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 :-

$\boxed{\text{Ch- a, b}}$, c, d, e, bacterio chlorophyll bacterio viridin.

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

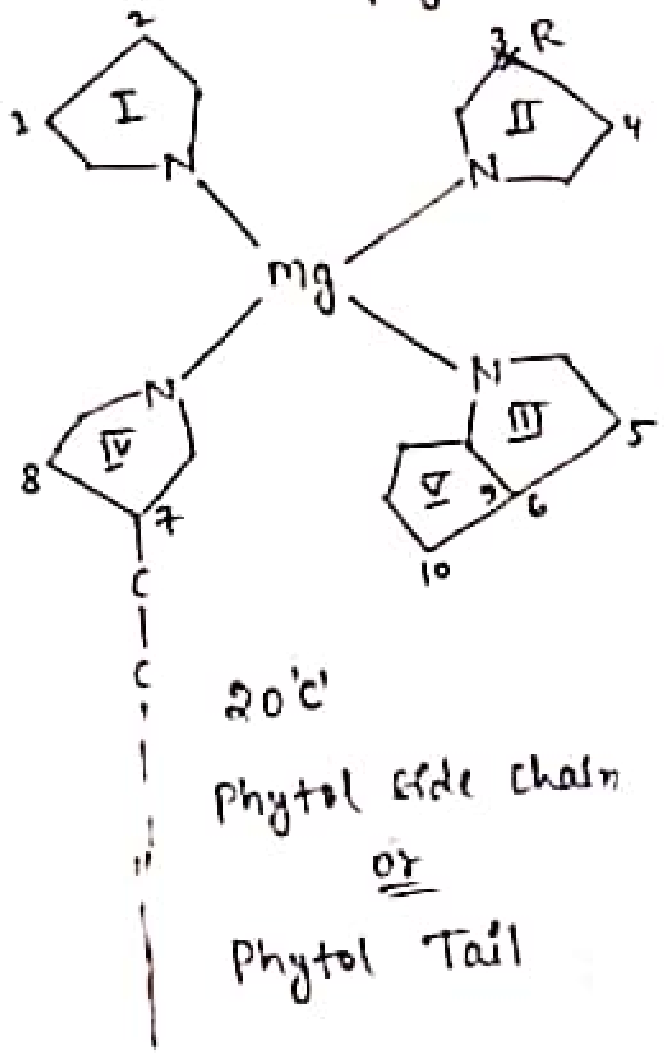
On the next page,
we will discuss difference b/w
Ch- a & b.

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

$R = -CH_3 \rightarrow$ ch-a

$= -CHO \rightarrow$ 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.

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

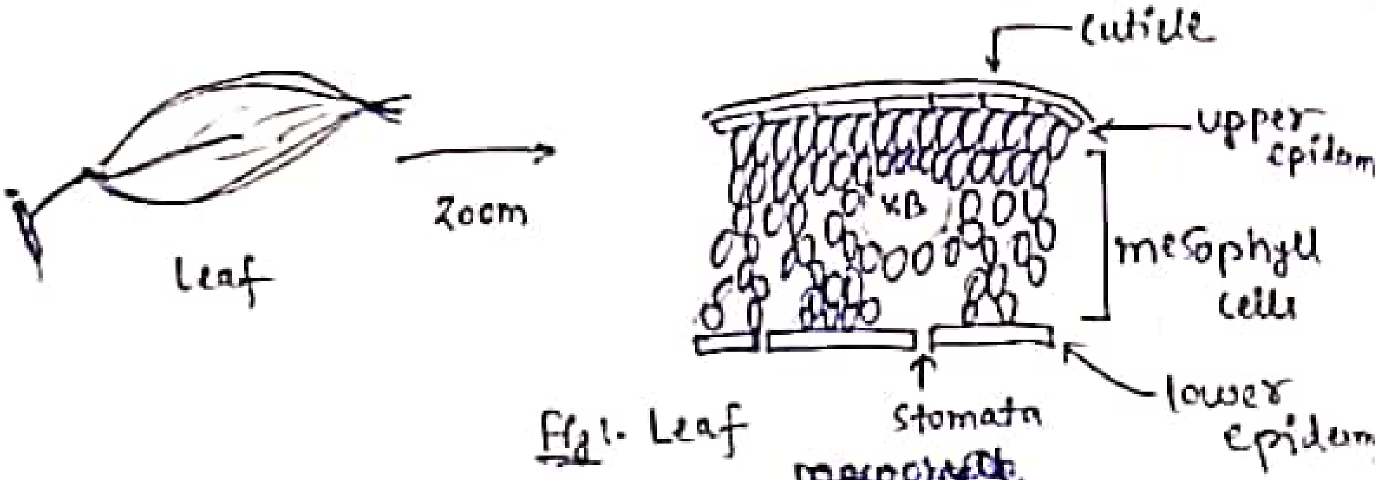
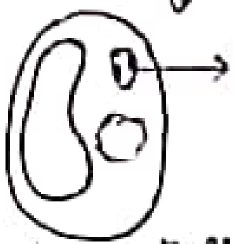


Fig:- Leaf

mesophyll



mesophyll cell

Fig:-

Photophosphorylation / Light Rxn

⇑

Thylakoid

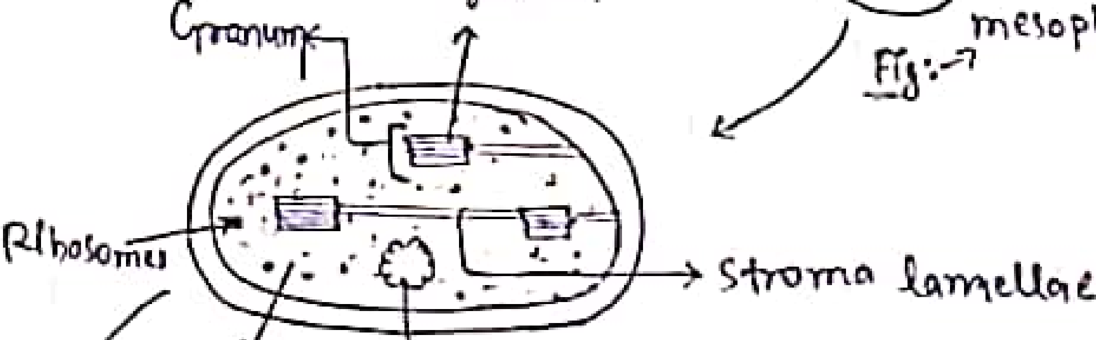


Fig:- chloroplast

Stroma

⇓

Dark Rxn / C_3 cycle / calvin cycle

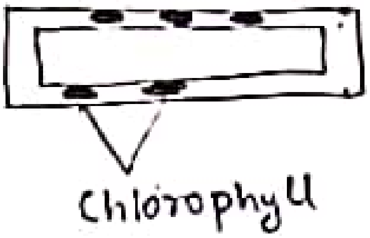


Fig:- Thylakoid

⇓

Light Rxn

Photophosphorylation

Light absorption & Action Spectrum :-

Light Quality ⇒ means wavelength.

→ Every pigment absorbs different wavelength of light.

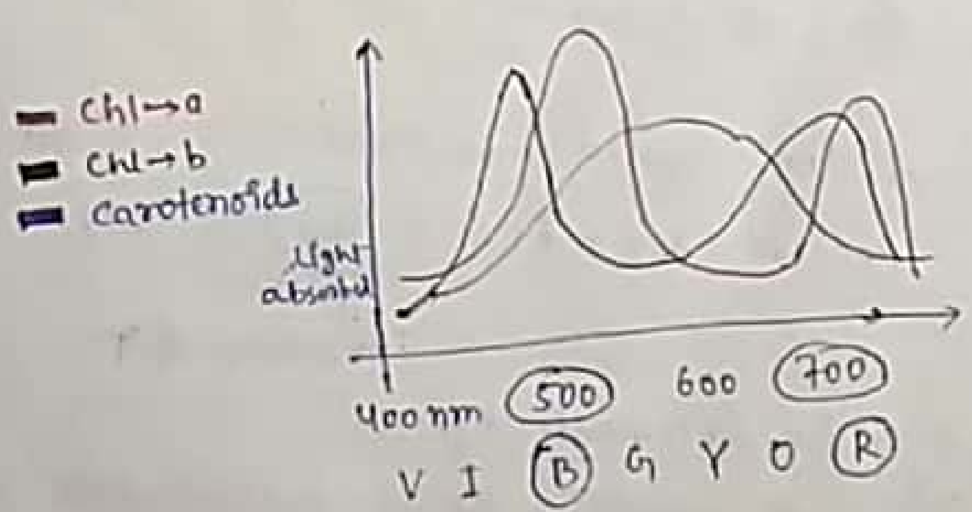
→ most of the absorption takes place by Chlorophyll-a & b at 500 and 700 nm

→ 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 & ~~6~~80 nm.

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

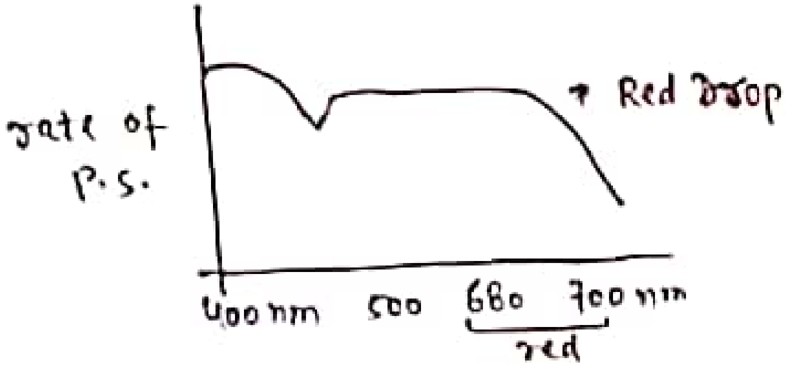
→ Action spectrum is recorded by Spectrophotometer



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

Emerson's effect & Red ~~Dro~~ 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

↑ 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	PS - II
(700 nm)	~~(563)~~ (653-680)

Quantosome :-

→ It is the photosynthetic Unit.

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

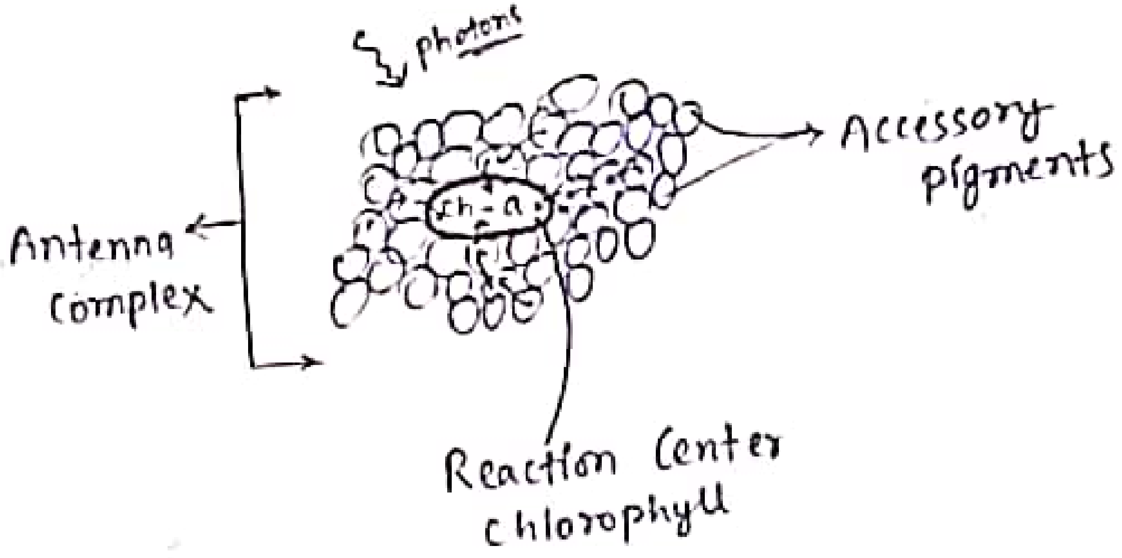
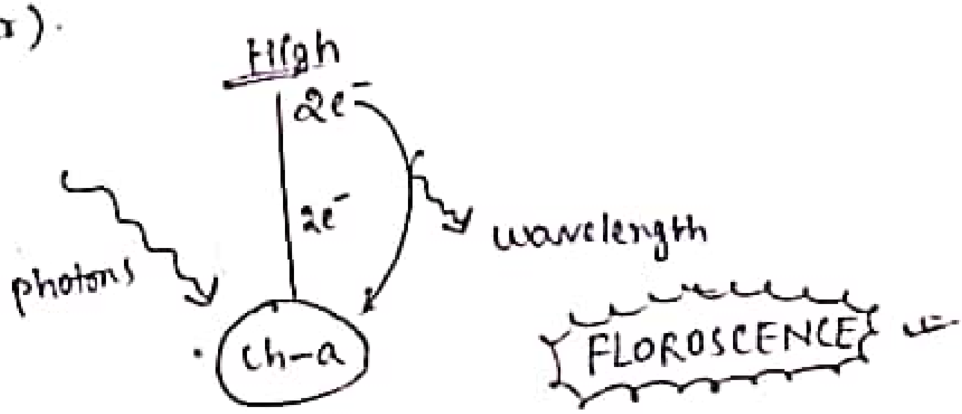


Fig :- Quantosome

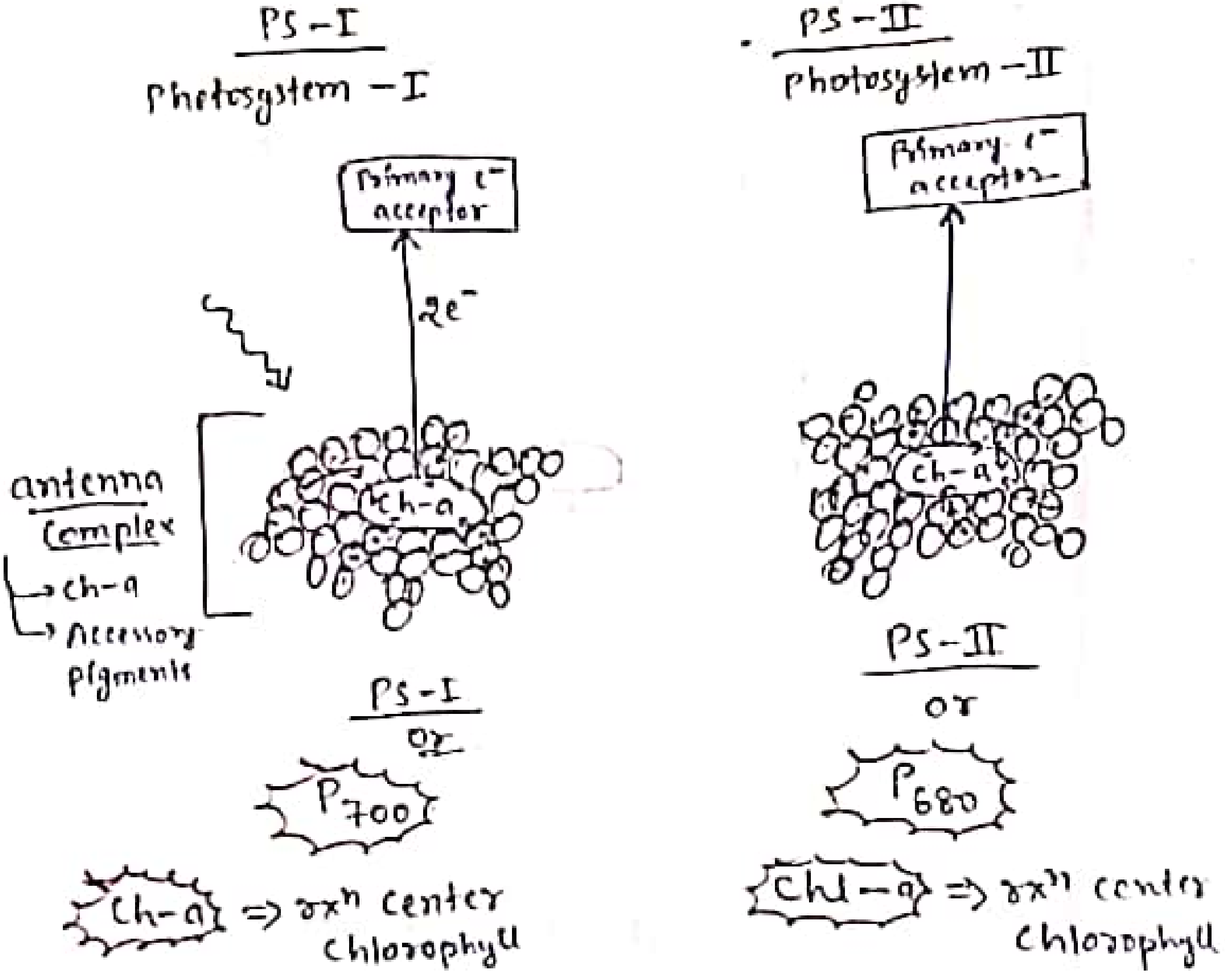
Now,
when an isolated "chlorophyll-a" is taken in test tube, it shows Floroscence (emission of colour).



Photosystem :-

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

→ Discovered by Engelman.



Photosynthesis :-

Process
- Light dependent rxⁿ ⇒ Light Rxⁿ or $\boxed{\text{Photophosphorylation}}$
- Light independent rxⁿ or Dark rxⁿ / calvin ~~se~~ 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 '**Z Scheme**'.

→ 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.

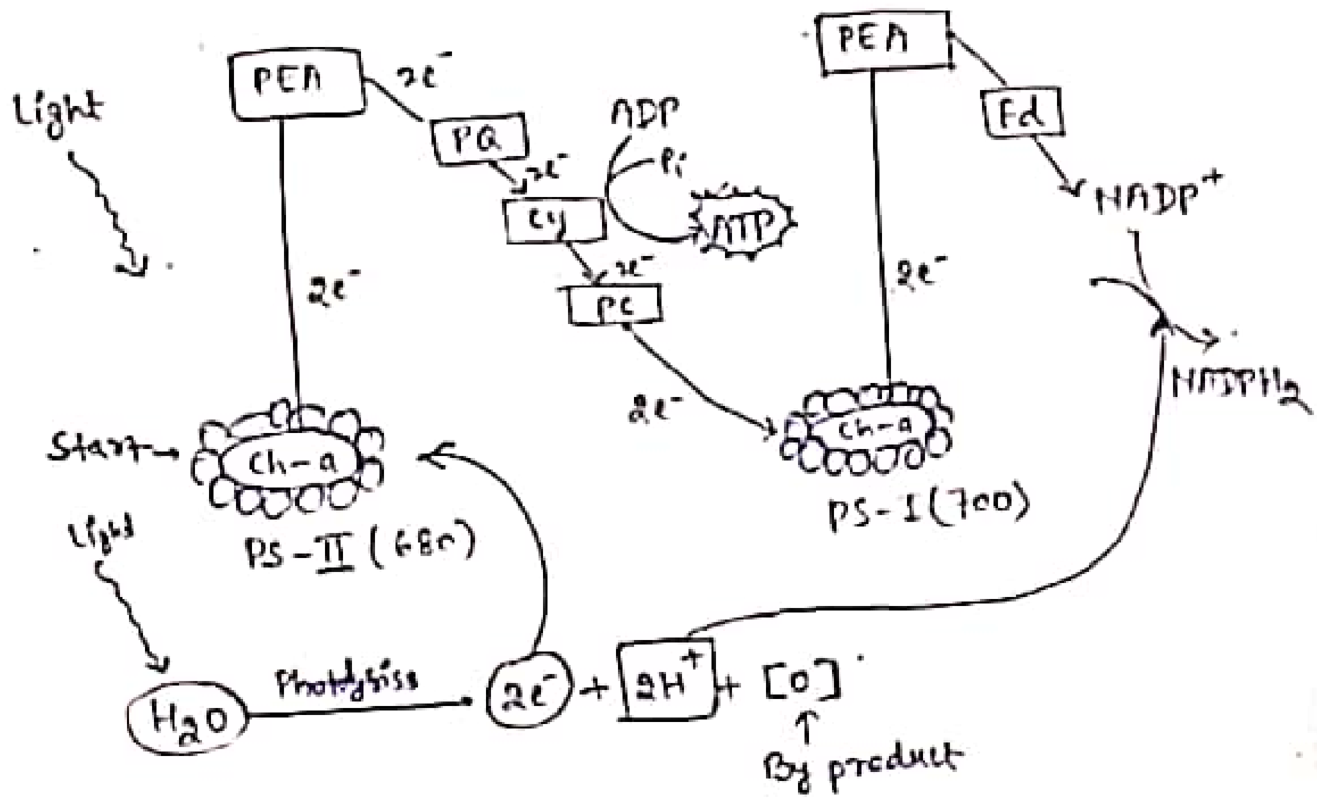
→ The photolysis of H_2O provides $2H^+$ to $NADP^+$ to form $\boxed{NADPH_2}$

↓

A reducing substance which reduces CO_2 to carbohydrates in Dark rxn.

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

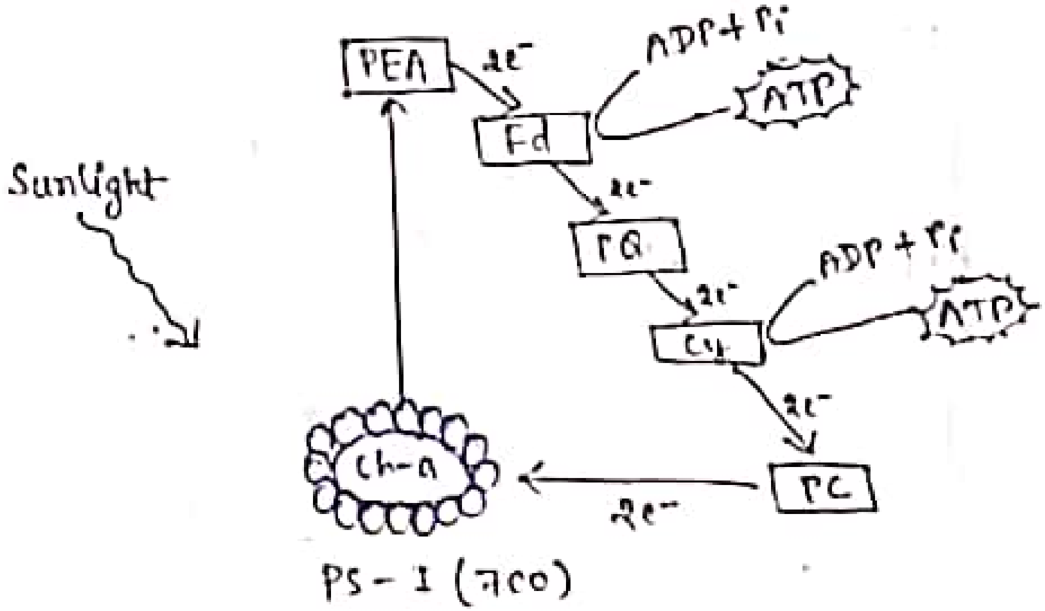
→ NADP reductase ~~enz~~ catalyst is present on outer membrane of thyllakoid.



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 photophosphorylation.	Involved only in Non-cyclic photo-phosphorylation.
3. Ratio of chlorophyll & carotenoid	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

H Chemiosmotic Theory / Hypothesis :-

→ Site of H_2O splitting i.e. for 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>.

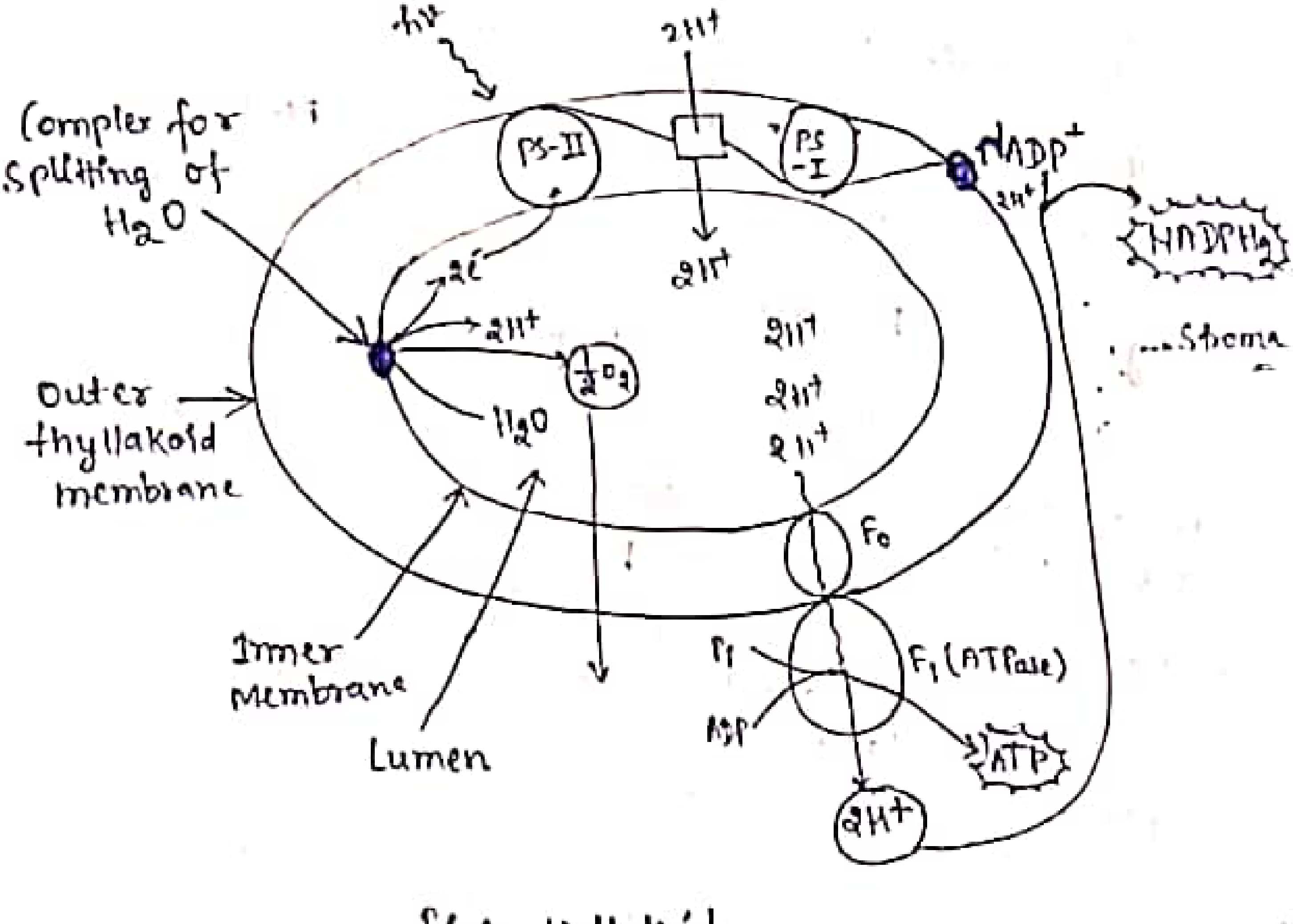


Fig:- Thyllakoid

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 rxn, 1st stable ~~compo~~ inter-mediate 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) ~~Regen~~ Reduction

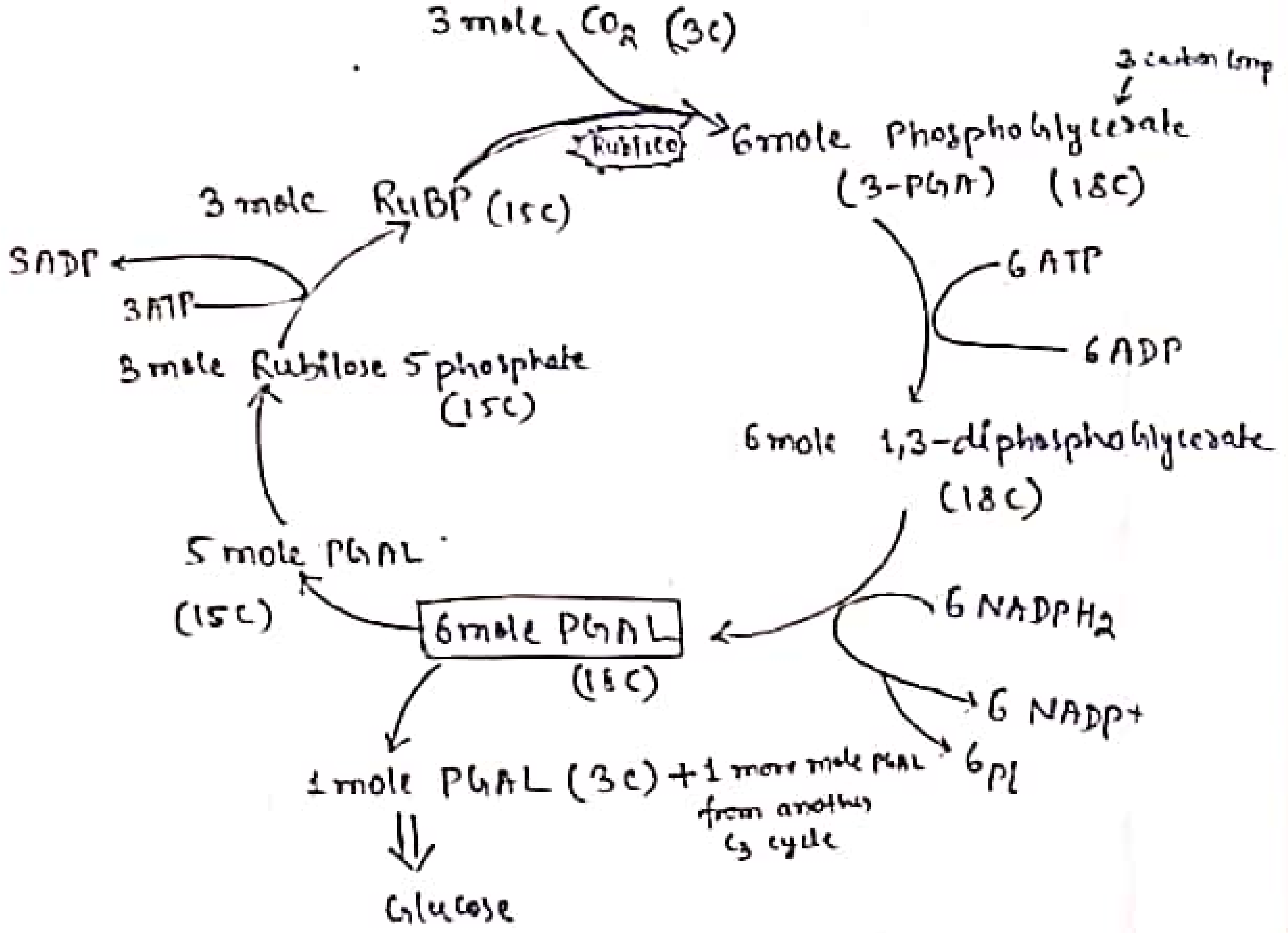
(iii) Regeneration of RuBP (5c)

→ 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>

$$\left.\begin{array}{l} \dfrac{\begin{array}{r}6\ ATP\\ +\ 3\ ATP\end{array}}{9\ ATP} \times 2 = 18\ ATPs \\ \qquad\qquad\qquad\ \ \&\ 12\ NADPH_2 \end{array}\right\} Ans.$$

↑ from one Calvin cycle

Note:- → The 6 molecules of PGAL formed in the centre of rx^n 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.

gme ~~Condn for acting as oxygenase :-~~

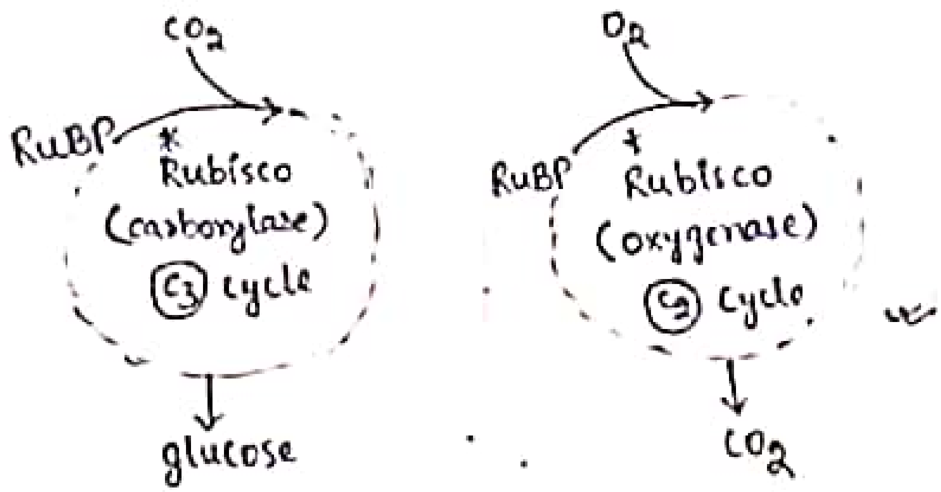
Condn for acting as oxygenase :-

* 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.



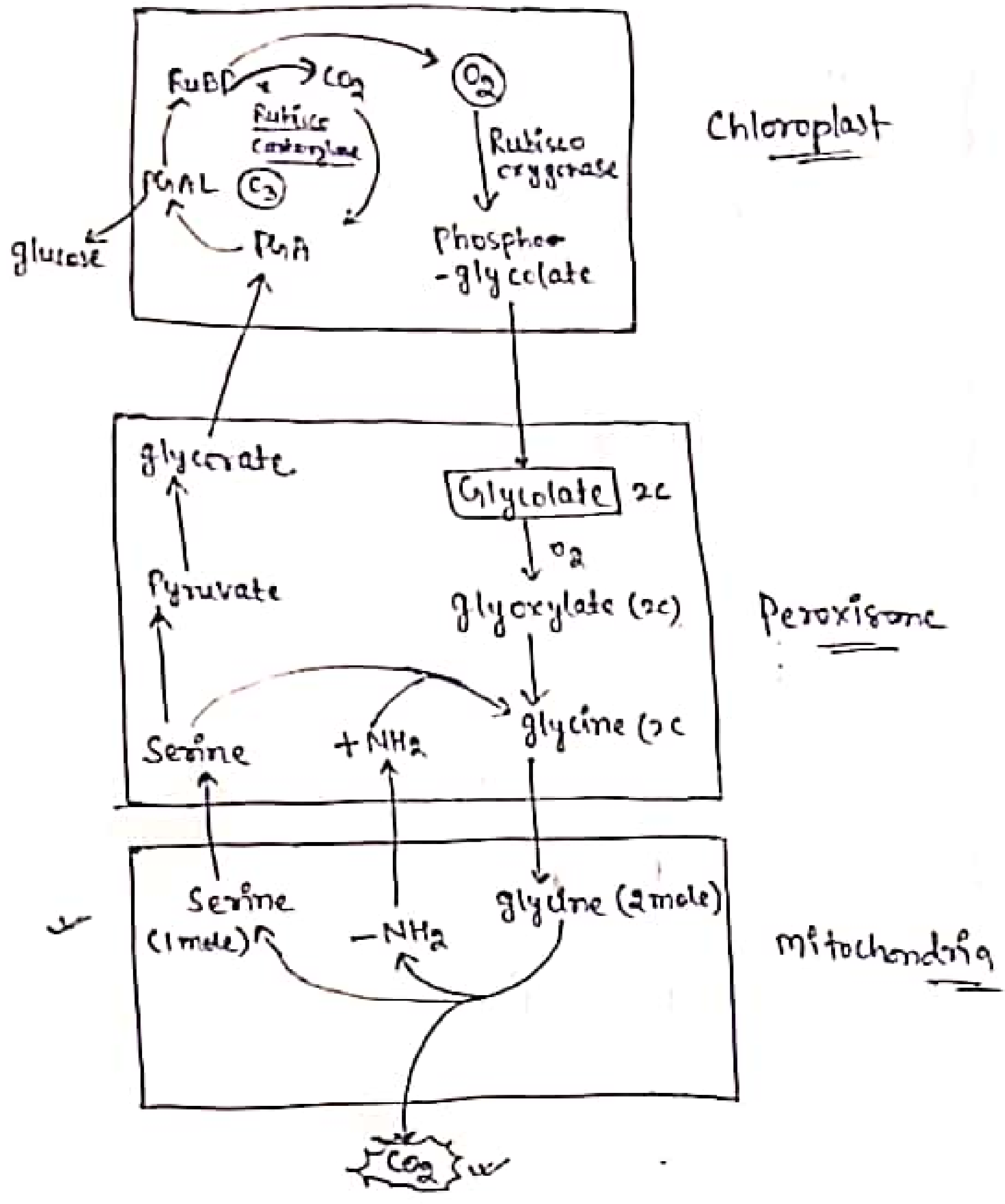
→ photorespiration is also called C_2-cycle because, the first stable compound formed is of 2 carbon containing glycolate.

→ 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 :-

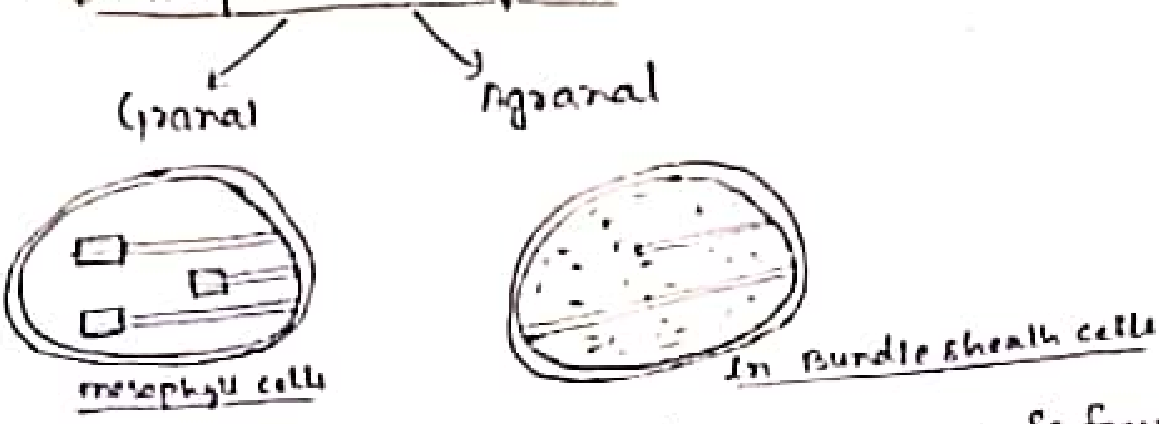
→ Also Known as "Hatch-Slack cycle".

→ 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 :-



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

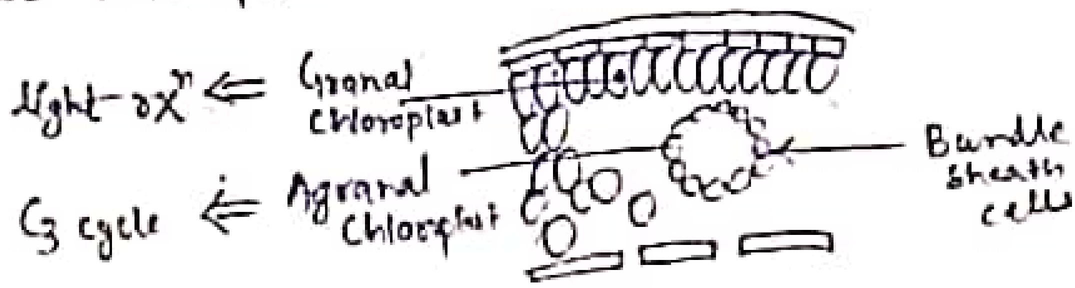
→ However, agranal chloroplast is found in BUNDLE SHEATH cells & predominantly, agranal is full of stroma where dark rx^n takes place & there is no release of O_2.

→ 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.

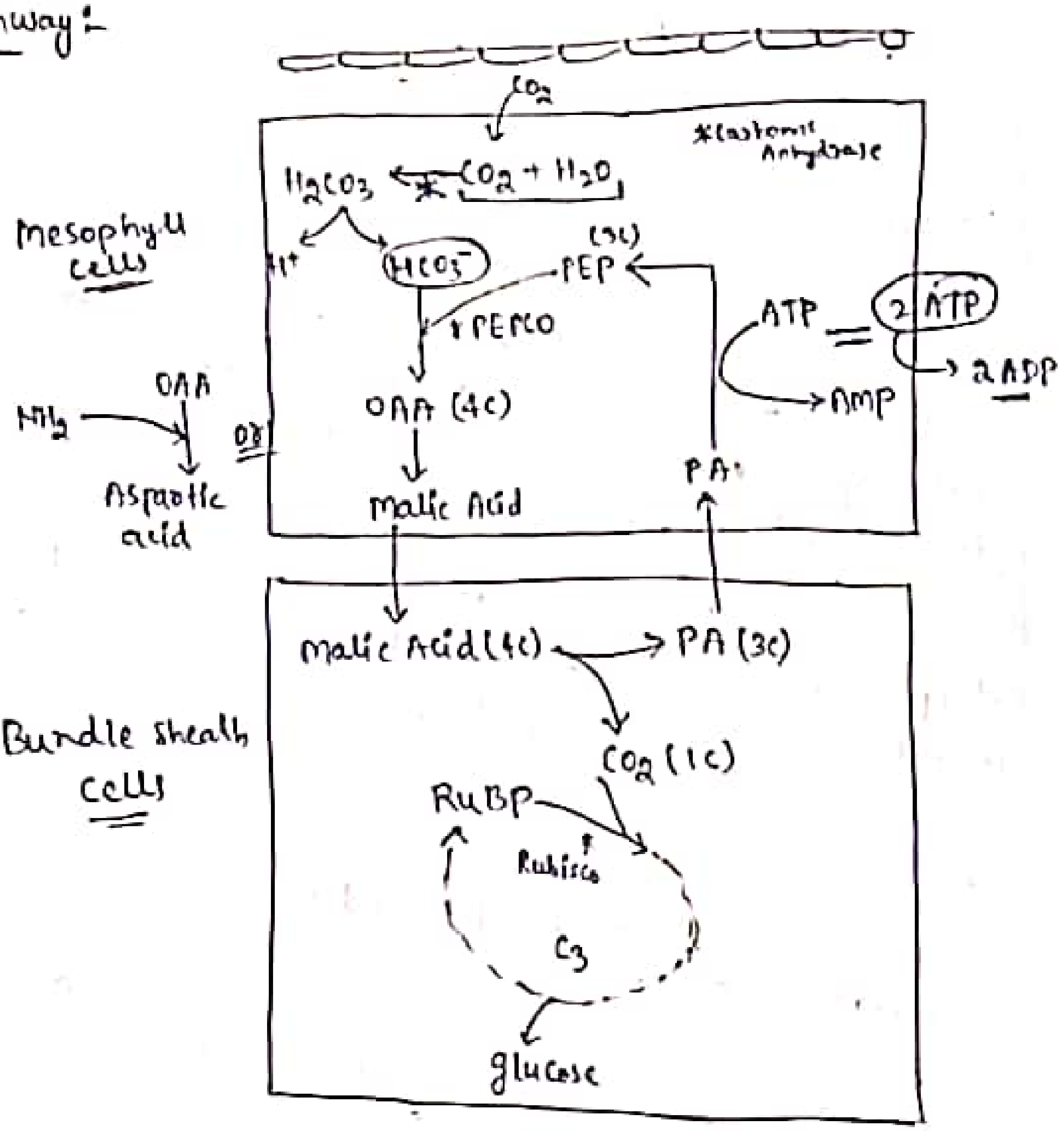
→ It encloses Agranal Chloroplast and provides a barrier to O_2 concn in mesophyll cells and also keeps the agranal chloroplast cooler.



→ Hence, 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 reqd

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 (phosphoglycerate) (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

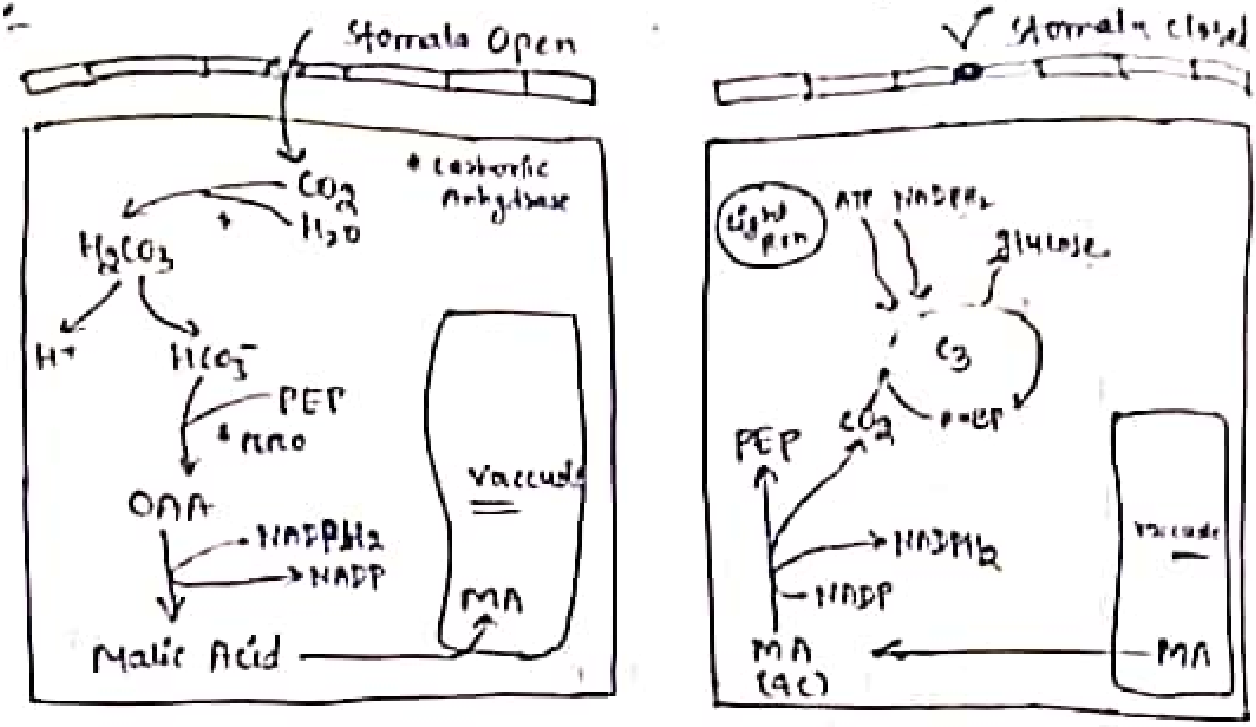
→ Stomata open during night in these plants.

→ 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:-



During night During Day

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 rx^n

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 conc^n, 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.