NEET- 2020- 45 Days Crash Course

Date : 11th August 2020

Chapter Name : Photosynthesis in PLANTS

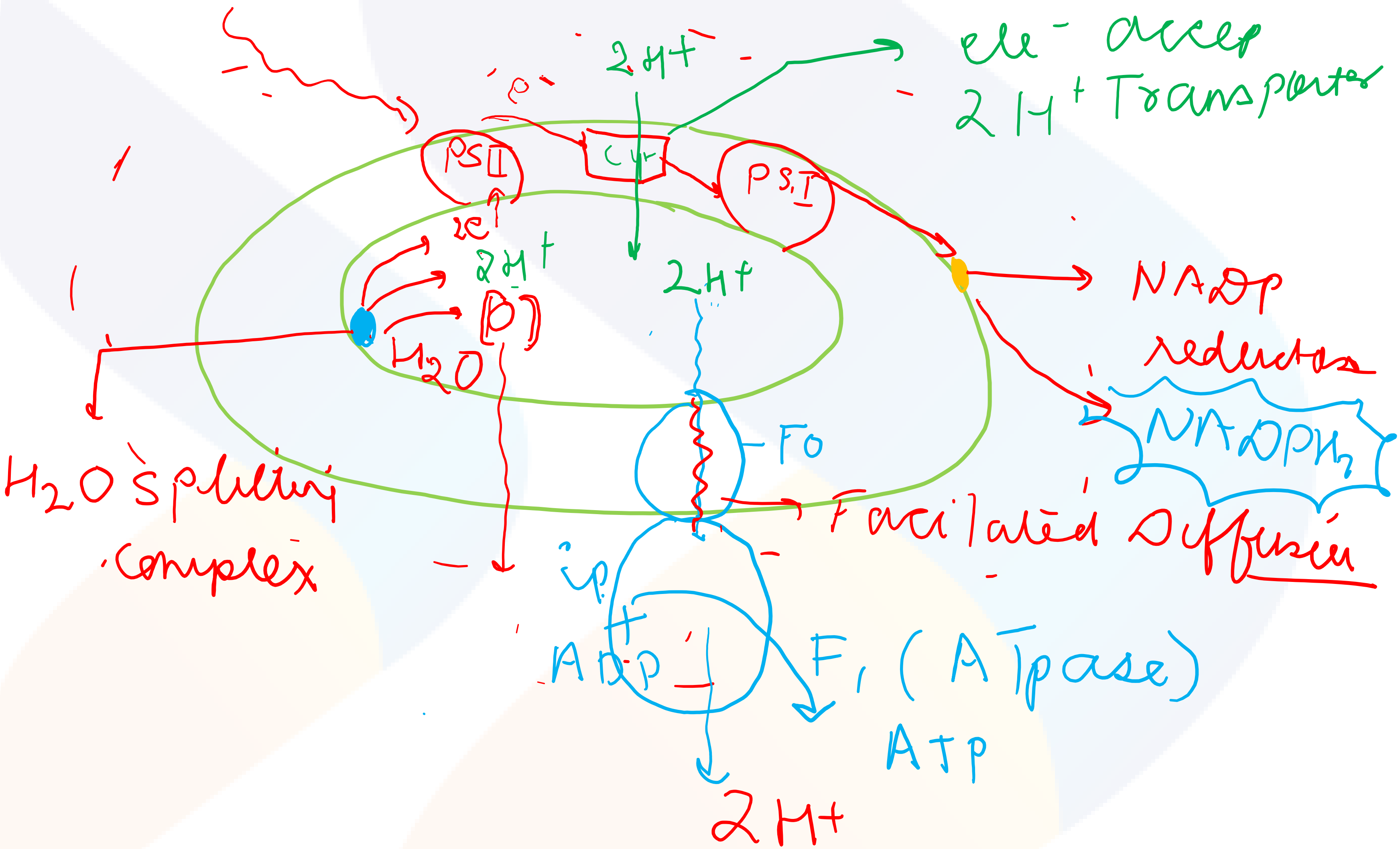
Lecture Outline :
C3 cycle
C4 cycle , CAM cycle , photorespiration
Compensation Point

CHEMIOSMOTIC THEORY- I

Chemiosmotic theory

- Proposed by Peter Mitchell
- During ETC of photosynthesis concentration of H^+ gradually increases in thylakoid lumen.
- During cyclic photphosphrylation PQ leads to shifting of H^+ from stroma to thylakoid lumen.
- On the other hand during non cyclic photophoshorylation there are three causes of difference in H^+ ion concentration.
- This differential H^+ ion concentration leads to development of proton gradient and electrical potential across thylakoid memberane.
- PMF do not allow stay of H^+ ions in lumen so H^+ start to move towards stroma through CF_0 particle selectively.
- The passage of $3H^+$ ions leads to activation of ATP synthase and it forms ATP from ADP and Pi.
- Some physiologist believe that synthesis of one ATP is required passage of $2H^+$ ions.

CHEMIOSMOTIC HYPOTHESIS



DARK REACTION and Warburg effect

(B) Dark Reaction/Blackman Reaction/Calvin cycle/C_3–Cycle/Biochemical phase/ Carbon assimilation/photosynthetic carbon reduction cycle (PCR-Cycle)/Reductive pentose phosphates pathway

- Blackman reaction is called as dark reaction, because no direct light is required for this.
- I[st] stable compound of Calvin cycle is 3C–PGA (Phosphoglyceric acid) thus Calvin cycle is called as C_3–cycle. (First compound is unstable, 6C keto acid)
- Rubisco (Ribulose bis-phosphate carboxylase-oxygenase)
- Is main enzyme in C_3–cycle, which is present in stroma & it makes 16% protein of chloroplast. Rubisco is most abundant enzyme.
- CO_2–acceptor in Calvin cycle is RuBp. This carboxylation reaction is catalysed by rubisco.
- C_3, C_4, C_5, C_6 and C_7 monosaccharides are intermediates of calvin Cycle

Warburg effect

- Inhibitory effect of high conc. of O_2 on photosynthesis is called as Warburg effect (It is due to Photorespiration).
- 6 turns of Calvin cycle are required for the formation of one glucose.

STEPS OF CALVIN CYCLE – I

Carboxylation →

$$6,\ RuBp\ (RuDp) + 6,CO_2\ (HCO_3^{-}) \xrightarrow[\text{(Carboxydismutase)}]{\text{Rubisco}} 6C\ \text{unstable comp.} \longrightarrow 12,3.PGA\ (3C)$$

Glycolytic reversal →

$$12\ \text{Mol.}\ \boxed{3-PGA}\ (3\ C) + 12ATP \xrightarrow{\text{Triokinase}} 12,\ 1,3.BiPGA$$

$$12,\ 1,3.BiPGA \xrightarrow[12NADPH_2\ \rightarrow\ 12NADP^{+}]{\text{Dehydrogenase}} 12,\ 3.PGAL\ (\text{Triose phosphate}) + 12H_3PO_4$$

5 Molecules of PGAL isomerise in to DHAP (Dihydroxy acetone phosphate).

$$3,\ PGAL + 3\ \text{mol. DHAP} \xrightarrow{\text{Aldolase}} 3,\ \text{Fructose-1,6-Biphosphate}$$

9C (3C × 3) (9C) (3C × 3) (18C) (6C × 3)

$$[1\ \text{mol. fructose} \xrightarrow{\text{Isomerase}} \boxed{C_6H_{12}O_6}\ \text{Glucose} \longrightarrow \text{Sucrose/Starch}]$$

STEPS OF CALVIN CYCLE – II

Regeneration of ribulose 1,5 biphosphate

2, fructose.P + 2, PGAL $\xrightarrow{\text{Transketolase}}$ 2 Mol, Erythrose.P + 2 Mol. Xylulose.P
(12C) (6C) (8C) (10C)

2, Erythrose.P + 2, DHAP $\xrightarrow{\text{Aldolase}}$ 2, Sedoheptulose–1,7–BiP
(8C) (6C) (14C)

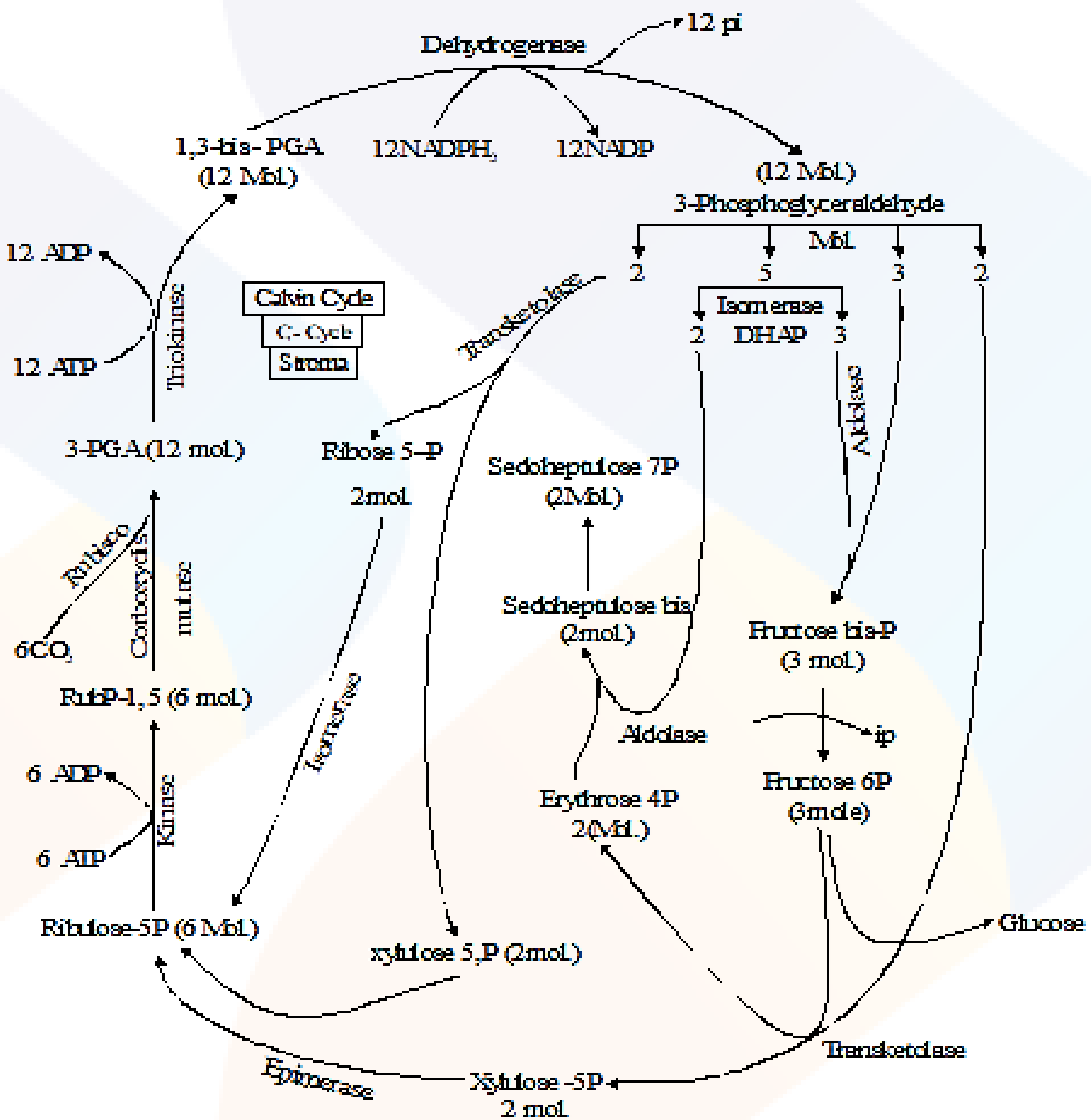
2, Sedoheptulose–P + 2 PGAL $\xrightarrow{\text{Trans Ketolase}}$ 2, Xylulose–P + 2, Ribose–P
(14C) (6C) (10C) (10C)

2 + 2, Xylulose–P $\xrightarrow{\text{Epimerase}}$ 4, Ribulose–5P
(20C)

2 , Ribose–5P $\xrightarrow{\text{Isomers}}$ 2 Ribulose–5P
(10C)

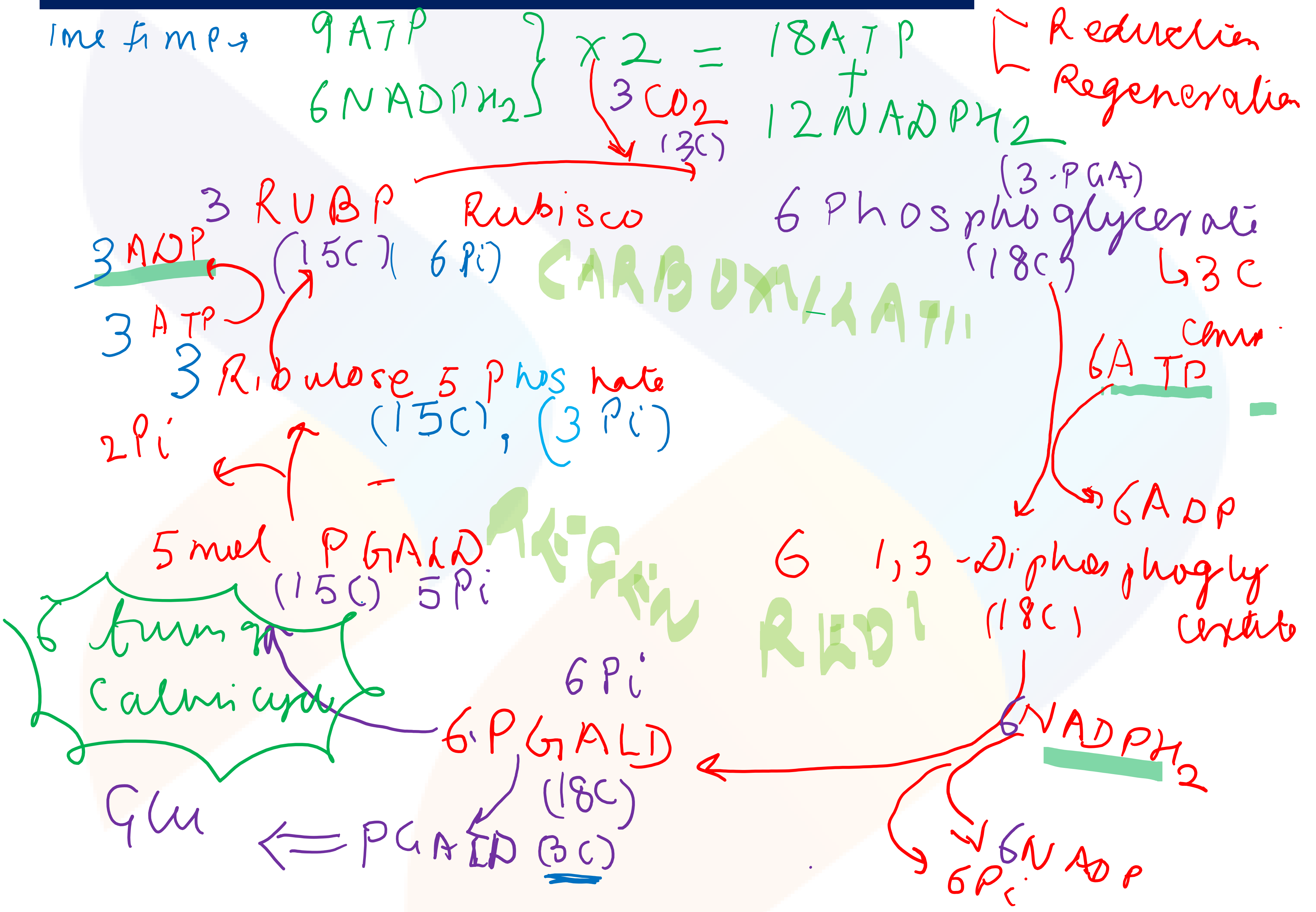
6, Ribulose–5P + 6ATP $\xrightarrow{\text{Kinase}}$ 6, Ribulose-1, 5-BiP (CO2 acceptor) + 6 ADP

STEPS OF CALVIN CYCLE – III



C3 – CYCLE

- Carboxylation
- Reduction
- Regeneration



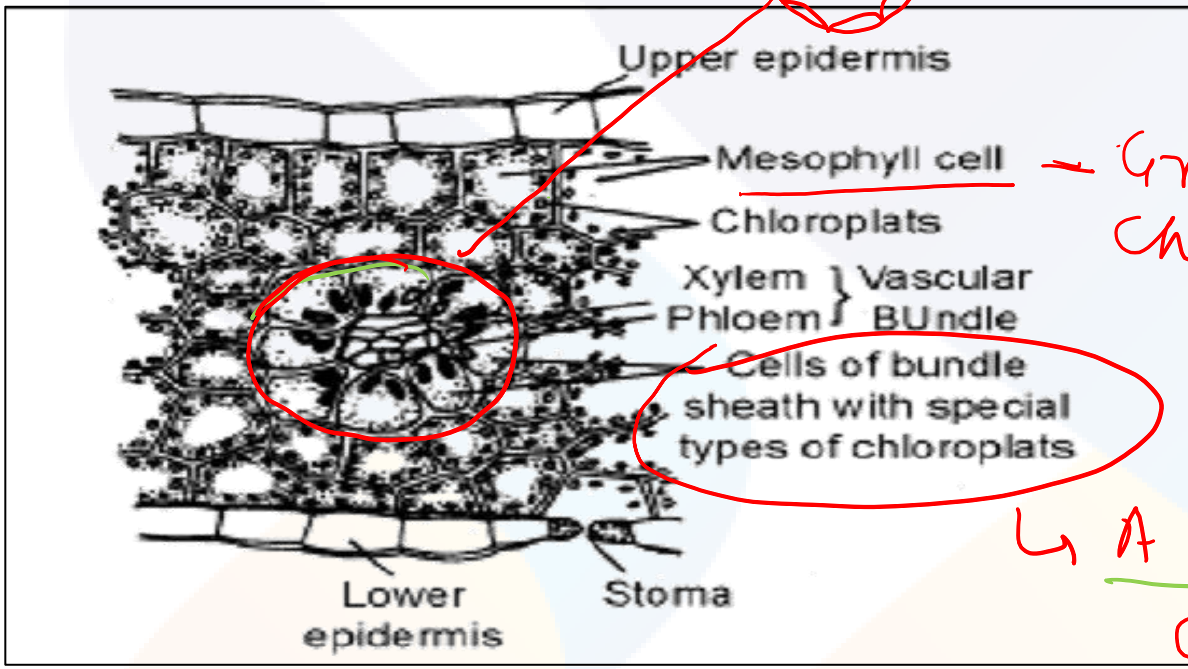
HATCH AND SLACK PATHWAY

CO_2 concentrating mechanism/Co-operative photosynthesis/Dicarboxylic acid cycle (DCA cycle) /C_4 cycle/Hatch & Slack Pathway

- ❖ Kortschak and Hartt first observed that 4C, OAA (Oxaloacetic Acid) is formed during dark reaction in sugarcane leaves
- ❖ Hatch & Slack (Australia) (1967). Studied in detail and proposed pathway for dark reactions in sugarcane & maize leaves
- ❖ First stable product of this reaction is OAA. Which is 4C, DCA (Dicarboxylic Acid)
- ❖ Dicots with C_4–cycle are Euphorbia sps., Amaranthus, Chenopodium, Boerhavia, Atriplex rosea, Portulaca, Tribulus
- ❖ Wheat and barley (monocot) are C3 species. rice sp. devlopes as C_4 plants by plant breeding scientists

KRANZ ANATOMY

Kranz (Wreath) anatomy



(i) Green bundle sheath cells (BS cells) present around the vascular bundles.

(ii) Dimorphic chloroplasts present in leaf cells. Chloroplast of B.S. cells or Kranz cells are larger and without grana. Mesophyll chloroplast are small and with grana.

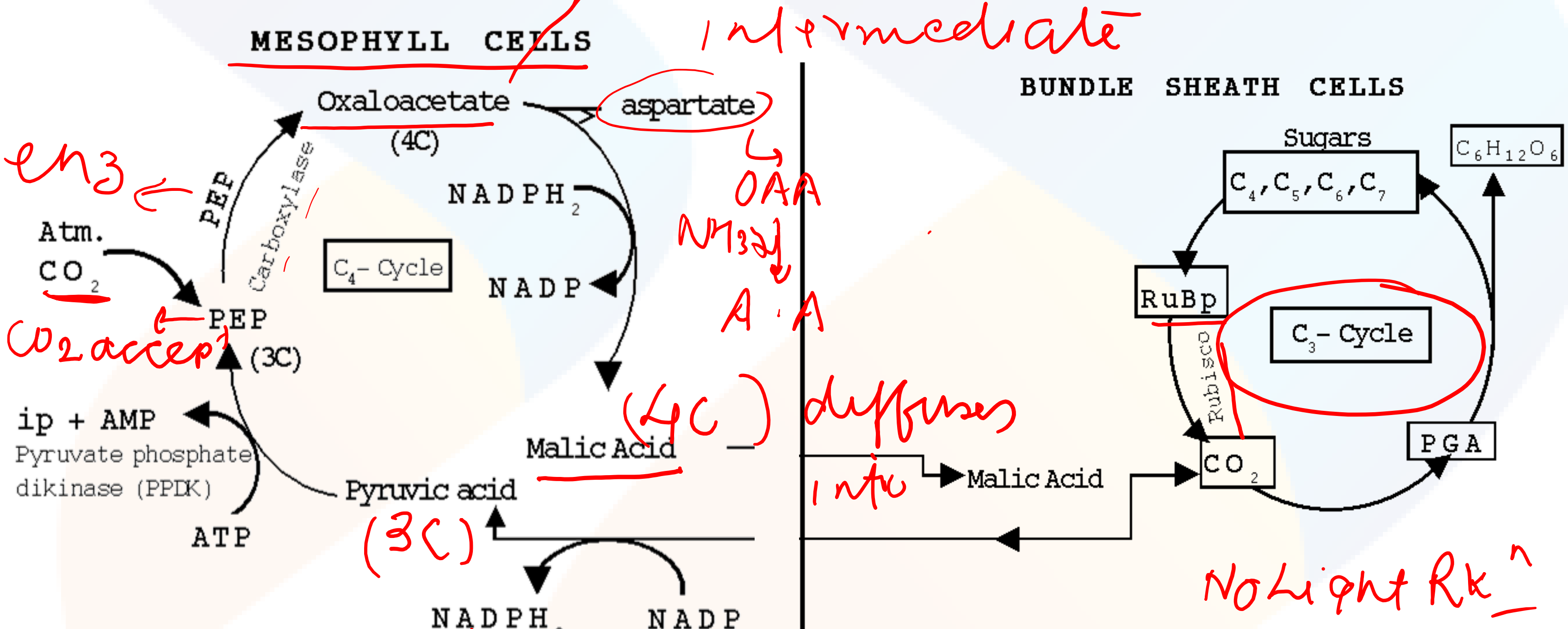
C4 CYCLE - I

- ❖ Rubisco present in BS cells, while PEPCase in mesophyll cells
- ❖ C_4–Plant, C_3–cycle occurs in bundle sheath cells, while C_4–cycle occurs in mesophylls.
- ❖ Operation of Hatch and Slack pathway require cooperation of both photosynthetic cell i.e. mesophyll cells and BS cells.
- ❖ Photosynthetically C_4 plants are more efficient as there is no warburg effect or photorespiration, Because at the site of Rubisco (BS cells) no O_2 is release & (mesophyll cells pumps more CO_2 for C_3 cycle).
- ❖ C_4–plants found in tropical habitats and adapted themselves,
- ❖ If concentration of O_2 increases artificially, then photorespiration may be started in C_4 plants.
- ❖ First carboxylation in C_4–cycle occurs by PEP Case in mesophyll cytoplsam, carboxylation or final CO_2 fixation by C_3 cycle occurs in bundle sheath cells.

C4 CYCLE– II

- Primary CO_2 acceptor in C_4 mesophyll is PEP (Phosphoenol Pyruvate). (3C–compound), while RuBp in bundle sheath cells.

- 12 $NADPH_2$ & 30 ATP needed for production of 1 Hexose (Glucose) in C_4–plants.



. Granal chloroplast.

. Syn. of $NADPH_2$ & ATP, evolutions of O_2

. Absence of Calvin cycle & **Enzyme Rubisco**

. Agranal chloroplast.

. Absence of Z-scheme or PS-II, no evolution of O_2

. $NADPH_2$, from mesophyll chloroplast, C_3 cycle occur

SPECIAL FEATURES of C_4 PLANTS

- C_4 plants are more efficient plants at present CO_2 concentration.
- Present level of atmospheric CO_2 is generally not limiting factor for C_4 plants.
- C_4 plants posses low CO_2 compensation points. (8-10 ppm)
- The productivity (fertility) in C_4 plants, does not increase when CO_2 concentration is increases. because :
- Mesophyll cells pump more CO_2 for Calvin cycle. (due to decarboxy-lation of malic acid)
- Thus concentration of CO_2 is high around the site of Rubisco in C_4 plants, thus little or no chance of photorespiration.

C4 cycle

Character	C_3 plant	C_4 plant
CO_2 accep	RUBP	PEP - MS RUBP - B.S
1st stable comp	PGA	OAA
Type of chloroplast	Granal in M.S	Granal - MS Agran - B.S
Cycle (Fin^n)	only C_3	C_4 - MS C_3 - B.S
Site of C_3 cycle	Mesophyll	Bundle sheath
optimum Temp	10-20°C	30°C
Prod^n of ATP	18 ATP	30 ATP → 18 - C_3, 12 - C_4
Enzymes	Rubisco	Rubisco & Pepco

CAM–PLANTS – I

CAM–Plants / Crassulacean acid metabolism / Dark CO2 fixation / Dark Acidification

- Oleary and Rouhani discovered CAM–process in members of Crassulaceae family. Succulent xerophytie plants

- Eg. are .– Kalanchoe, Bryophyllum, Sedum, Kleinia, Opuntia, Crassula, Agave, Aloe, Euphorbiasps, Pineapple, Welwitschia (Gymnosperm) etc.

- Primary acceptor of CO_2 is PEP (Phosphoenol pyruvate) and oxaloacetic acid is the first product of carboxylation reaction.

4C

Stomata opens in the night

- In CAM plants stomata are of scotoactive type, so initial CO_2 fixation is found in night but light reactions operates at day time. Final CO_2 fixation (C_3 cycle) occurs in day time. PEPcase induces carboxylation reaction in night.

- PEP carboxylase & Rubisco present in mesophyll cells. (No Kranz–anatomy)

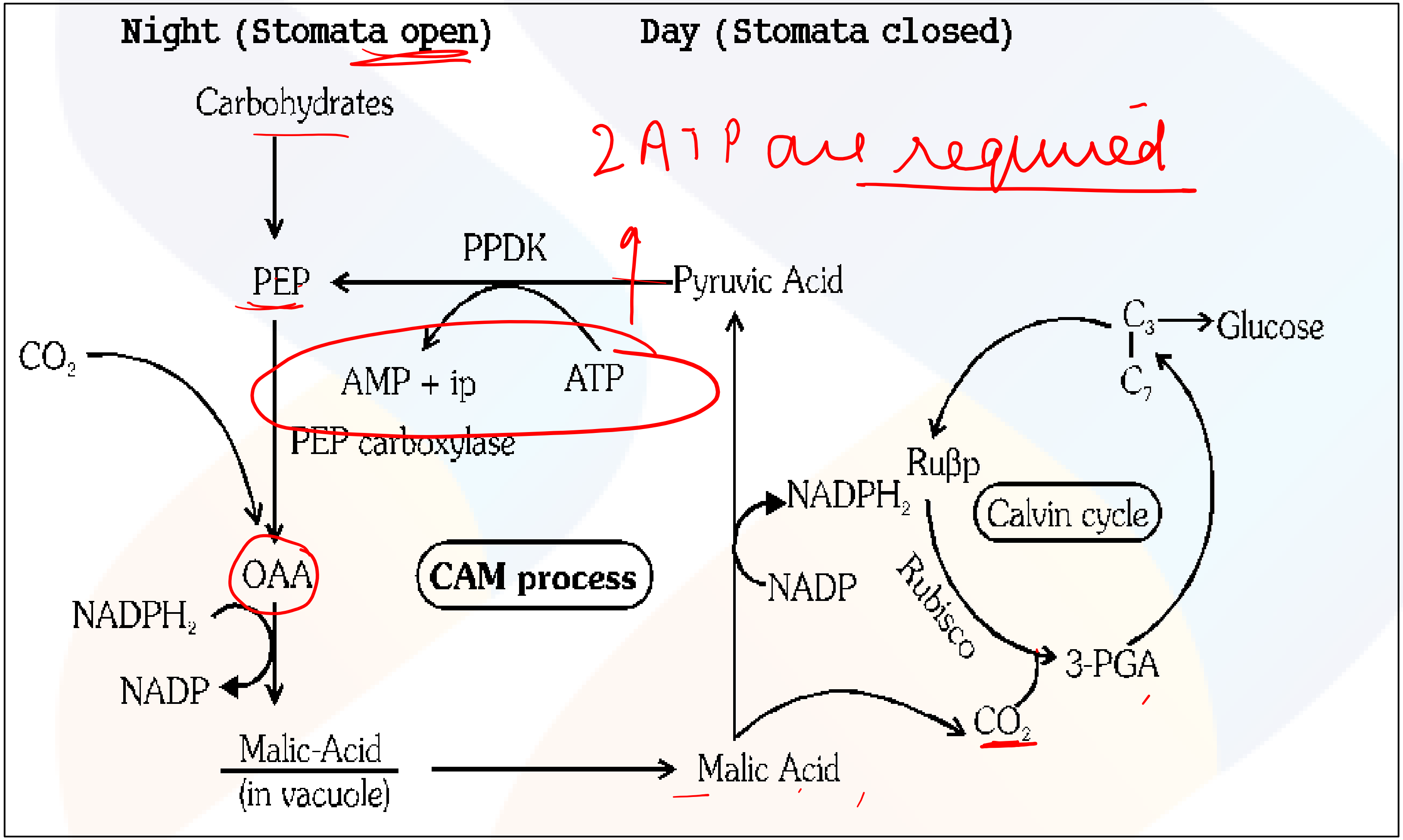
- In CAM plants 30 ATP and 12 $NADPH_2$ are required as assimilatory power for 1 glucose synthesis.

C_4 - 12ATP, C_3 = 18ATP

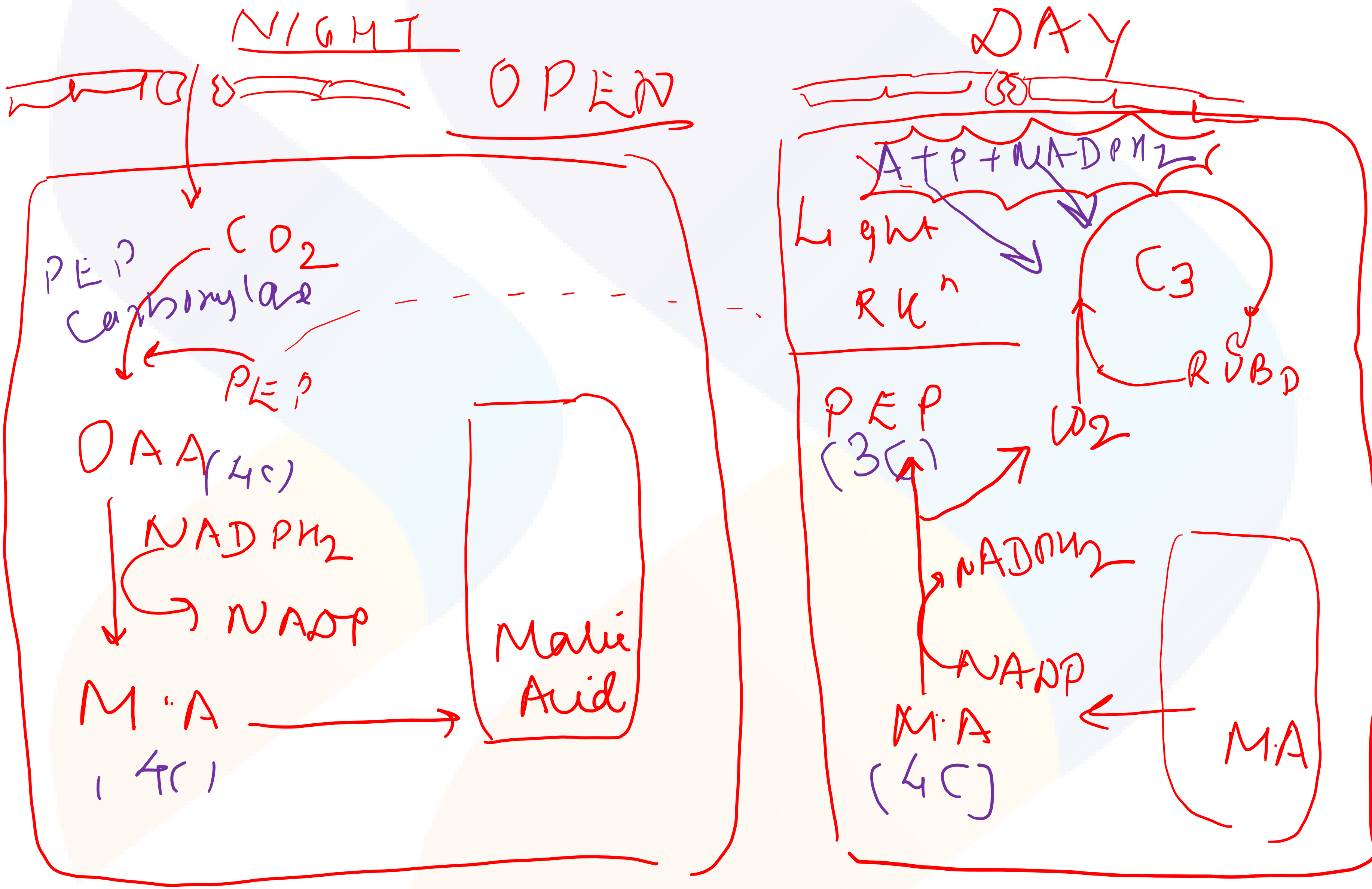
CAM–Plants – II

Succulent xerophytes

❖ CAM plants exhibits ecophysiological adaptation with xeric habits.



CAM PATHWAY



NIGHT
OPEN
CO2
PEP carboxylase
PEP
OAA (4C)
NADPH2
NADP
M·A (4C)
Malic Acid
DAY
ATP + NADPH2
Light Rxn
C3
RuBP
CO2
PEP (3C)
NADPH2
NADP
M·A (4C)
M·A

PHOTORESPIRATION– I

Photosynthetic carbon oxidation cycle/C_2 Cycle/Photorespiration/Glycolate–Metabolism

- Term was given by 'Krotkov'

- First of all Krotkov et. al indicated that more CO_2 evolves during day time in C_3 plants.

- Decker & Tio discovered photorespiration and clarified that C_2–cycle or glycolate pathway operates during day time in C_3–plants & Rubisco acts as oxygenase at higher concentration of O_2 and low CO_2 concentration in the C_3 – green cells.

- The light dependent uptake of O_2 & release of CO_2 in C_3 photosynthetic cell is called photo–respiration.

- Photorespiration is not linked with ATP generation (in place ATP are consumed) as ordinary dark respiration, thus it is harmful or wasteful process linked with C_3 cycle

- It occurs in chloroplast, peroxisomes & mitochondria (three cell organalle reaction).

PHOTORESPIRATION– II

$$RuBP + CO_2 \xrightarrow{\text{Rubisco}} 2PGA$$

$$RuBP + O_2 \xrightarrow[\text{Low } CO_2,\ \text{High } O_2\ \text{con}^n,\ \text{High temp.}]{\text{RuBP – Oxygenase}} \underset{(3C)}{1\ PGA} + \underset{(2C)}{1\ Phosphoglycolate.}$$

- During photorespiration, 75 percent of the carbon lost by the oxygenation of RUBP is recovered. Because two molecules of glycine (2C + 2C = 4C) form one molecule of serine (3C). during this one carbon releases in form of CO_2 in mitochondria thus 25 percent carbon is lost.

- This serine molecule changes into PGA via different reactions of C_2 cycle.

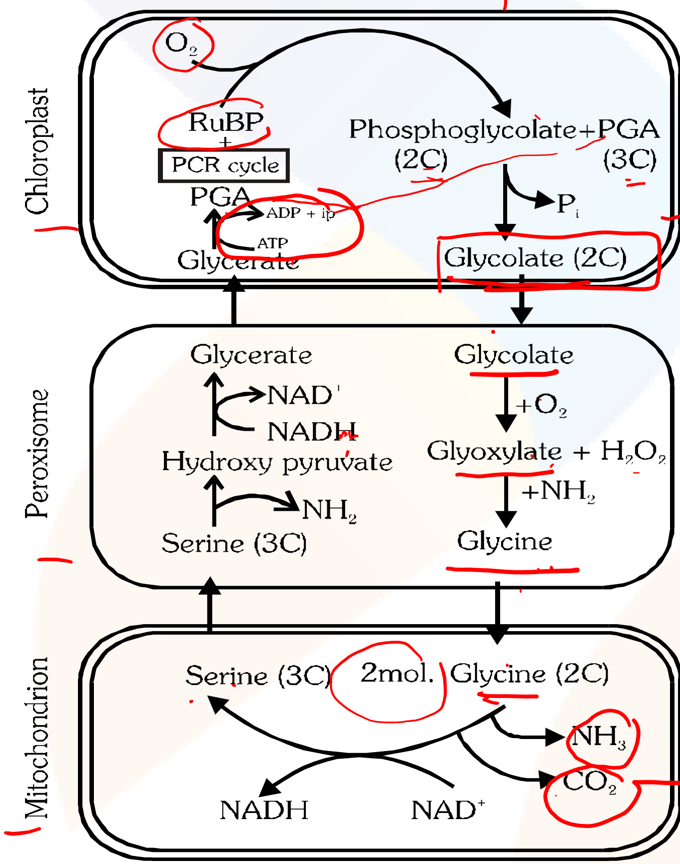
- H_2O_2 (Peroxisome) and NH_3 (Mitochondria) produced in photorespiration.

- Glycine (Peroxisome) and serine (mitochondria) are also formed in photorespiration.

PHOTORESPIRATION – III

- It is assumed that in C_3 plants, if photorespiration does not occur, then increases O_2 conc. which may oxidise (Photooxidation or Solarization) the different protoplasmic parts of photosynthetic cell at high light intensity.

RuBP oxygenase



Photorespiration/ photosynthetic carbon oxidation cycle.

C_2 cycle as glycolate is the 1st stable intermediate

1 mol glycine : 2C
2 mol " = 4C – CO_2
3 C → Serine

CO_2 evolved

FACTORS AFFECTING PHOTOSYNTHESIS – Light

1. Light

(a) Light Quality or wavelength

- photosynthesis takes place in red light than in Blue light. But rate of photosynthesis is highest in white light. Minimum in green light.

(b) Light Intensity

- Rate of photosynthesis is greater in intense light than diffused light. But at higher light intensity photooxidation (solarization) occurs and photosynthetic apparatus may get destroyed.

(c) Duration of Light

- On the basis of effect of light on plants may be LDP & SDP.

❖ Product of photosynthesis is greater in intermittent light than continuous light – **Warburg**

FACTORS AFFECTING PHOTOSYNTHESIS –Temperature and CO_2

2. Temperature

- Optimum temp. for photosynthesis is 20–35°C

↑ Temp ↓ P.S

- At high temp. rate of photosynthesis decreases due to denaturation of enzymes.

- Conifers & lichens can perform photosynthesis at –35°C, while thermal algae Oscillatoria at 70–80°C.

- Generally different habitat plants show, different response to photosynthesis.

at very ↑ Temp, Stomata close & Rate of P.S ↓

3. CO_2 (0.03%/314 ppm)

- An increase in CO_2 concn. upto 1% rate of photosynthesis is increased. Higher CO_2 concentration. is toxic to plant & also closes stomata

slight ↑ CO_2 — Raising P.S ↑

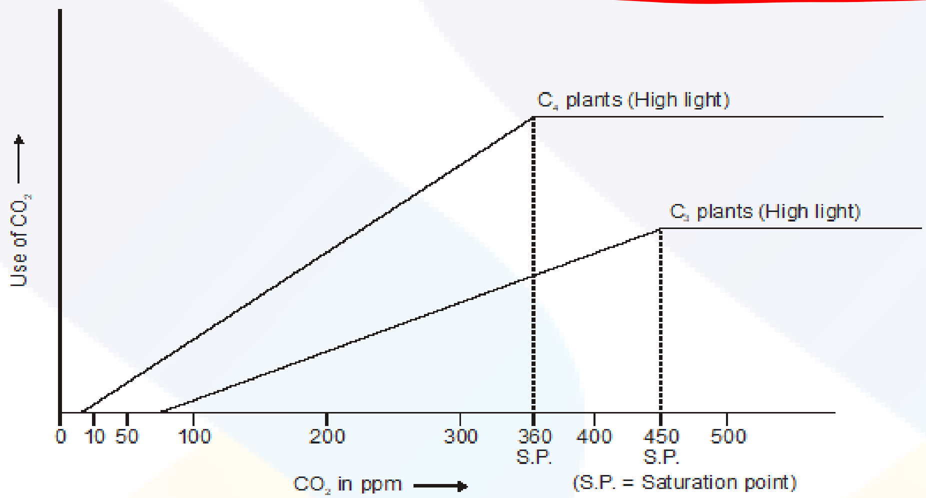
CO_2 fertilization effect

- C_4–Plants can photosynthesize at low CO_2 concn (upto 10 ppm). "CO_2 fixation in photosynthesis is equal to volume of CO_2 released. "CO_2 compensation point", when plant saturated with full light. → ***QNEET*

FACTORS AFFECTING PHOTOSYNTHESIS –CO_2 O_2 and Water

❖ CO2 compensation point for C4 plants is 8-10 ppm

** QNEET



4. O_2

❖ High O_2 concn. reduces photosynthesis due to photorespiration.

Warburg's effect

5. Water

❖ Less availability of water reduces the rate of photosynthesis (stomata get closed)

Factors Affecting Photosynthesis –Chlorophyll, Product, Leaf and Inhibitors

6. Chlorophyll

- The amount of CO_2 in grams absorbed by 1 gm. of chlorophyll in 1 hour is called as photosynthetic number or assimilatory number (Willstatter & Stoll).

7. Product

- Rate of photosynthesis decreases, when sugar accumulates in mesophyll cells.

8. Leaf

- Various leaf factors like leaf age and leaf orientation effect the rate of photosynthesis. In young & mature leaves photosynthesis is more than old (senescent) leaves.

9. Inhibitors

- DCMU (Diuron/Dichlorophenyl Dimethyl Urea)CMU (Monuron), PAN,Atrazine, Simazime, Bromocil, Isocil– inhibit the photosynthesis by blocking PS–II. They stop e– flow between P-680 & PQ.

Factors Affecting Photosynthesis- Minerals, Law of limiting factors

10. Minerals

- Mg and Nitrogen are essential for structure of chlorophyll and enzymes. Thus reduction in N_2 and Mg supply to plants effects adversely the rate of photosynthesis.

Law of limiting factors – (Blackman)

- It is the modification of Law of minimum by Liebig. "When a process is conditioned to its rapidity by a number of factors, then rate of process is limited by the pace of the slowest factor" (CO_2, light, chlorophyll, water, temp.)

- CO_2 becoming limiting in clear sky, but light limiting in cloudy days.

- Atmospheric CO_2 is not limiting factor for C_4 plants & submerged hydrophytes.

BACTERIAL PHOTOSYNTHESIS – I

- Certain bacteria are capable for photosynthesis Eg :- Chlorobium (Green Sulphur), Chromatium (Purple Sulphur), Rhodospirillum, Rhodopseudomonas (Purple non sulphur).
- Cyclic photophosphorylation is an important method in bacterial photosynthesis.
- Absorption of Infra red spectrum takes place during bacterial photosynthesis thus no red drop.
- Pigment system of bacteria denoted by – B–890 or 870
- Evolution of O_2 is not related to bacterial photosynthesis, because water is not e– donor and PS II is absent.
- Only one ATP is produced in each turn of cyclic photophosphorylation, in bacteria.
- Olson 1970 gave a non cyclic scheme in bacterial photosynthesis.

$$6CO_2 + 12\ H_2S \xrightarrow[\text{Pigments in chromotophores}]{\text{IR light}} C_6H_{12}O_6 + 6H_2O + 12S.$$

- Bacteria has only one pigment system, PS I.

Difference Between Photorespiration And Respiration

Photorespiration	Dark respiration
1. Occurs in the chloroplast, peroxisome and mitochondria.	1. Occurs in cytoplasm, mitochondria.
2. Wasteful process.	2. Useful process.
3. NH_3 & CO_2, H_2O_2 are produced	3. CO_2, H_2O & ATP generated.
4. In green cells of C_3. Plants.	4. In all living cells.
5. Occurs during day time only.	5. All time.

Photophosphorylation – Comparison

Cyclic photophosphorylation	Non – cyclic photosphorylation
1. Only PS.I involved in cyclic process.	1. Both PS.II & PS.I works in non. Cyclic process.
2. The $e^{|}$ expelled from chl. 700 is cycled back.	2. The $e^{|}$ expelled from reaction center is not cycled back. Its loss is compensated by $e^{|}$ from H_2O.
3. Phosphorylation of two place.	3. Phosphorylation at one site.
4. Photolysis of water and evolution of O_2 does not take place.	4. Photolysis of water and evolution of O_2 takes place.
5. $NADP^+$ is not reduced.	5. $NADP^+$ is reduced to NADPH.
6. Activated by 680 NM↑ light.	6. Activated by 680 NM↓

C_3, C_4 & CAM Pathway Comparision -I

C_3. Pathway	C_4. Pathway	CAM – pathway
1. I[st] stable compound is 3.C PGA	1. I[st] stable compound is 4C O.A.A.	1. First formed compound is O.A.A.
2. 18 ATP & 12 $NADPH_2$ used for 1 glucose formation	2. 30 ATP & 12 $NADPH_2$ used for 1 glucose formation	2. 30 ATP and 12 $NADPH_2$ used for Production of 1 glucose
3. Kranz anatomy absent	3. Kranz anatomy present	3. Kranz anatomy absent
4. Presence of photorespiration	4. Absence of photorespiration	4. Photorespiration may present
5. One type of carboxylase enzyme, Rubisco only	Two type of carboxylase enzyme Rubisco & PEP case	5. Two types of carboxylase enzyme Rubisco & PEP case
6. CO_2 acceptor – RUBP	6. Primary CO_2 acceptor – PEP & RUBP is secondary acceptor Low CO_2 compensation point (8 – 10 PPM)	6. High CO_2 compensation point (40. 100 PPM)
7. Exhibits high CO_2 compensation point (40.100 PPM)		7. High CO_2 compensation point (40. 100 PPM)
8. Transpiration ratio (TR) 500 – 1000	8. TR – 200 – 300	8. TR – 50 – 100