27/02/17

Photosynthesis

Historical Background :-

(1) Van Helmont :-

→ Food comes from water not the soil.

(2) Joseph Priestley :-

→ plants restore to the air whatever breathing animals & burning candle removes.

exp:- plant & candle in closed jar

(3) Jan Ingenhouzz :-

→ sunlight is essential for P.S.

→ exp. on aquatic plants.

(4) Sachs :-

→ plants produce glucose during P.S.

(5) Engelmann' :-

→ exp. with green algae 'CLADOPHORA'.

→ Carried out Action Spectrum.

(6) Van Niel :-

→ exp. on purple-green bacteria.

→ P.S. is light dependent.

→ H_2 from suitable oxidisable compound is used to reduce CO_2.

(7) Robert Hill :-

→ Plant use light energy to generate reducing power.

(8) Theodore de' Saussure :-

→ H_2O is essential for P.S.

(9) Emerson :-

→ 2 photosystem are there. (PS-I, II).

→ Emerson's effect (Red Drop).

→ Light & Dark reactions.

(10) M. Calvin :-

→ C_3 cycle.

Photosynthesis :-

Raw material :-

H_2O & CO_2, sunlight and pigments

Three types of Pigments for Photosynthesis :-

(1) Chlorophyll :-

Ch- a, b, c, d, e, bacterio chlorophyll bacterio viridin.

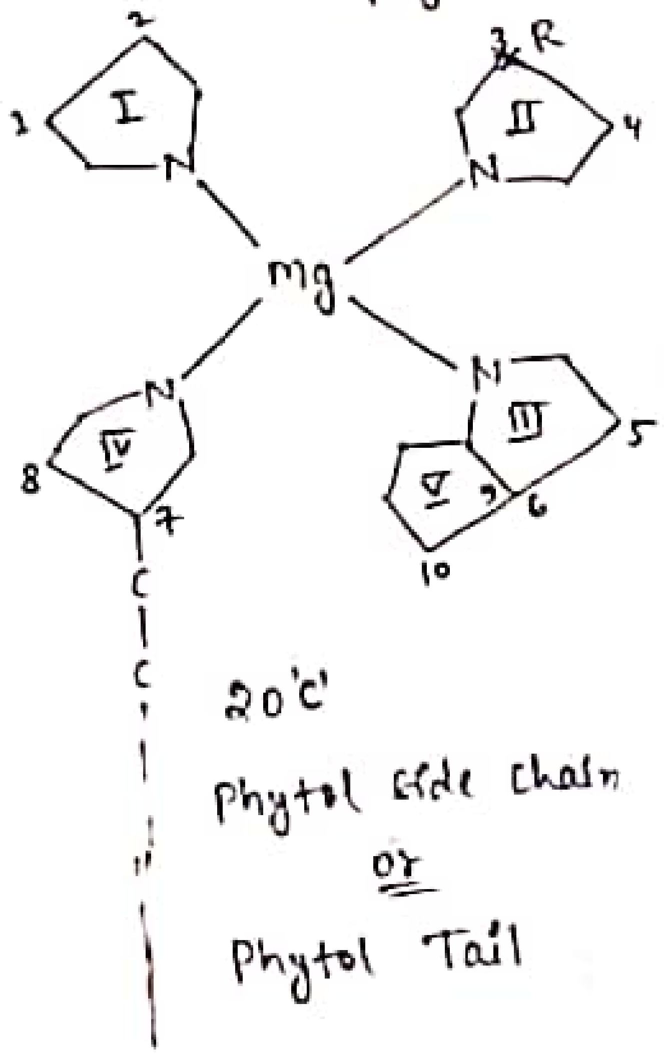
Chlorophyll → Head → Porphyrin Head
Chlorophyll → Tail → Phytol side chain

On the next page, we will discuss difference b/w Ch- a & b.

Ch-a	Ch-b
→ at position 'R', (-CH$_3$) group is present	→ at position 'R', (-CHO) group is present.
→ Bluish Green	→ Olive Green.
→ In reflected light it appears Red.	→ In reflected light it appears Brownish Red.
→ In transmitted light appears Green.	→ In Transmitted light appears yellowish-green.

* Structure of chlorophyll :-

→ Porphyrin Head
→ Phytol side chain/Tail.



I - IV = Pyrole Rings
V = Cyclopentanone
→ porphyrin Head
or
Tetra pyrolic Head

R = -CH$_3$ → ch-a
= -CHO → ch-b

(2) Carotenoids (lipids) :-

Ⓐ Carotene
→ $C_{40}H_{56}$
→ Orange Red

Ⓑ Xanthophylls
→ $C_{40}H_{56}O_2$
→ Yellowish Brown
Ex:- Fucoxanthin, Lutein

(3) Phycobillins :-
→ Predominant in BGA.

Ⓐ Phycocyanin
→ purple

Ⓑ Phycoerythrin
→ Red

Note:-

Ch-a ← Reaction Center chlorophyll

all other pigments ← Accessory pigments

Site of photosynthesis :-

Leaf → mesophyll cells → Chloroplast.

Chloroplast → Thylakoid or Granum ; Stroma

Thylakoid or Granum ⇑ light rxn takes place

Stroma ⇑ Dark Rxn takes place

* Light dependent photosynthesis
⇓
Light Rxn ← Granna

* Light Independent photosynthesis
⇓
Dark Rxn or C_3 cycle/calvin cycle ← Stroma

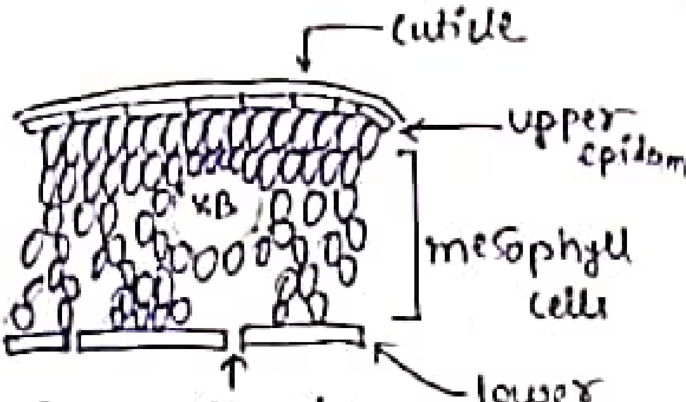
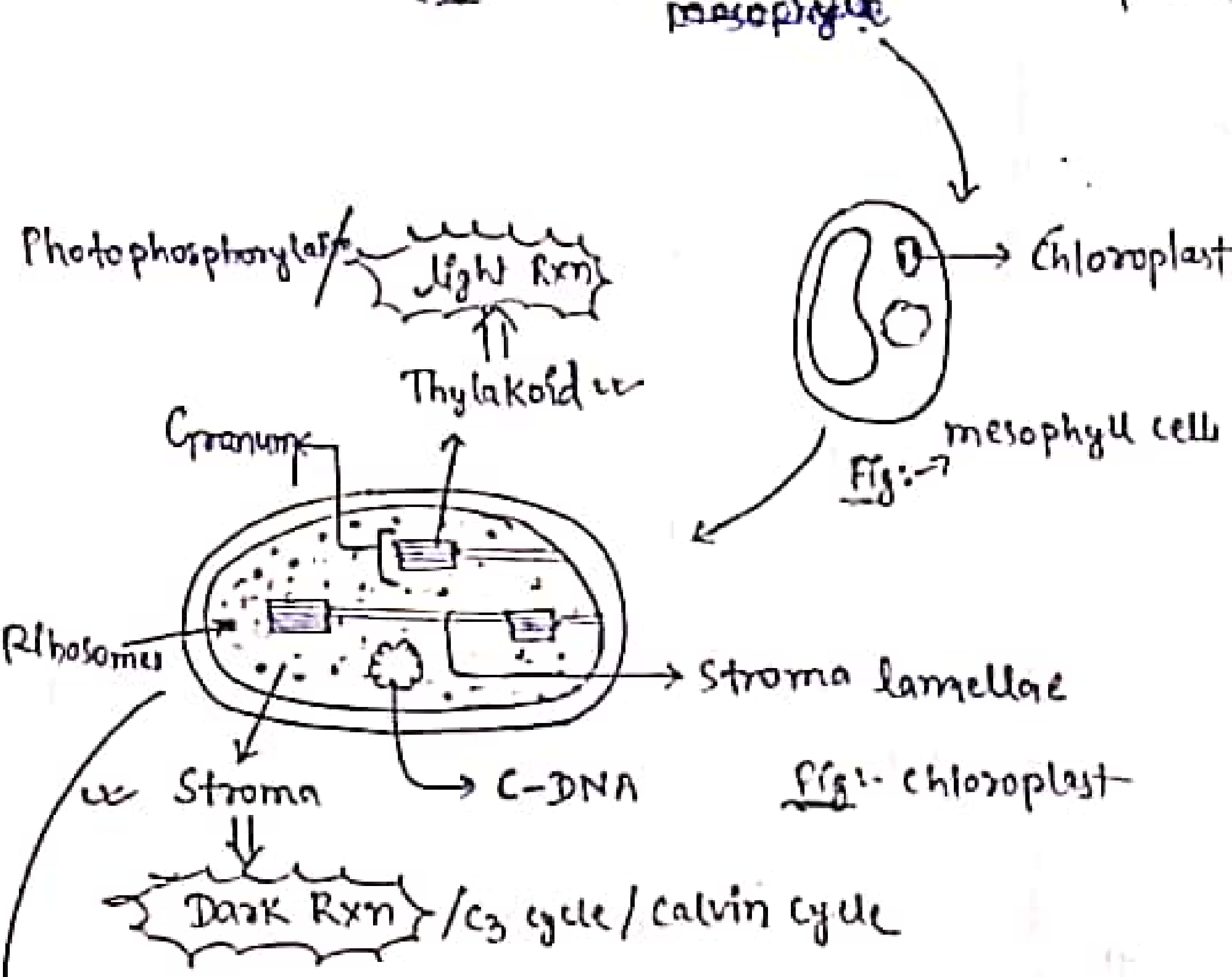


Fig 1. Leaf



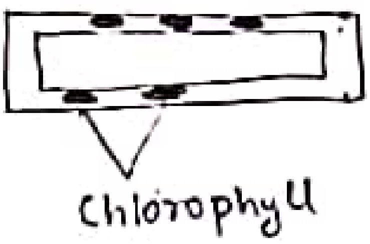


Fig:- Thylakoid

⇓

Light Rxn

Photophosphorylation

7) Light absorption & Action Spectrum :-

Light Quality ⇒ means wavelength.

→ Every pigment absorbs different wavelength of light.

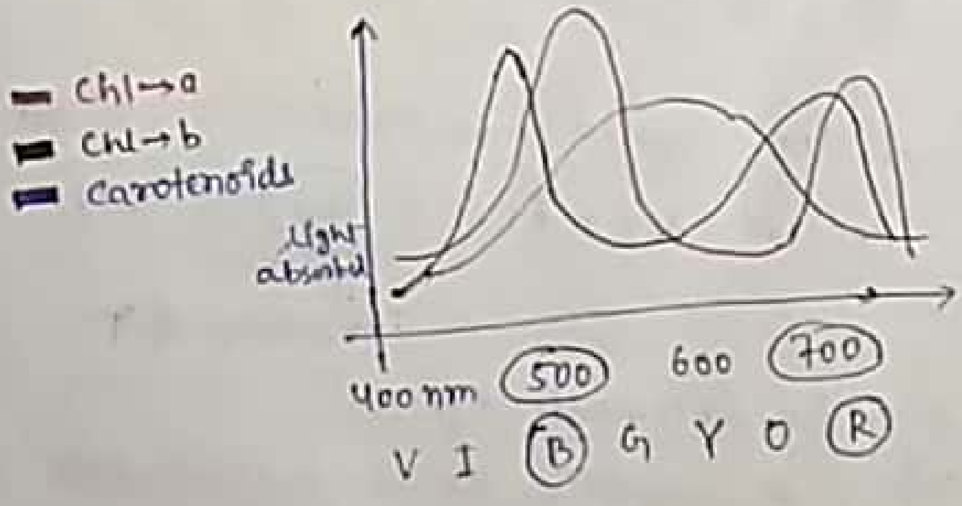
→ most of the absorption takes place by Chlorophyll-a & b at 500 and 700 nm

→ The absorption of light is depicted by a graph called 'ABSORPTION SPECTRUM'.

→ The absorption spectrum is also referred to as 'ACTION SPECTRUM', because rate of photo synthesis is high at 500 & 680 ~~nm~~ nm.

→ Action Spectrum was disovered by a scientist named Engelmann's by his exp. on green algae.

→ Action spectrum is recorded by Spectrophotometer

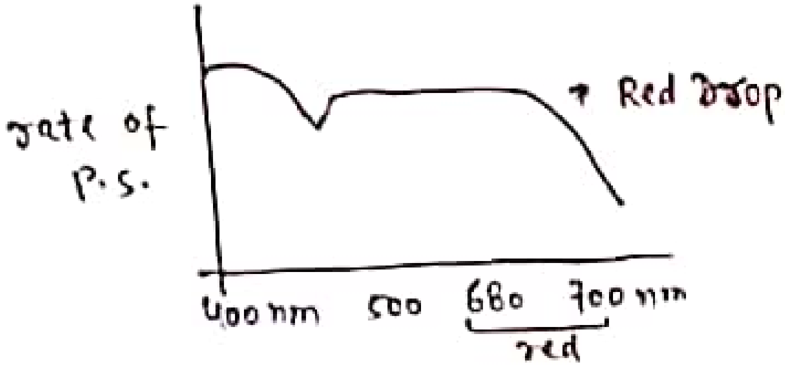


Hence,
Blue and Red light is mostly preferred for photosynthesis.

Emerson's effect & Red Drop:-

* Quantum Yield:-

  ↳ amount of O_2 released per quantum of light absorbed.



* Red Drop:-

  ↳ Sudden decline in the rate of Photosynthesis after 680 nm (red.)

When. leaf exposed individually to:-

P.S. at 700 nm ⇒ 10 qu. yield

P.S. at 653 nm ⇒ 53 qu. yield

But,

when leaf exposed simultaneously at 700 & 653,

P.S. at 700 & 653 ⇒ (72) qu. yield

↑ it

Enhanced Q.Y.

* Emerson's Enhancement Effect:-

  ↳ at exposition to 700 & 653 nm of light simultaneously, the Q.Y. is much higher than individually exposed to 700 & 653 nm.

→ There are 2 photosystems.

PS-I (700 nm)

PS-II (653-680)

Quantosome :-

→ It is the photosynthetic Unit.

→ It is a collection of pigments molecules which help in photosynthesis.

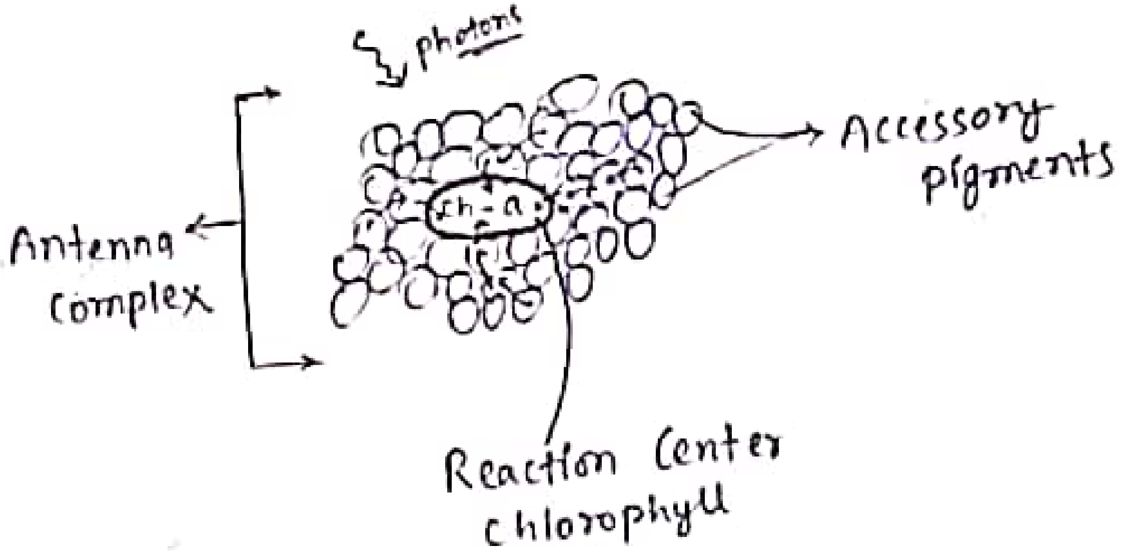
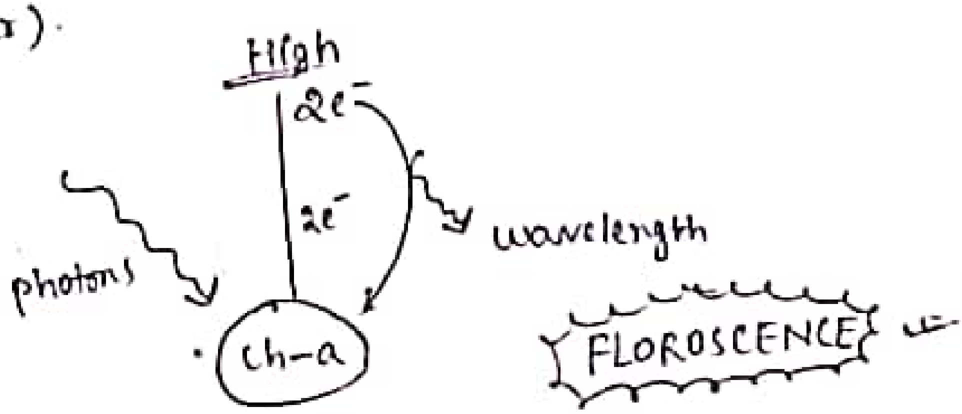


Fig:-> Quantosome

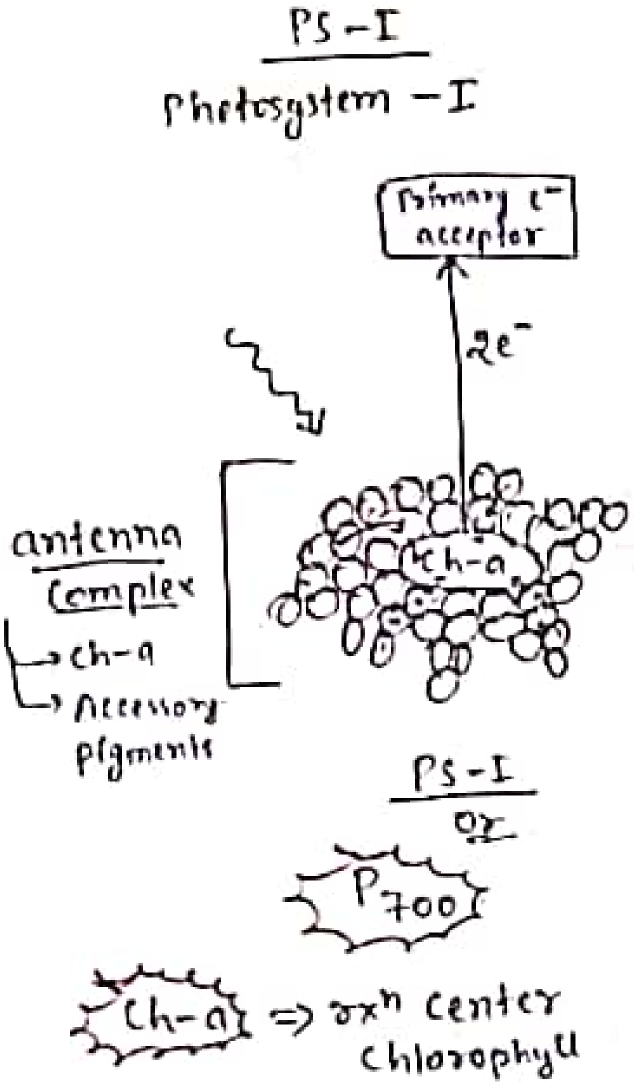
Now,
when an isolated "chlorophyll-a" is taken in test tube, it shows Floroscence (emission of colour).

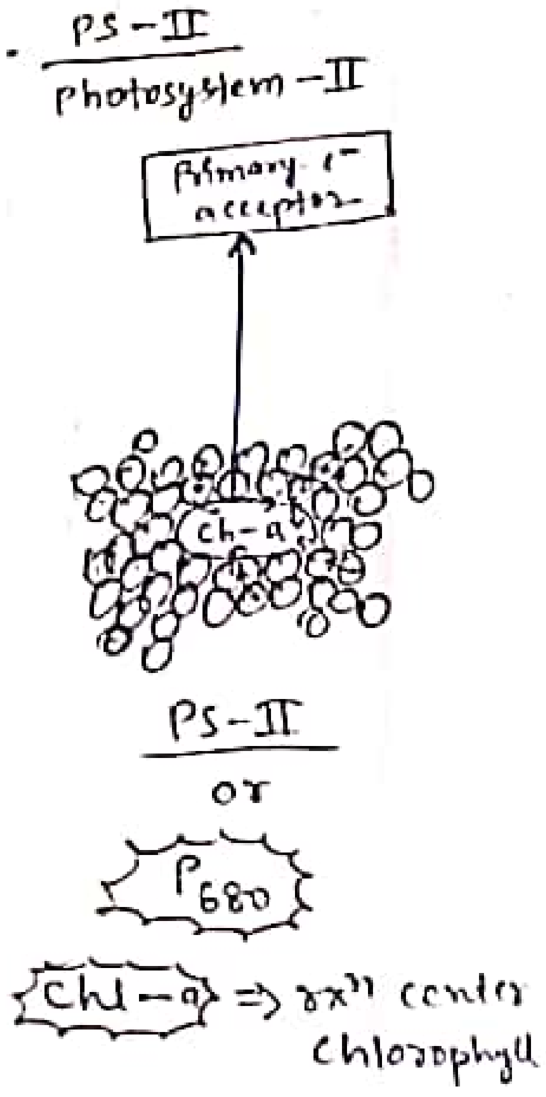


Photosystem :-

→ There are two types of photosystem namely PS-I & PS-II.

→ Discovered by Engelman.





Photosynthesis :-

Process
- Light dependent rxn => Light Rxn or Photophosphorylation
- Light independent rxn or Dark rxn / calvin cycle / C_3

Non-cyclic Photophosphorylation :-

→ occurs in Thylakoids.

→ Continuous supply of electrons and a pair of proton is provided by photolysis of water.

→ Also called as '<u>Z Scheme</u>'.

→ Both PS-I, PS-II are involved.

→ End products are ATP, O_2, $NADPH_2$

→ A pair of e^- is ~~ex~~ excited in presence of Sunlight & pass through E.T.S. to release ATP.

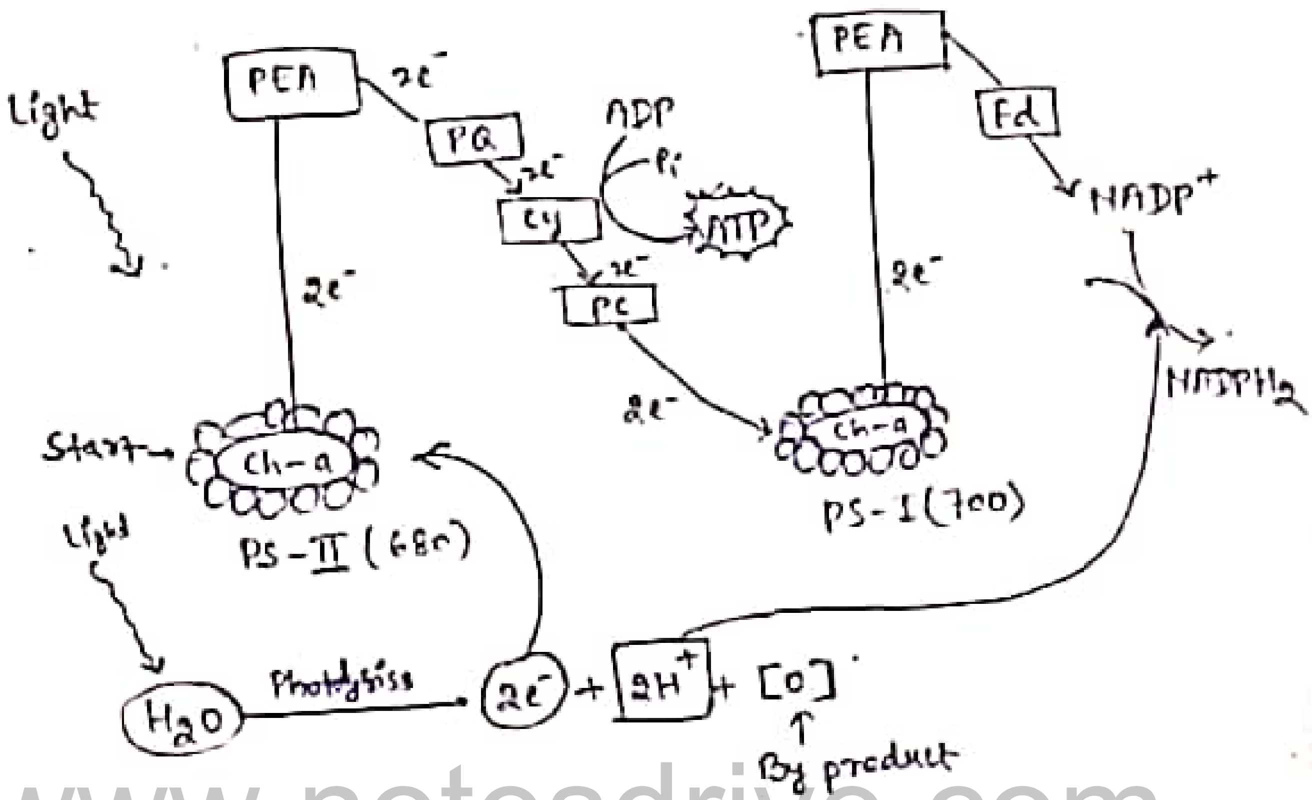
→ The photolysis of H_2O provides $2H^+$ to $NADP^+$ to form $NADPH_2$

↓

A reducing substance which reduces CO_2 to carbohydrates in Dark rx^n.

→ Complex for photolysis of H_2O is present on inner membrane of thyllakoid. i.e, O_2 is collected in lumen of thyllakoid.

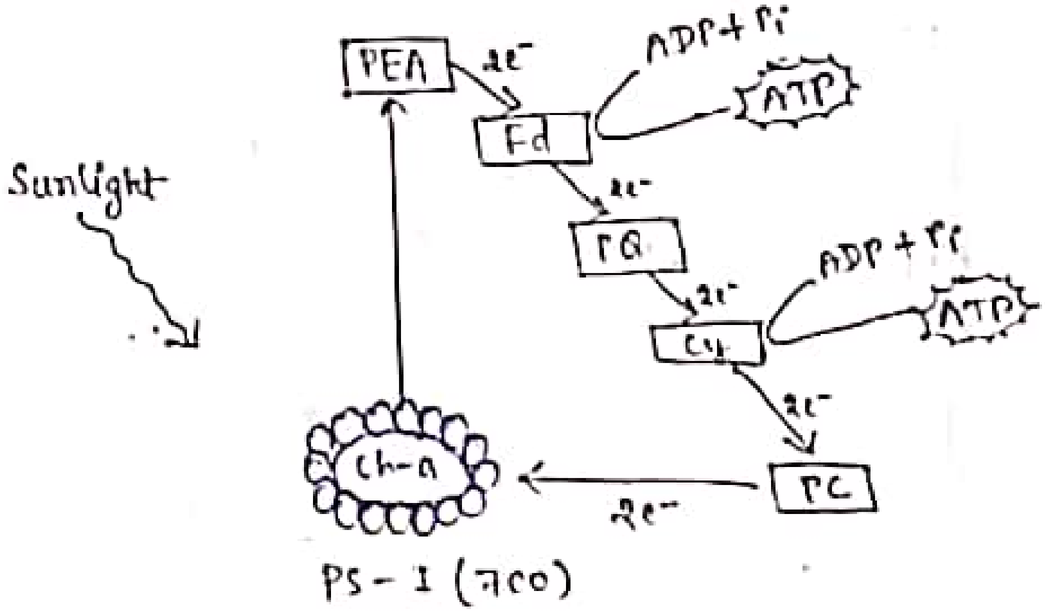
→ NADP reductase enz. catalyst is present on outer membrane of thyllakoid.



PEA → Primary e^- acceptor.
PQ → Plasto Quinone
Cy → Cytochrome Complex
PC → Plastocyanine
Fd → Ferridoxine.

Cyclic Photophosphorylation :-

- Only PS-I is involved.
- No photolysis of H_2O.
- Only ATP is synthesized.
- No reducing power ($NADPH_2$) is generated
- Occurs in stroma lamellae.



Note:-
During photosynthesis,
only 15-20% process is cyclic otherwise, maximum process is non-cyclic (O_2 liberation).

Comparison b/w cyclic & Non-cyclic Photophosphorylation

Characters	Cyclic Photophosphorylation	Non-cyclic Photoph-
1. Product Synthesized	only ATP	ATP & $NADPH_2$
2. Biproduct	× × × × ×	O_2 is the biproduct
3. O_2 evolved	× × ×	✓
4. P.S. requirement	PS-I	PS-II & PS-I
5. Source of e^-	No external source of e^- is needed	H_2O is the external source of e^-
6. Condition Req.	→ low int. of light → low conc. of CO_2 → In anaerobic condn.	→ optimum int. of light. → conc. of CO_2 is high. → In aerobic.

Comparison b/w PS-I & PS-II :-

Characters	PS-I	PS-II
1. Reaction Center	P_{700} (chl-a)	P_{680} (chl-a)
2. Cycling	Involved in both cyclic & non-cyclic photophospho-rylation.	Involved only in Non-cyclic photo-phosphorylation.
3. Ratio of chloro-phyll & carotenoids	chl : Carotenoids 20-30 : 1	chl : Carotenoids 3.7 : 1
4. Location	on the membrane of thyllakoid & stroma lamellae both.	on membrane of thyllakoid only.
5. oxygen	PS-I is not associated with photolysis complex	PS-II is associated with photolysis complex
6. Source of e^-	from chl-a in cyclic PP from P-S-II in noncyclic P.P.	From photolysis of water

Chemiosmotic Theory / Hypothesis :-

→ Site of H_2O splitting is the complex is inner side of membrane of thyllakoid.

→ Site of NADP reductase enzyme is outer membrane of thyllakoid.

→ Site of O_2 produced = lumen

→ Site of ATP & $NADPH_2$ production is Stroma.

→ Fo particle helps in facilitated diffusion of H^+.

→ Cytochrome acts as <u>H^+ acceptor</u> as well as <u>e^- transporter</u>.

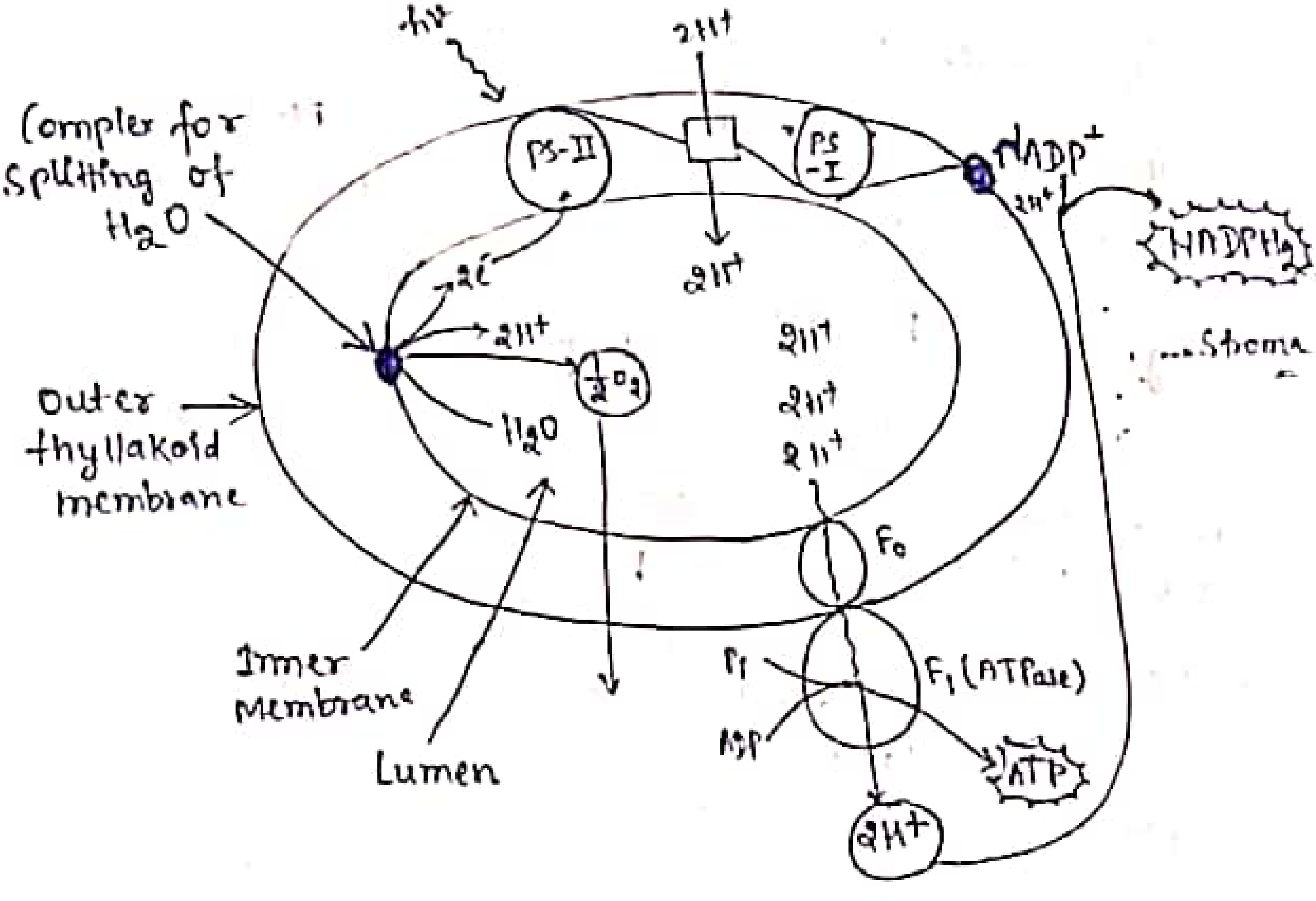


Fig:- Thyllakoid

Dark Reaction / C_3 Cycle / Kelvin cycle :-

→ Also known as 'Biosynthetic Pathway' because ultimately it synthesizes Glucose.

→ Discovered by Melvin Calvin. Hence, also known to be Calvin cycle

→ In dark rx^n, 1st stable compound intermediate formed is a 3-carbon compound called Phosphoglycerate (PGA). Hence, called C_3 cycle.

→ we start calvin cycle with 3 molecules of CO_2 for our convinience. However, naturally, plants execute Calvin cycle with 1 CO_2 molecule.

vvi → 6 calvin cycles are needed to synthesize 1 molecule of Glucose.

→ Calvin cycle occurs in 3 steps :-

(i) Carboxylation

(ii) Reduction

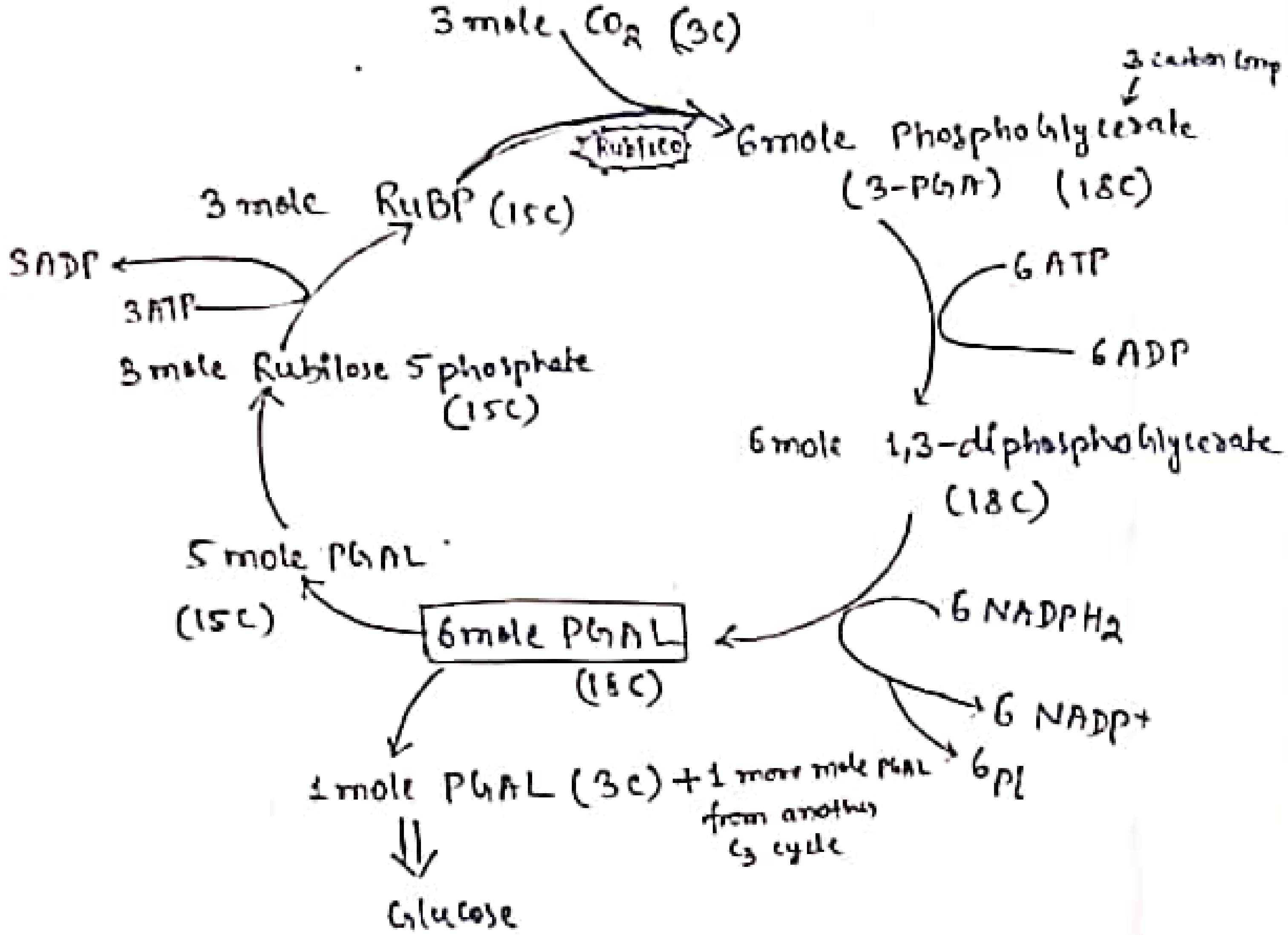
(iii) Regeneration of RuBP (5c)

→ RUBP = Rubilose Bis-phosphate (5c)

→ RUBP combines with CO_2 in presence of an enzyme called as RuBISCO.

RuBISCO = Rubilose Bisphosphate Carboxylase oxygenase

→ RUBISCO can act as carboxylase as well as oxygenase under different conditions



<u>For synthesis of 1 molecule of Glucose</u>

$$\frac{6\ ATP + 3\ ATP}{9\ ATP} \times 2 = 18\ ATPs \ \& \ 12\ NADPH_2$$

↑ from one Calvin cycle

Ans.

Note:- → The 6 molecules of PGAL formed in the center of rxn is actually fragmented in (5+1) molecule in which 5 molecule is used up in regeneration of RUBP while 1 molecule goes for glucose synthesis

Photorespiration / C_2 cycle / Glycolate cycle lants In

→ Rubisco acts as both carboxylase as well as oxygenase under diff. conditions.

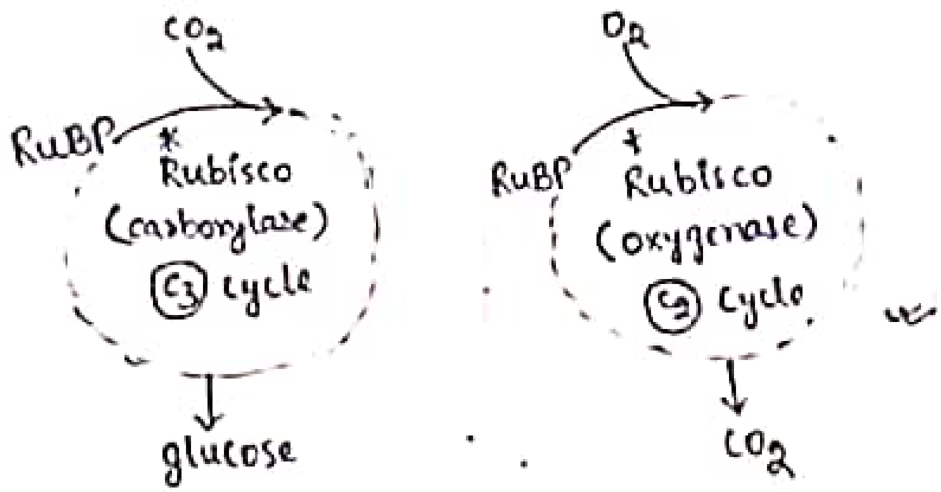
Imp. ✓ **Condn for acting as oxygenase :-**

- High temp
- High concentration of O_2

↓

Rubisco acts as oxygenase

→ photorespiration is a harmful process in which O_2 is taken in & CO_2 is given out.



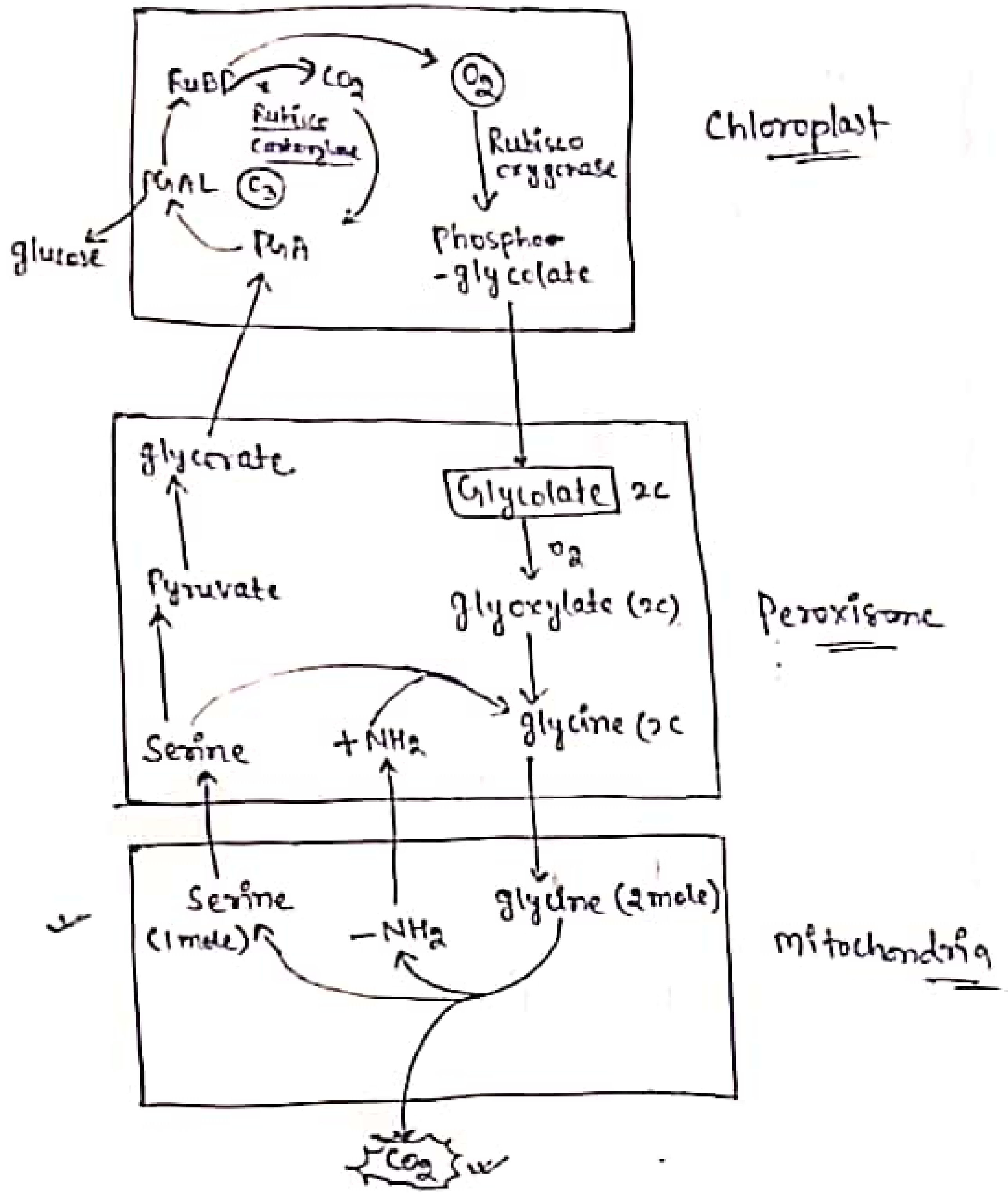
→ photorespiration is also called C_2-cycle because, the first stable compound formed is of 2 carbon containing glycolate.

→ Peroxysome also takes part in this process other than chloroplast & mitochondria.

→ At the time of conversion of glycine (2 mole) into serine (1 mole), the CO_2 is released.

→ Shown by plants of Temperate region

Ex:- wheat, rice, beans, barley.



C_4 Cycle / pathway :-

→ Also Known as "Hatch-Slack cycle".

→ This pathway is used to avoid the problem of photorespiration

→ Photorespiration can be avoided by checking high temp & high $[O_2]$ conc^n.

→ Some adaptations are seen in C_4 plants in order to avoid photorespiration.

(1) Dimorphic Chloroplast :-

Granal — Agranal

→ In granal, predominantly grana is found where light rxⁿ takes place. These are found on upper side of mesophyll cells.

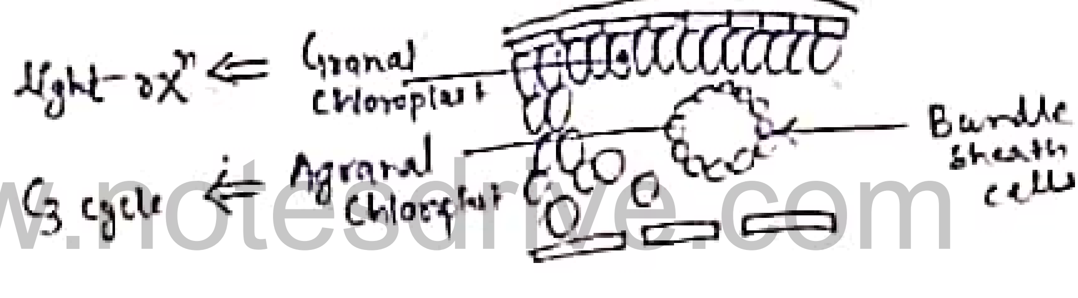
→ However, agranal chloroplast is found in BUNDLE SHEATH CELLS & predominantly, agranal is full of stroma where dark rxⁿ takes place & there in no release of O_2.

→ Bundle sheath cells are present in deeper side of leaf, so that the agranal chloroplast might not face the problem of high temp.

(2) Kranz Anatomy :-

→ presence of bundle sheath cells around vascular tissues.

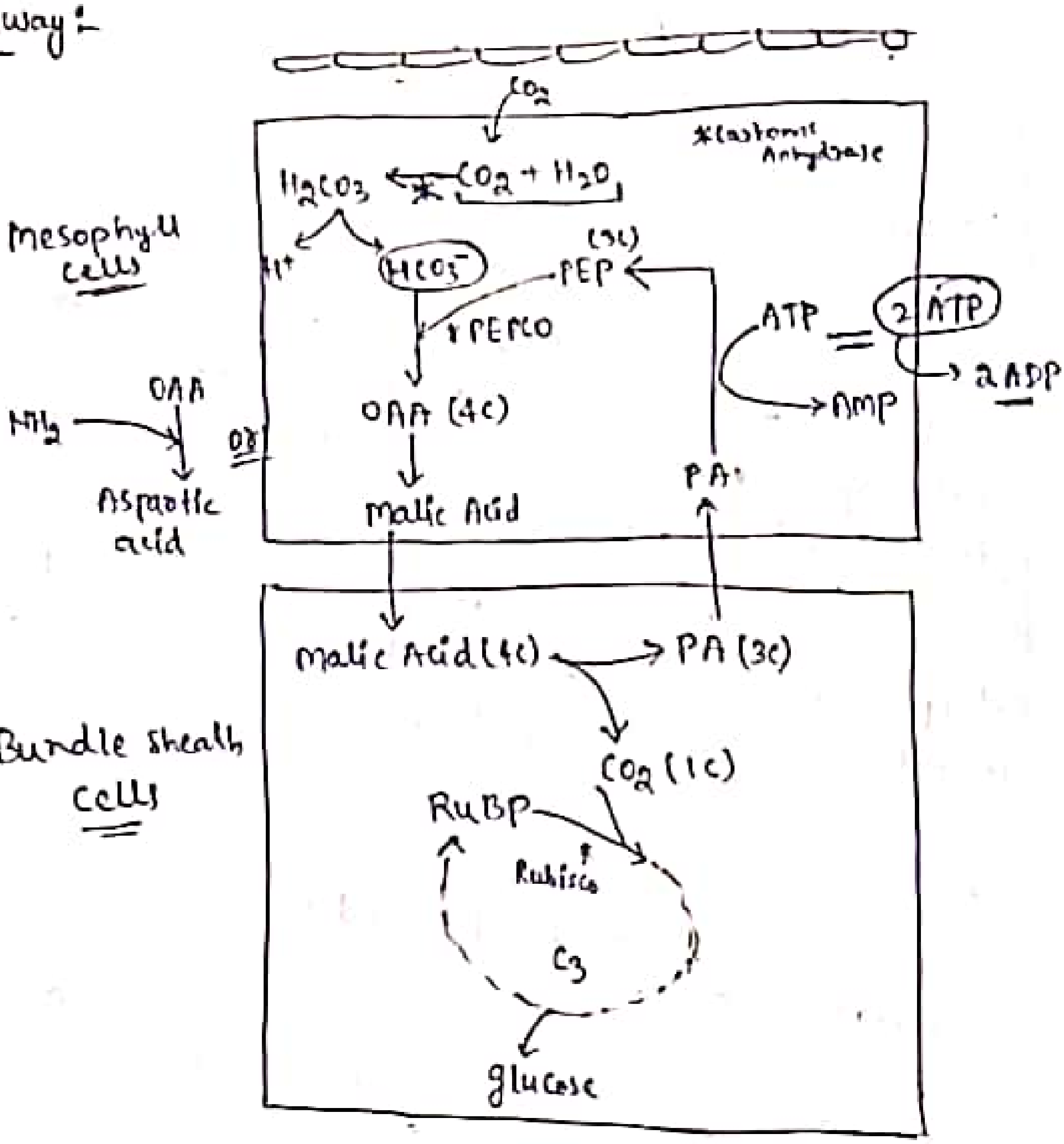
→ It encloses Agranal Chloroplast and provides a barrier to O_2 concⁿ in mesophyll cells and also keeps the agranal chloroplast cooler.



→ Hence, to the problem of high [O_2] and high temp. gets solved by some adaptation (like dimorphic chloroplast + Bundle sheath cells) made by C_4 plants.

→ Ex:- Maize, Sorgham, Sugarcane, Euphorbia, Chenopodium etc.

Pathway:-



PEP = Phosphoenol pyruvate (3C)

(OAA) = Oxalo Acetic Acid (4C)

PEPCO = PEP Carboxylase.

C_3 ATP/Glu → 18 ATP ...
C_4 ATP/Glu → 12 ... + 18 ... 30 ATP

Comparison b/w C_3 & C_4 plants :-

Characters	C_3 plants	C_4 plants
(i) CO_2 acceptor	CO_2 acceptor → RUBP	CO_2 acceptor is PEP → Mesophyll cell " " " RUBP → Bundle sheath cell
(ii) 1st stable compound	PGA (phosphoglyceraldehyde) (3C)	OAA (oxaloacetic Acid) (4C)
(iii) Types of chloroplast	Granal chloroplast in mesophyll cells.	granal → In mesophyll Agranal → " Bundle sheath cell
(iv) cycle(s)	Only C_3 cycle	C_4 & C_3 cycles.
(v) site of C_3 cycle	C_3 → mesophyll	C_3 → In bundle sheath cells
(vi) optimum temp.	10-20° C	30° C
(vii) No. of ATP reqd per glucose formation	18 ATPs	30 ATPs < 18 → C_3, 12 → C_4
(viii) Enzymes	Rubisco	PEPCO & Rubisco.

CAM Plants / Crassulacean Acid Metabolism :-

→ This pathway is adopted by the plants of xeric condn, where water loss (transpiration) is a major issue.

→ They simply change the timing of opening & closing of stomata for gaseous exchange in order to avoid transpiration

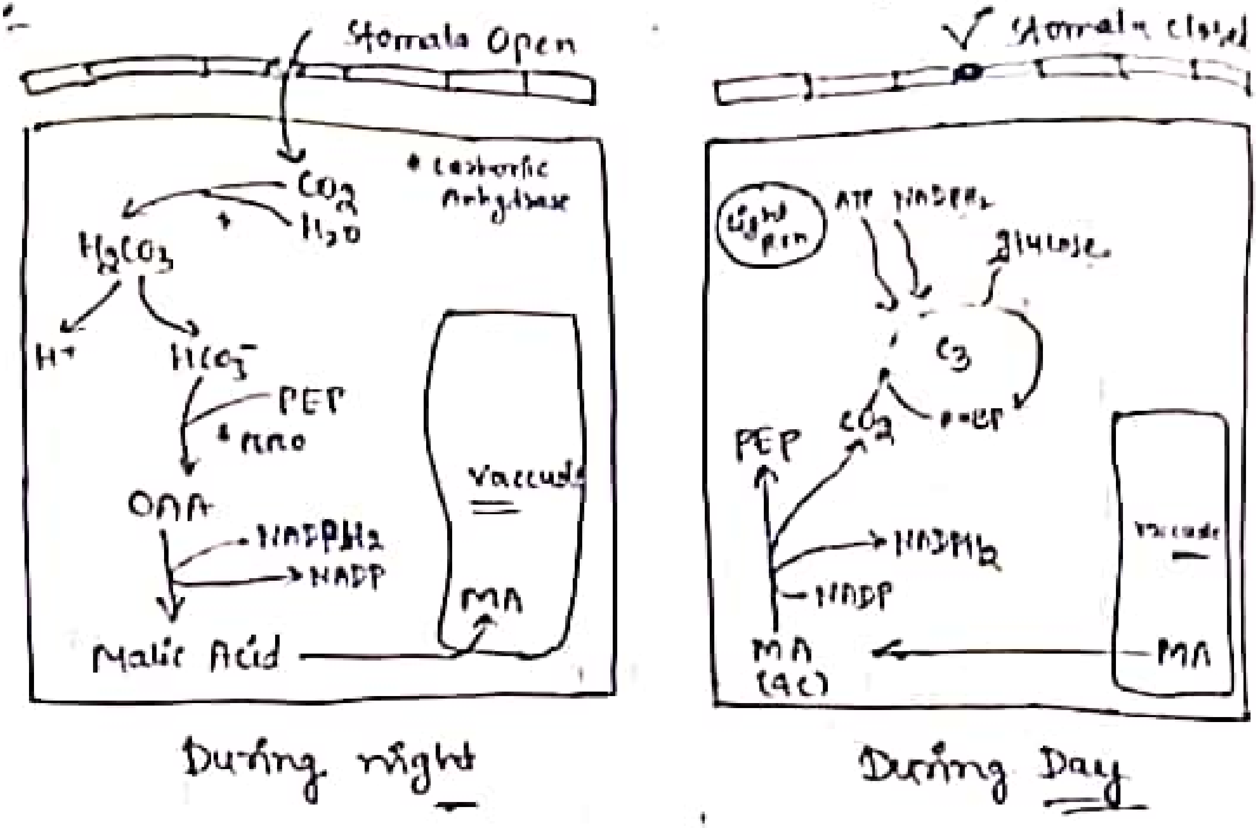
→ Stomata open during night in these plants.

→ Stomata remains closed during day.

→ Such plants whose Stomata opens at night & closes at day are called **SCOTOACTIVE Stomata**.

→ Ex:- Succulent xerophyte → cacti & Some members of Euphorbeacea family.

Pathway:-



Factors affecting the rate of photosynthesis:-

* **Cardinal Points**:-
  - → By Sachs
  - → Any quantity has 3 limits.

Let temp:-

temp —
- → Minimum
- → Optimum
- → Maximum.

* **Blackmann's law of limiting factor :-**
  - Factor which is in least or minimum can decide the rate of photosynthesis

Ex :-
rate of PS rxn :-

let

Light	Chloro.	CO_2	H_2O
10	10	10	2

So, H_2O is limiting factor as present in min quantity

Factors affecting P.S. rate

External Factors
Light, $[CO_2]$, $[O_2]$, temp, $[H_2O]$

Internal Factors
Chloro, protoplasm, No. of Chloroplasts, No. of Stomata & position, Assimilator Number

→ **External factors :-**

(1) **Light :-**
(a) quality → Blue & Red
(b) Intensity → Sciophytes ⟷ shade plants
→ Heliophytes ⟷ sun plants

(c) Duration → 10-12 hrs.

→ Increase in light Int. ↑ rate of P.S
→ very high light Int. slows P.S. & stops.

(2) **CO_2 :-**
→ slight inc. in CO_2 concn, rate of PS ↑ called as CO_2 fertilisation effect.
→ excess CO_2 can reduce P.S. rate. called CO_2 toxicity.

(3) O_2 :-

→ inc. in $[O_2]$ decreases P.S. rate Called as Warberg's Effect.

→ inc. in O_2 can increase photorespiration.

(4) Temperature :-

→ Slight increase in temperature increases the rate of P.S.

→ V. High temperature, decrease P.S ↓ & ultimately stops.

(5) H_2O :-

→ Essential for P.S.

→ Internal Factors :-

(1) Protoplasmic factor :-

(2) Chlorophyll Content :-

* Assimilator No. → Amount of CO_2 fixed per gm. of chlorophyll per hour

(3) No. of chloroplasts

(4) No. of stomata & position :-

(5) Accumulation of photosynthate ↓ rate of P.S

Translocation of Photosynthate :-

↓

product of P.S

Synthesized as **Glucose** ⟶ Transported as ~~Suc~~ **Sucrose** ⟶ Stored as **Starch**

* Reducing Sugar
* disachharide
* Non-reducing sugar
* polysachharide

* Tissue helping in translocation = phloem.

* Translocated from site of production in leaves ⟶ to ⟶ Storage organ

Note:- Rubisco is the most abundant protein in the living world.