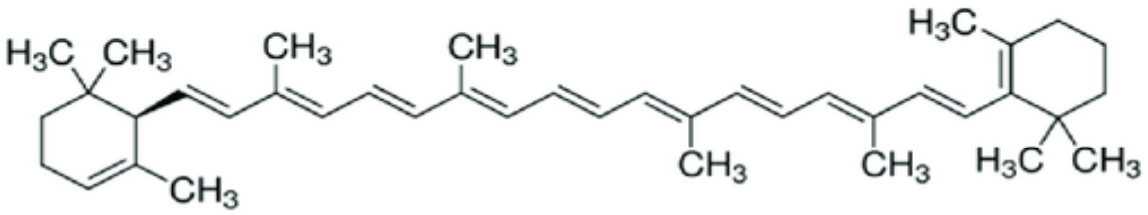
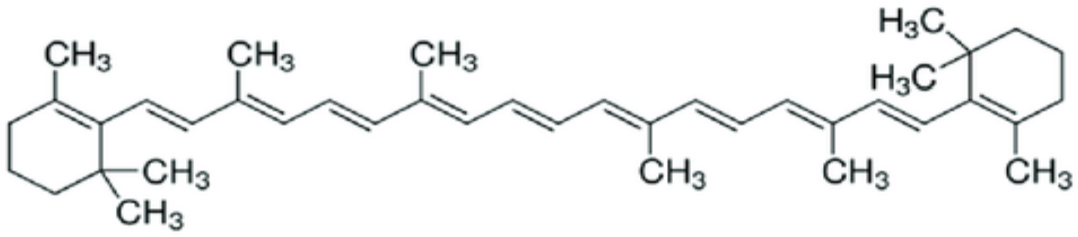
3rd carbon – methyl group – Chl a
aldehyde group – Chl b

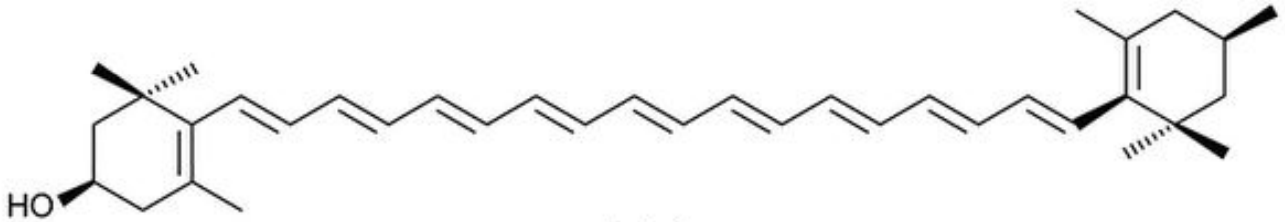
CAROTENOIDS

- Accessory pigments of photosynthesis
- Absorb light in between 400-500 nm and so orange in colour
- They shield the chlorophyll molecules against photo oxidation and trap solar energy of shorter wavelengths and transfer to chlorophyll
- they consist of long chains of C atoms linked by conjugated single and double bonds with six c rings at each end.

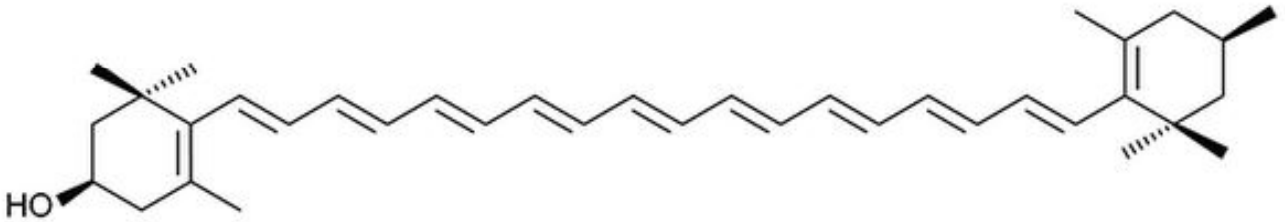
2 types

- **CAROTENES – alpha & beta**
  - **unsaturated hydrocarbons with C & H**
- **XANHTOPHYLLS – Lutein, lycopene, zeaxanthin**
  - **oxygen containing derivatives of carotenes**

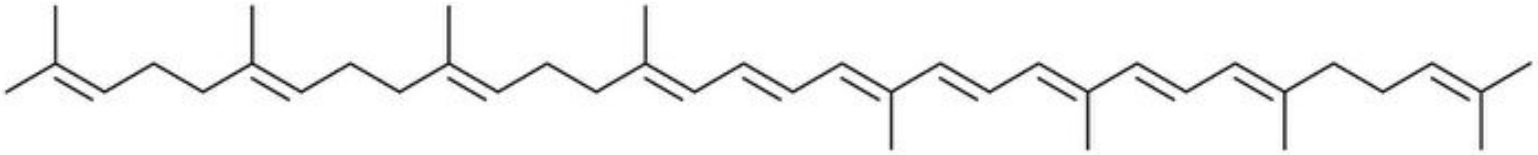
Type	Basic Structure
α-Carotene	
β-Carotene	



Lutein



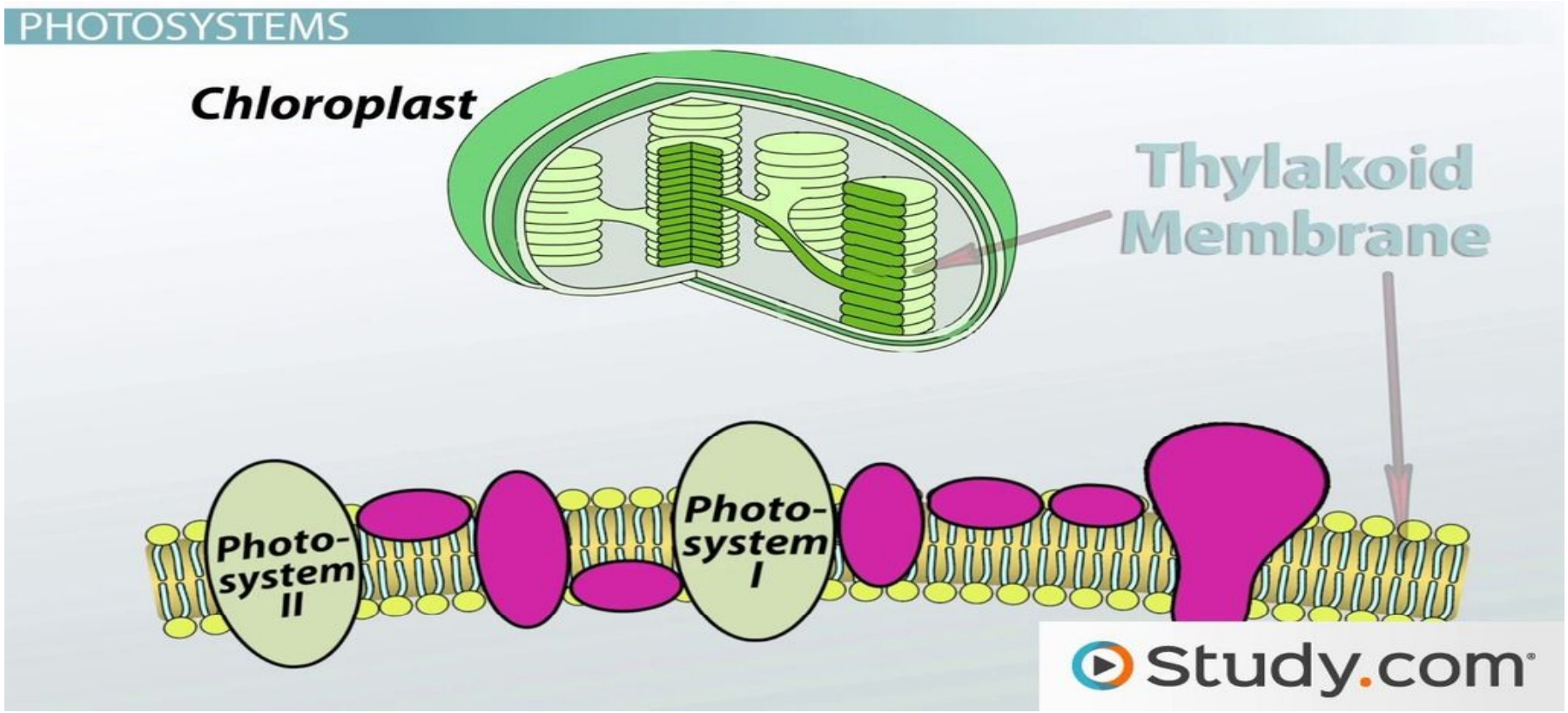
Zeaxanthin

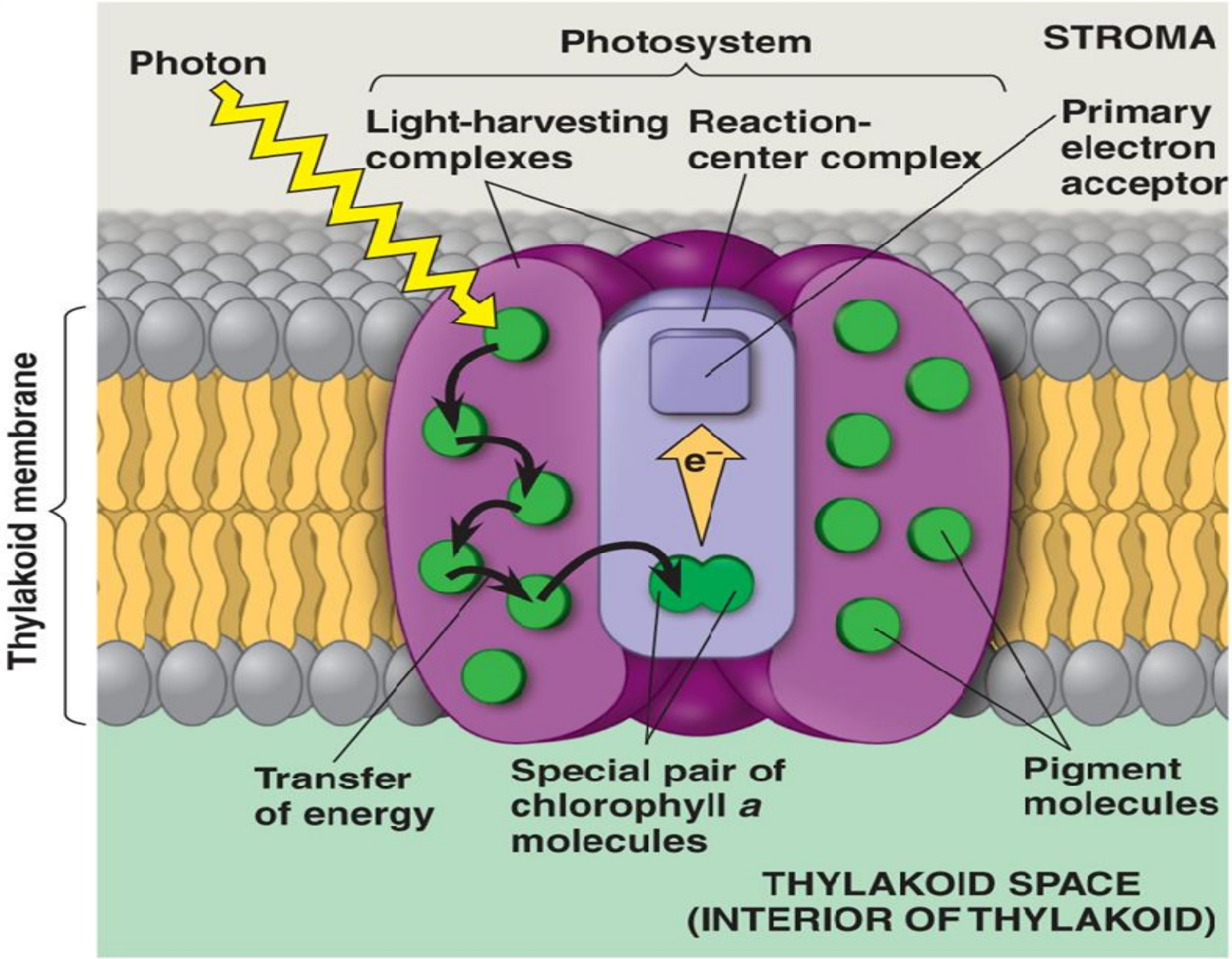


Lycopene

PIGMENT SYSTEMS/ PHOTOSYSTEMS

THEY ARE INTEGRAL MEMBRANE PROTEIN COMPLEXES SEEN IN THYLAKOIDS



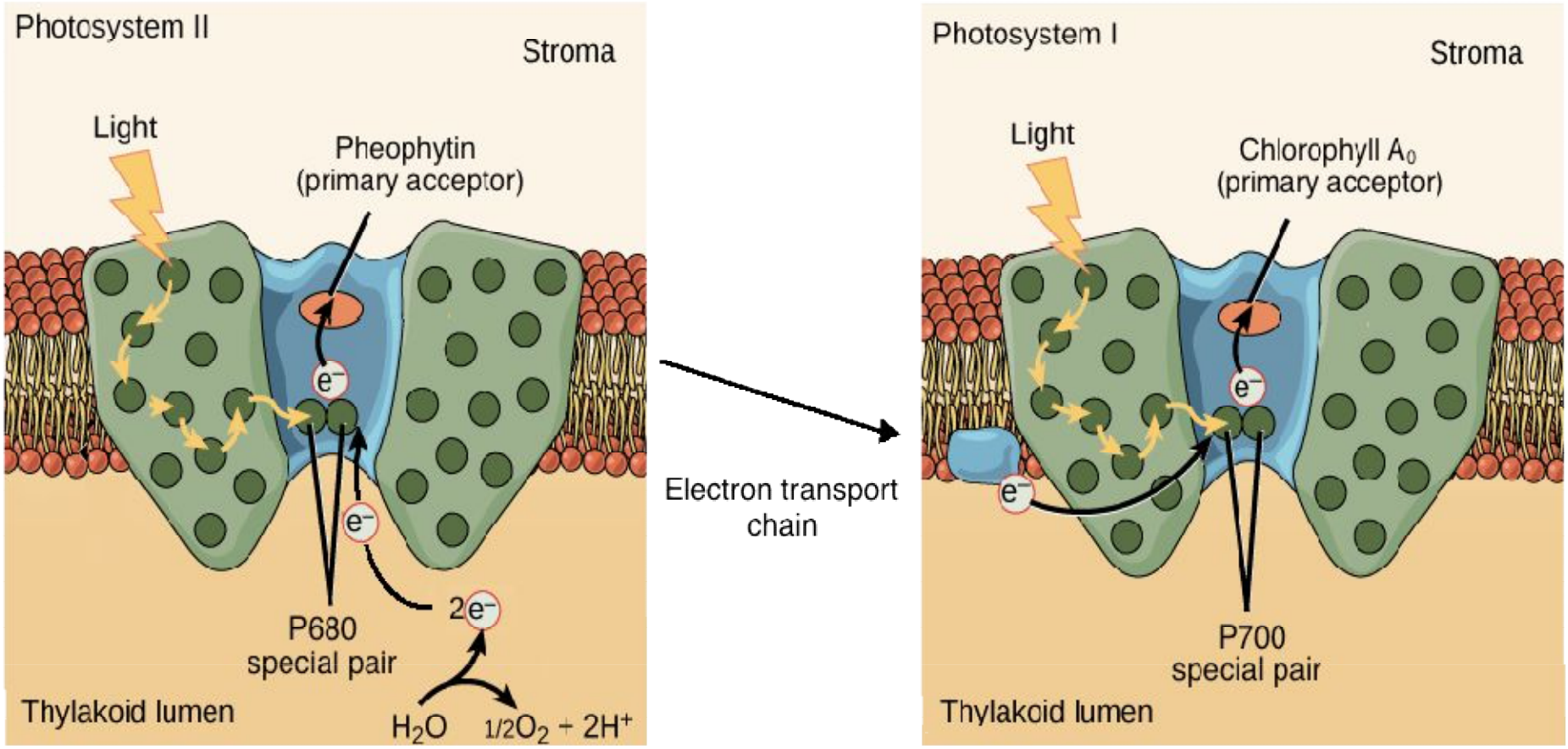


Photosystem I (PSI) :

- 200 chlorophyll molecules, 50 carotenoids
- a molecule of P700 (REACTION CENTER OF PS I)- absorbs light at 700nm
- one cytochrome f, one plastocyanin, two cytochrome b, one or two ferredoxin molecules.
- outer surface of thylakoid mmebrane
- both cyclic and non cyclic photophosporylation

Photosystem II (PSII):

- 200 chlorophyll molecules, 50 carotenoids
- a molecule of P680 (REACTION CENTER OF PS I)- absorbs light at 680nm
- one primary electron acceptor, one plastoquinone, four plastoquinone equivalents.
- inner surface of thylakoid mmebrane
- only in non cyclic photophosporylation


Photosystem II
Stroma
Light
Pheophytin
(primary acceptor)
e⁻
e⁻
2 e⁻
P680
special pair
Thylakoid lumen
H2O
1/2O2 + 2H+
Electron transport
chain
Photosystem I
Stroma
Light
Chlorophyll A0
(primary acceptor)
e⁻
e⁻
P700
special pair
Thylakoid lumen

	Photosystem I	Photosystem II
Light	Photosystem I absorbs light of 700nm wavelengths.	Photosystem II absorbs light of 680nm wavelengths.
Active Center	Photosystem I has active center P700.	Photosystem II has active center P680.
Photophosphorylation	Photosystem I is involved in cyclic and non-cyclic photophosphorylation.	Photosystem II is involved only in non-cyclic photophosphorylation.
Main Function	The main function of photosystem I is the synthesis of ATP.	The main function of photosystem II is a synthesis of ATP and photolysis of water.
Located at	Photosystem I is located at the outer surface of grana of thylakoid.	Photosystem II is located in at the inner surface of grana of thylakoid.
Binding Proteins	Photosystem I has larger binding proteins.	Photosystem II has smaller binding proteins.

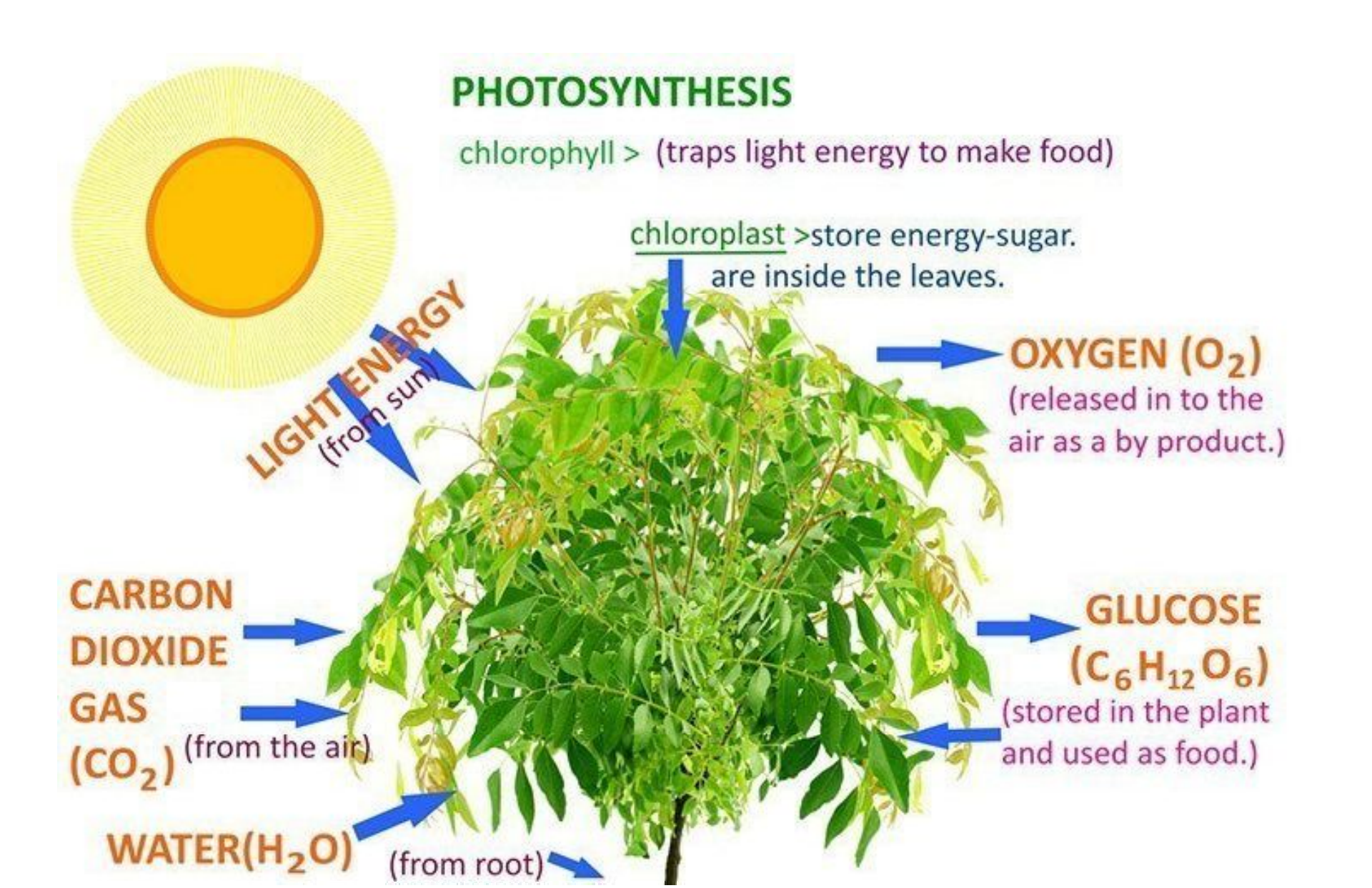
$$6CO_2 + 6H_2O \xrightarrow{\text{Photosynthesis}} C_6H_{12}O_6 + 6O_2$$

carbon dioxide + water → glucose + oxygen

BiologyWise.com

Photosynthesis

is one of the reasons because of which life exists on Earth today.


PHOTOSYNTHESIS
chlorophyll > (traps light energy to make food)
chloroplast >store energy-sugar.
are inside the leaves.
LIGHT ENERGY
(from sun)
OXYGEN (O_2)
(released in to the
air as a by product.)
CARBON
DIOXIDE
GAS
(CO_2)
(from the air)
GLUCOSE
($C_6H_{12}O_6$)
(stored in the plant
and used as food.)
WATER(H_2O)
(from root)

Photosynthesis

"photo" means "light"
"synthesis" means "putting together"

Photosynthesis is a chemical reaction that takes place in the chloroplasts in green plant cells, where light energy is used to convert carbon dioxide and water into glucose and oxygen.

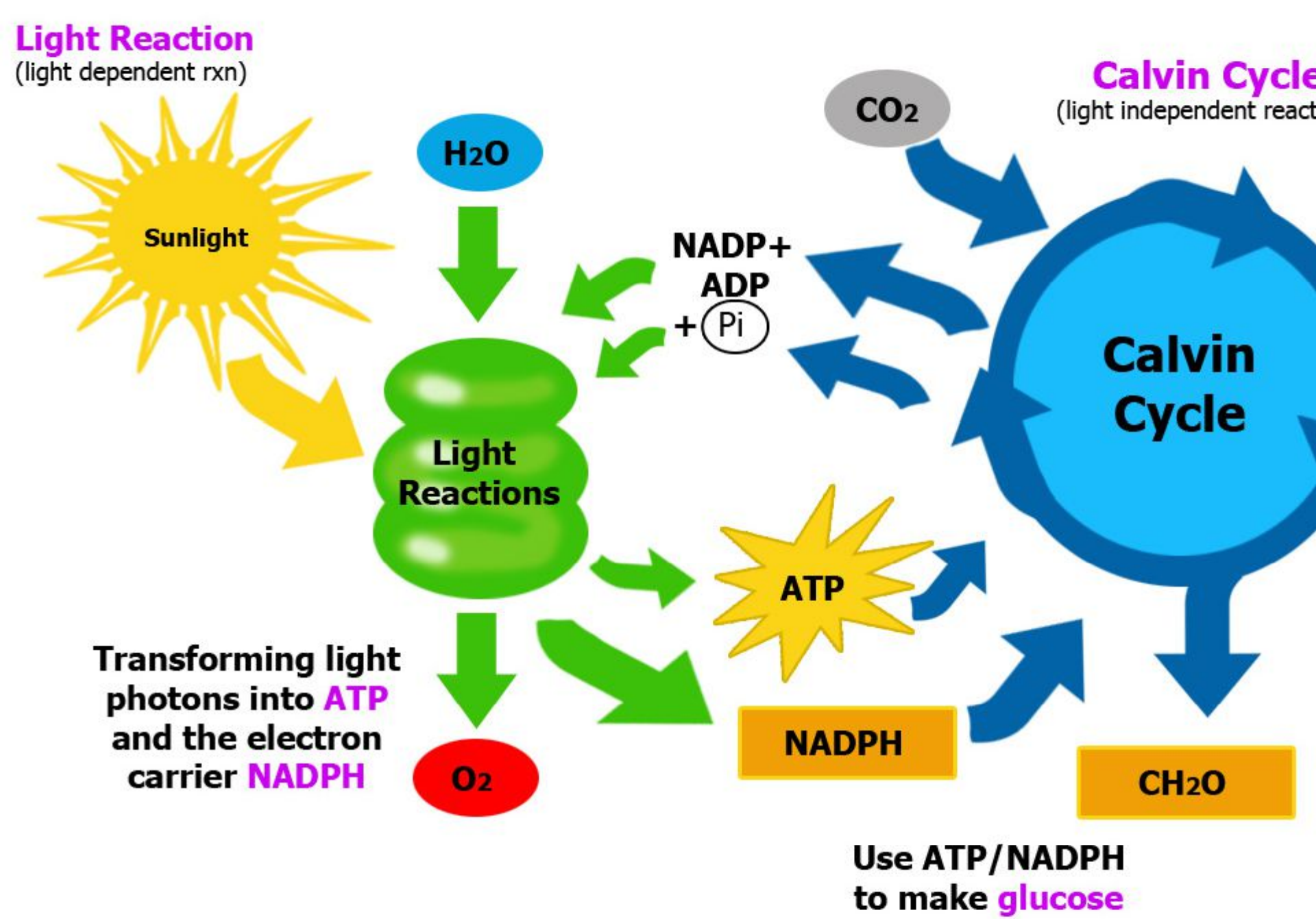
PHOTOSYNTHESIS

Light reactions

Light needed to produce organic energy molecules ATP and NADPH

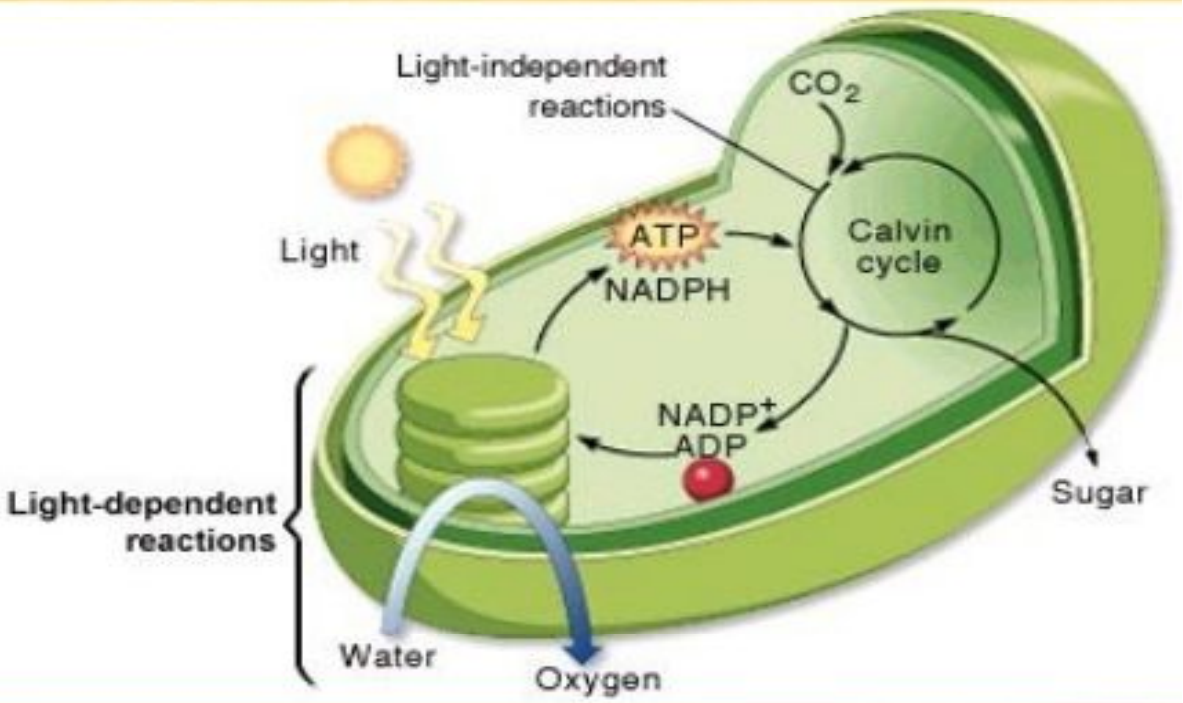
Dark reactions

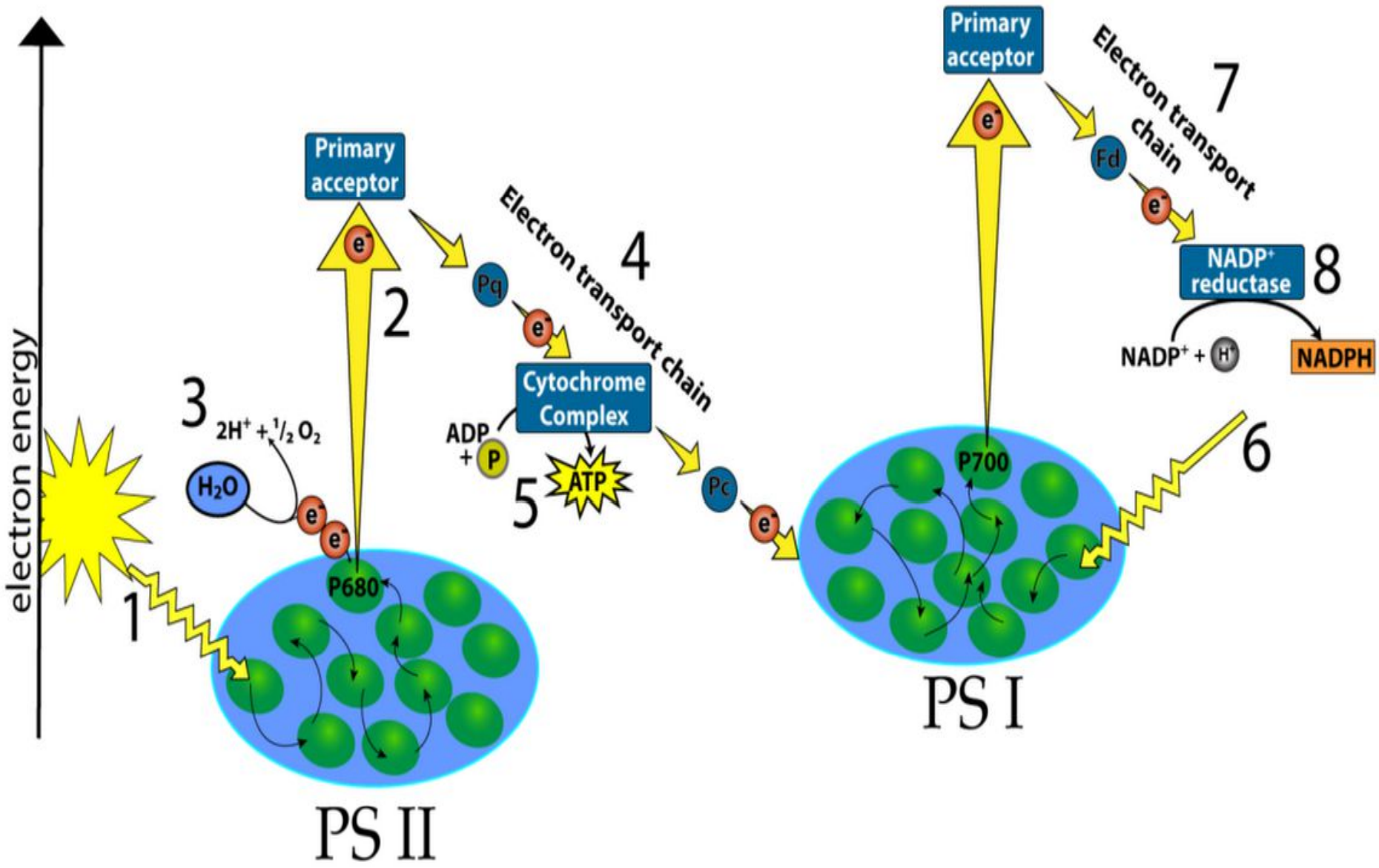
No light needed. Instead, DarK reactions use ATP and NADPH to produce energy mlecules

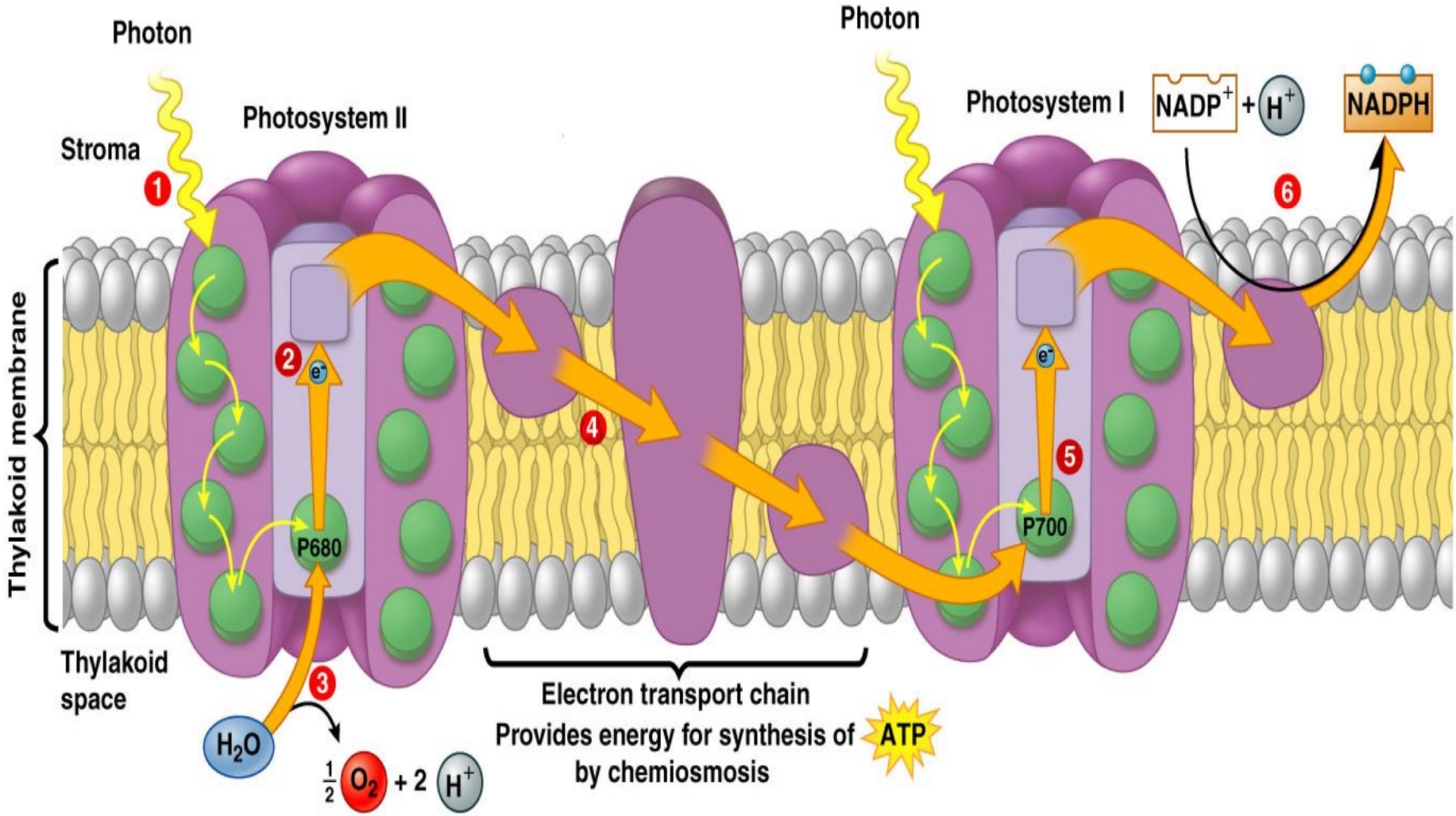


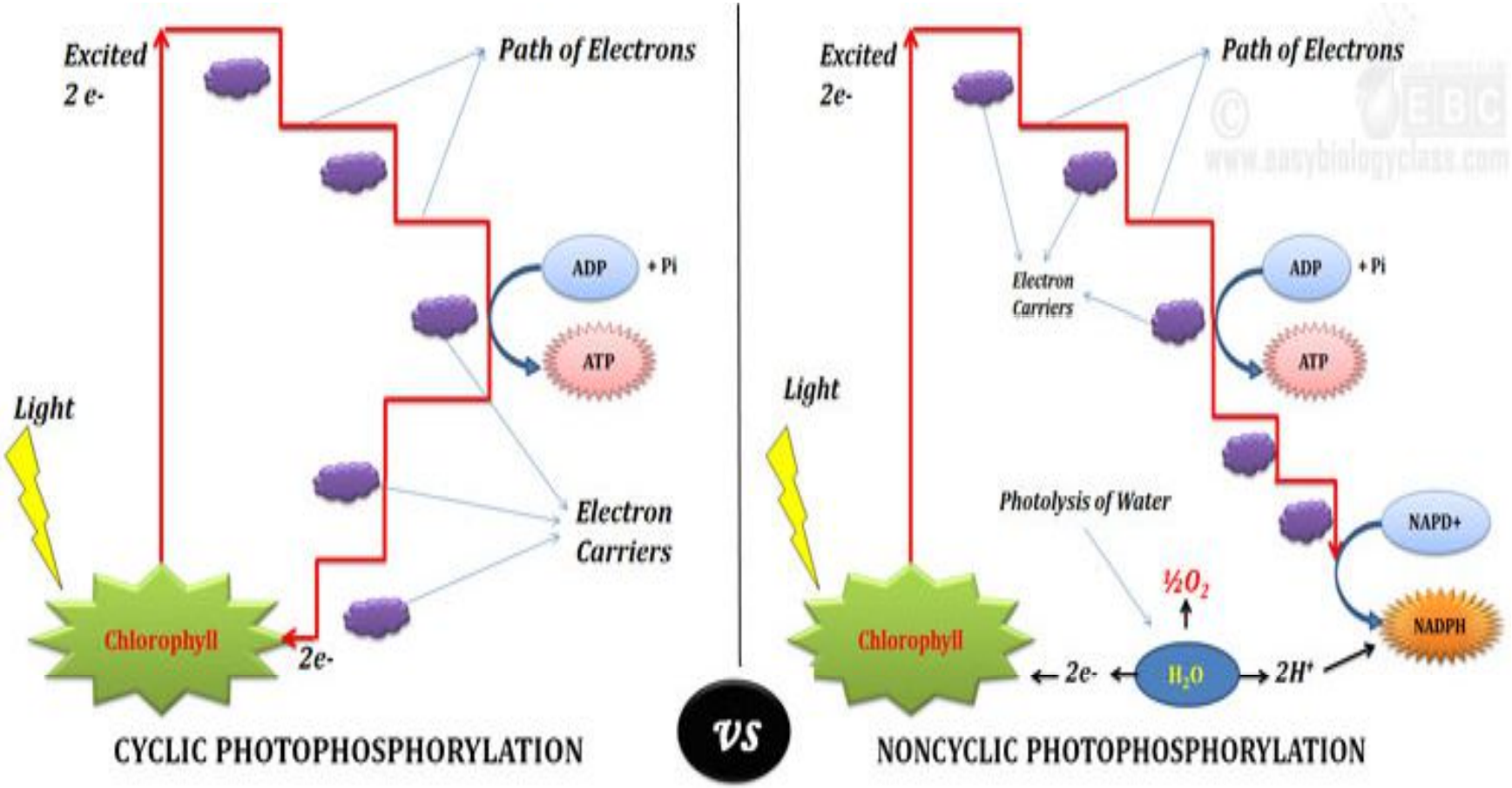
Light Reactions

- Occurs in the thylakoid membranes at regions called photosystems
- Reactants: light and water
- Products: oxygen, ATP, NADPH




electron energy
1
2
3
2H+ + 1/2 O2
H2O
P680
PS II
Primary acceptor
Pq
4
Electron transport chain
Cytochrome Complex
ADP + P
5
ATP
Pc
P700
PS I
6
Primary acceptor
Electron transport chain
7
Fd
NADP+ reductase
8
NADP+ + H+
NADPH




Excited
2 e-
Path of Electrons
ADP
+ Pi
ATP
Light
Electron
Carriers
Chlorophyll
2e-
CYCLIC PHOTOPHOSPHORYLATION
VS
Excited
2e-
Path of Electrons
Electron
Carriers
ADP
+ Pi
ATP
Light
Photolysis of Water
NAPD+
½O2
NADPH
Chlorophyll
2e-
H2O
2H+
NONCYCLIC PHOTOPHOSPHORYLATION

Comparison of Cyclic and Non-cyclic photophosphorylation

NON-CYCLIC	CYCLIC
Electrons do not come back to the same molecule	Electrons return to the same molecule.
First electron donor is water..	First electron is the P700 (PSI).
Involves both PSI and PSII	Involves only PSI
Last electron acceptor is NADP.	Last electron acceptor is P700 (PSI).
The net products are ATP, NADPH and O_2.	The product is ATP only