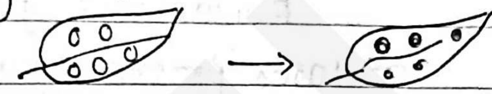
* Photosynthesis in Higher plants *

* Photosynthesis - Synthesis of organic matter in presence of sunlight.

Experiments

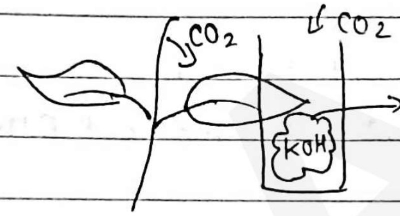
- Starch forms in leaves
- We need CO_2 to form starch.

① variegated leaf



+ Iodine turns into blue

②



→ Cotton takes all the CO_2

* Early Experiments

Joseph Priestley - (1770) Plant restore air whatever breathing animals and burning candle removes

Jan Ingenhousz (1730-1799) - Showed that in bright sunlight small bubbles are formed around green parts of plant while in dark they did not
- Later he identified these bubbles to be be oxygen.

Julius Von Sachs (1854) - Glucose is produced when plants grow and it is stored as starch

T.W. Engelmann (1843-1909)

→ anaerobic bacteria need O_2. (Bacteria mainly accumulate in the region of Blue & Red light)

Split the light using prism

Cladophora (Green algae)

Cornelius Van Niel (1817-1985) ⟶ concluded that O_2 is provided by H_2O & not by CO_2

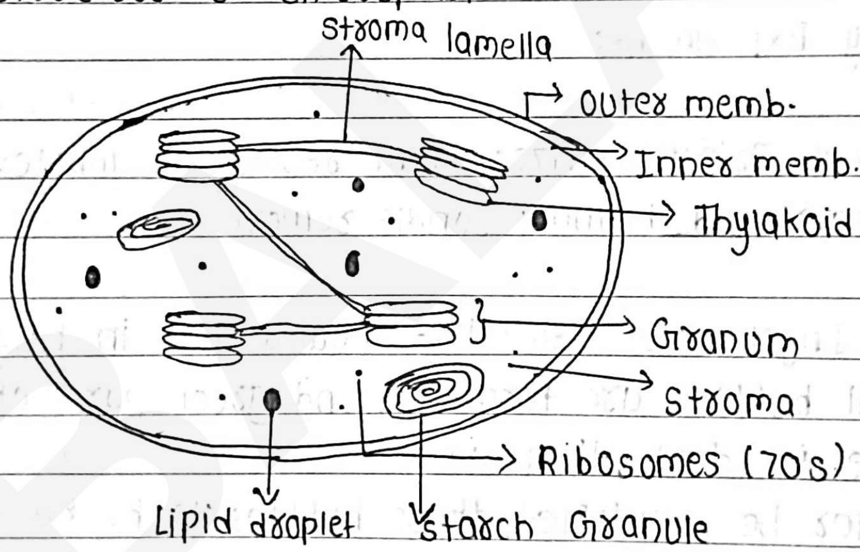
He was working on purple & Green bacteria.
↓
Uses H_2S instead of H_2O
Releases S gas

→ Later proved by using radio-isotopic techniques that O_2 is provided by H_2O

Reaction of Photosynthesis

$6\,CO_2 + 12\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,H_2O + 6\,CO_2$

* Structure of Chloroplast



* Light Reaction
Dependent on sunlight
↓ Forms
Chemical Energy
(ATP, NADPH) ⟶ uses dark rxn

Dark Reaction
Dependent on the product of light Reaction.
↓
Sugar

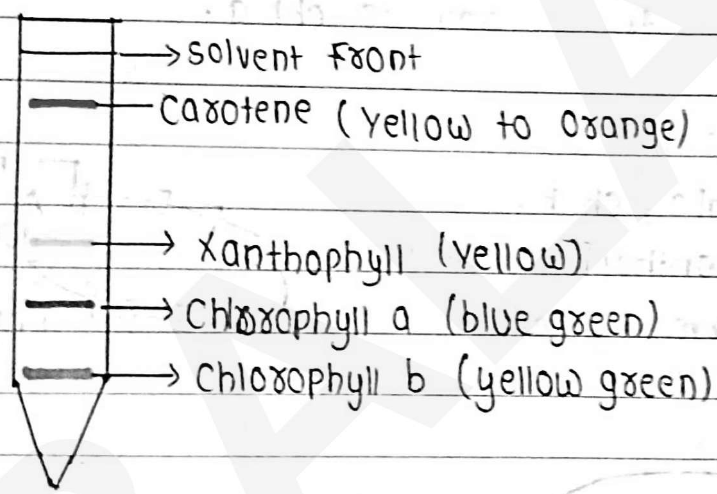
* How many Types of Pigments involved in Photosynthesis

Pigments - molecules that abosorbs light of specific wavelength
- In higher plants Pigments are of two types

Chlorophylls
- a
- b

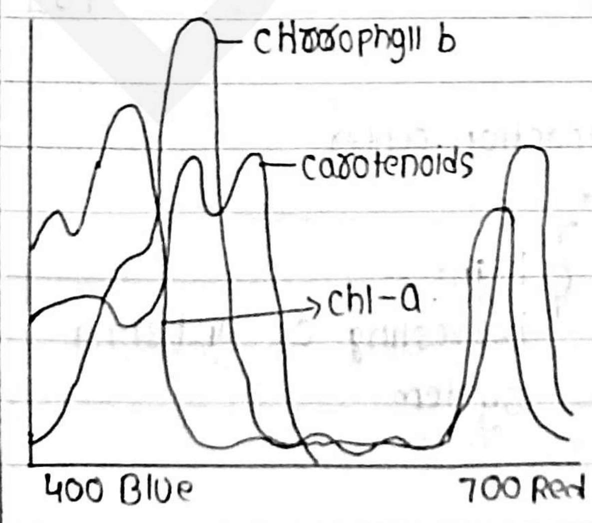
Carotenoids
- 2 types Carotenes & xanthophylls.

Paper Chromatography - Pigments are separated using this.

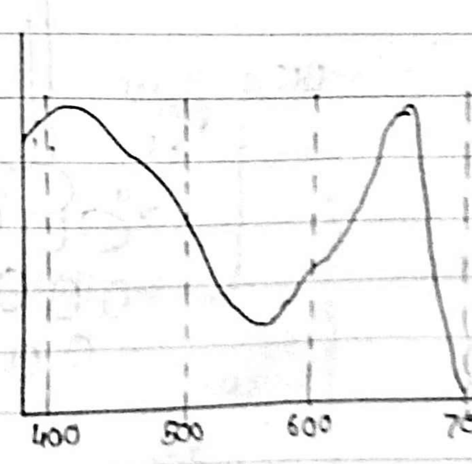


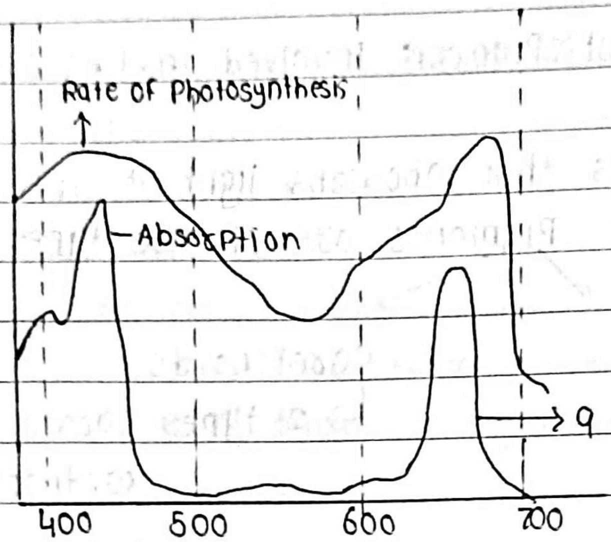
Chl a is the most abundant Pigment

Absorption Spectrum



Action Spectrum

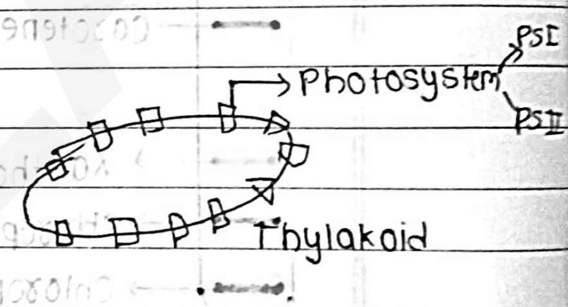


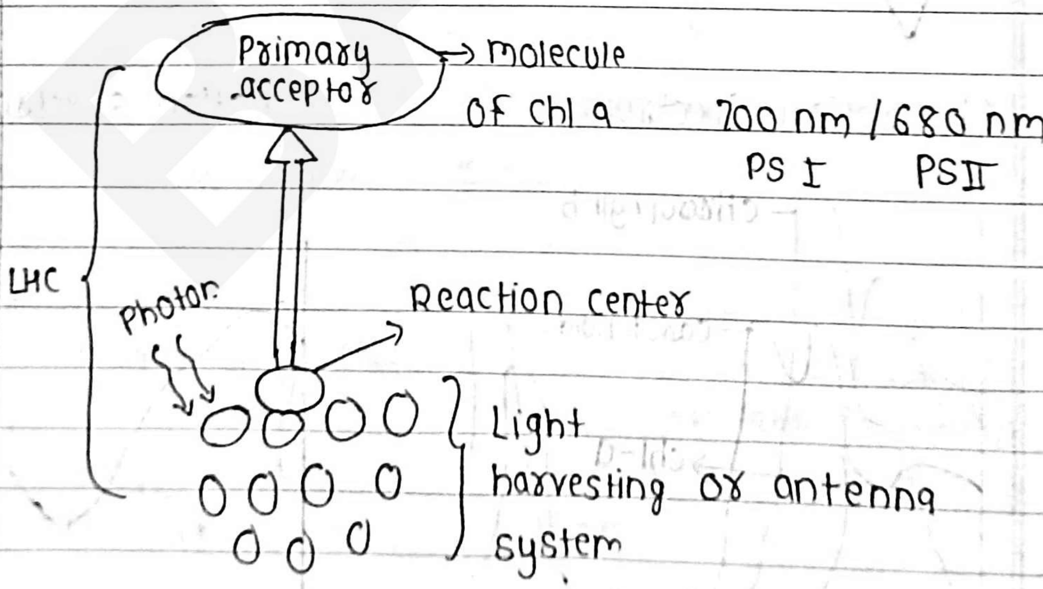


These graphs together shows that most of the photosynthesis takes place in the blue & Red Regions of the spectrum

Though chlorophyll is the major pigment responsible for trapping light other thaylakoid pigments like Chl b, xantophyll, carotenoid which are called ascessory pigments also absorb light and transfer the energy to chl a.

* Light harvesting Complex.
we have Chl a, Chl b, carotenoid, xanthophyll in Light harvesting complex

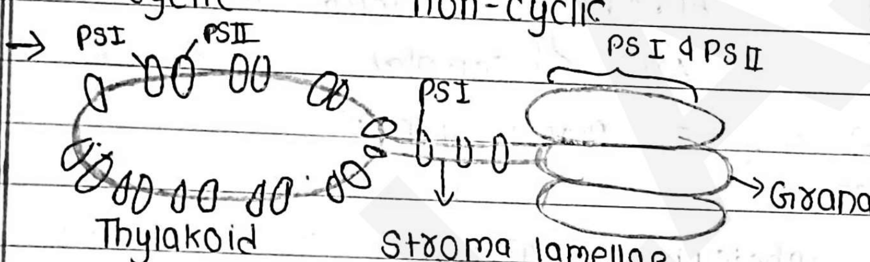




- The LHC are made up of hundreds of pigment molecules bound to proteins. Each photosystem has all the pigments (except one molecule of chl a) forming a LHC or antennae.
- The single chl a molecule forms the reaction centre.

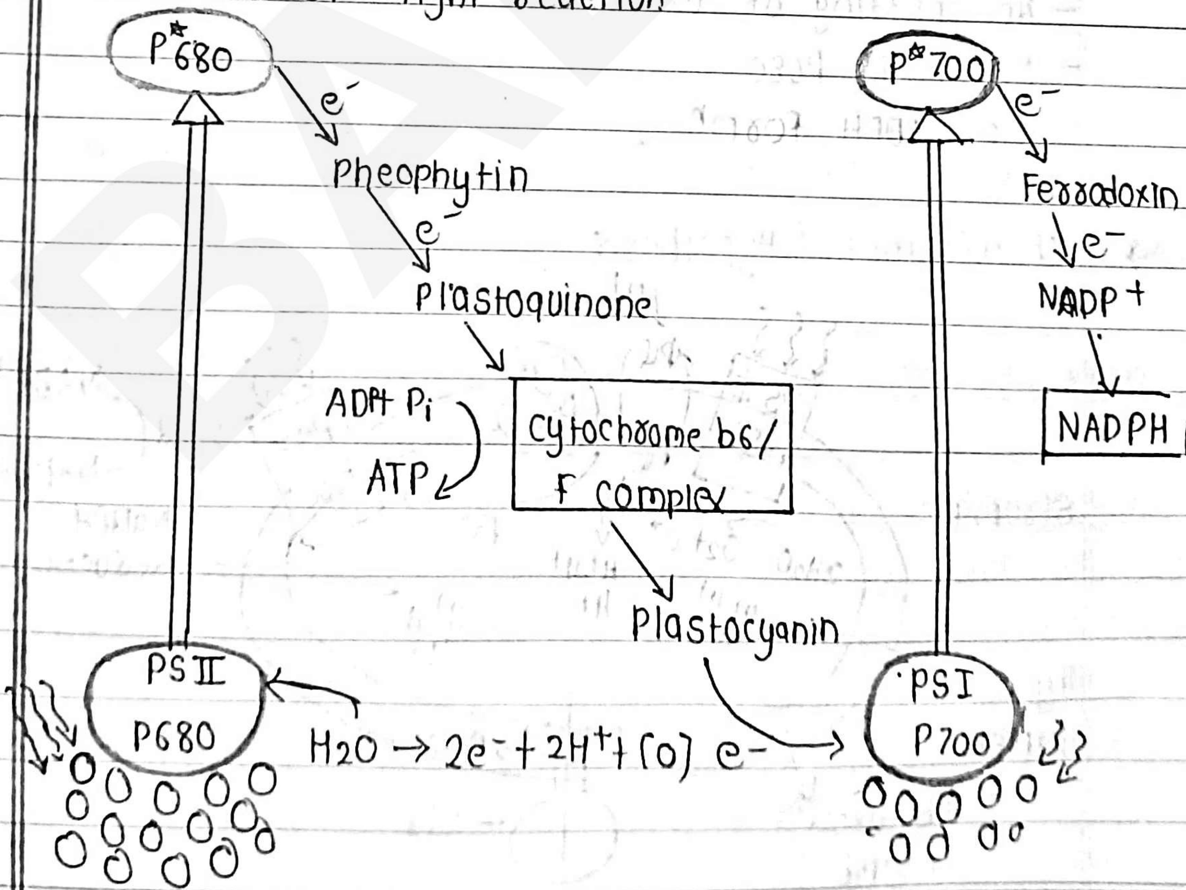
* Phosphorylation - Synthesis of ATP
- occurs in chloroplast and mitochondria.
- ~~Syn~~ If the ATP is produced in presence of sunlight called photophosphorylation.

cyclic | non-cyclic



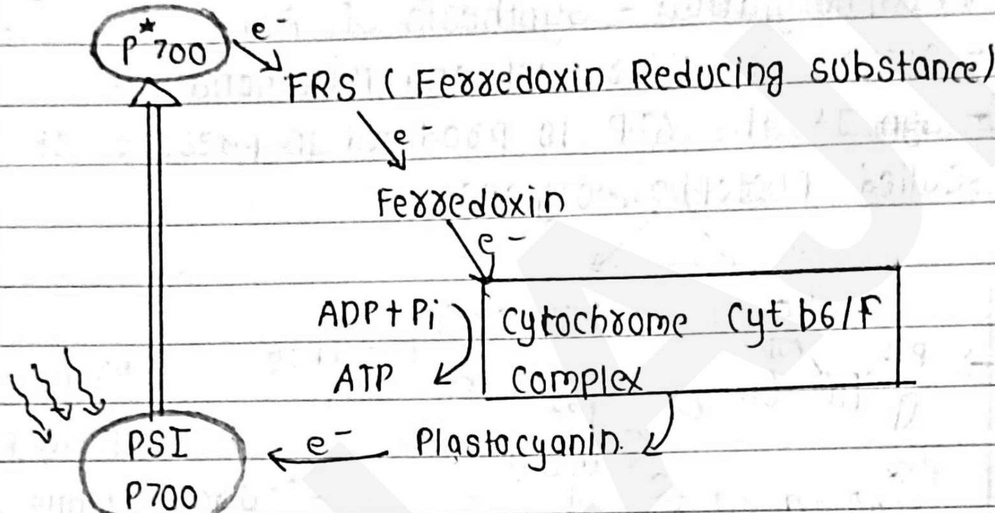
Thylakoid contain both PS I & PS II while Stroma lamella contain only PS I

* Z- Scheme of light reaction



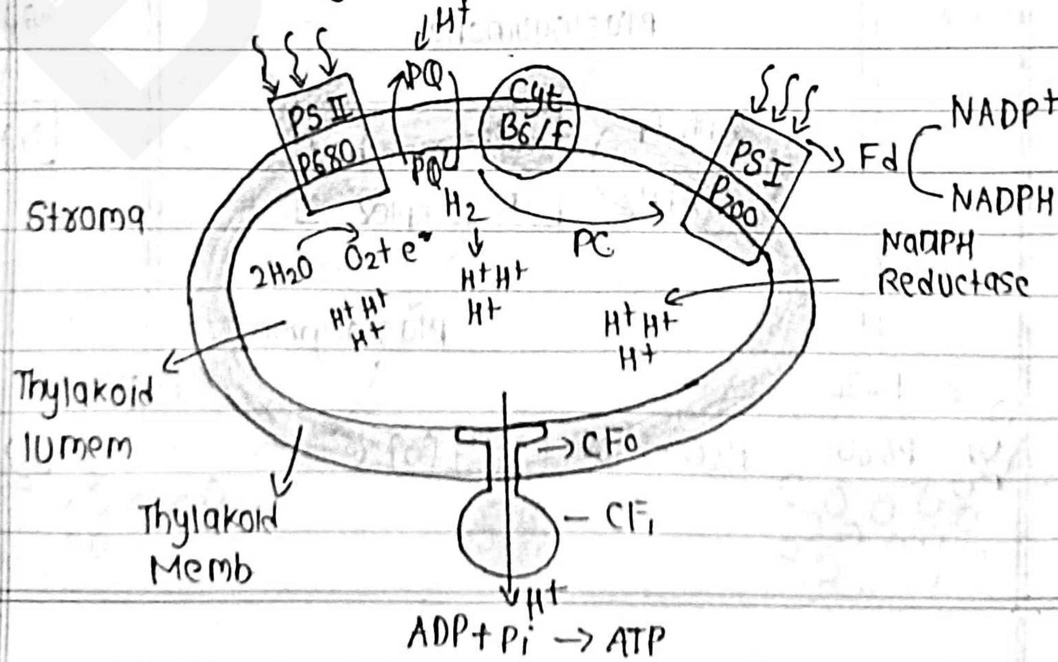
Cytochrome is a protein, it contain Fe (Iron)
Plastocyanin " " " Cu (copper)
Ferredoxin " " " (Fe & S)

* Cyclic Photophosphorylation



In cyclic photophosphorylation
- No splitting of water
- No PS II P680
- No NADPH form^r

* Chemiosmotic Hypothesis



Cause of Proton Gradient

→ Splitting of water cause accumulation of H^+ within the lumen of thylakoid.

→ Electron movement through ETS

ETS - Plastoquinone (PQ), Cyt B6F, Plastocyanic (Pc)

→ NADPH + H^+ form^n cause removal of protons from the stroma

⇓ cause Gradient of H^+

Proton decrease in stroma of Chloroplast &
proton increase in lumen of Thylakoid.

⇓

Breakdown of this Gradient cause formation of ATP (through ATP Synthase)

$\boxed{\text{ATP Synthase}}$ —
- CF_0 = in membrane of Thylakoid.
- CF_1 = outer surface of Thylakoid membrane facing stroma.

Cyclic Photophosphorylation	Non-Cyclic Photophosphorylation.
→ Only PS-I involved	→ Both PSI + PSII involved
→ Reaction centre - P700	→ Reaction centre is P680.
→ e⁻ released are cycled	→ e⁻ released not recycled.
→ Photolysis of water [X]	→ Photolysis of water [✓]
→ Only ATP synthesised	→ ATP + $NADPH_2$ formed
→ O_2 not Produced	→ O_2 produced
→ In Stromal Thylakoid	→ In Granal Thylakoid

* Dark Reaction
- Dark Reaction is also known as biosynthetic Phase
- Glucose forms in this Reaction.
- Melvin Calvin
  ↳ used Chlorella (Alga)
- 1st stable product is 3 Phosphoglyceric Acid (PGA) →(3C)

3-PGA (3C)	Oxaloacetic Acid (4C)
1st stable Product	1st stable Product
C_3 Plants	C_4 Plants

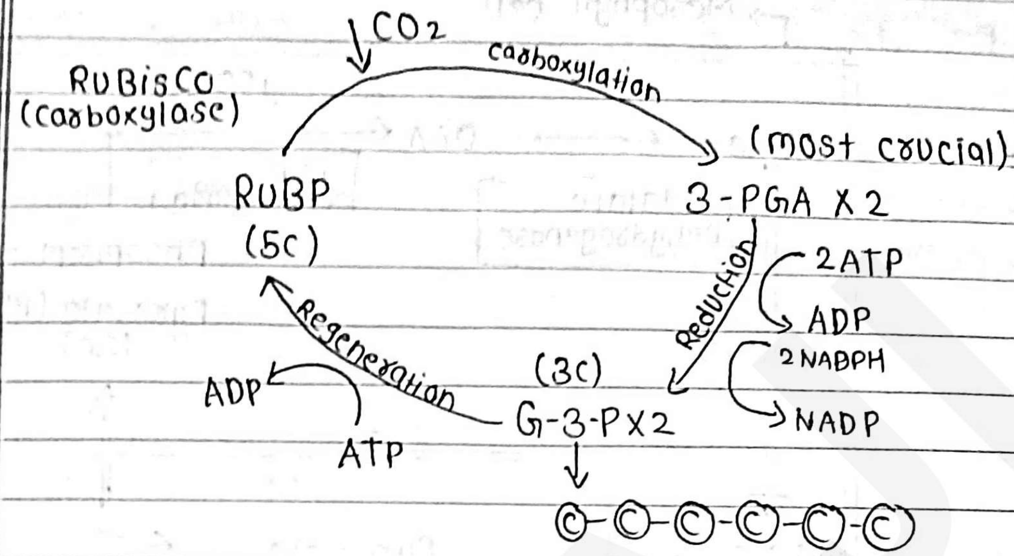
* The Primary Acceptor of CO_2

$$\underbrace{\underset{(5C)}{RUBP} + \underset{(1C)}{CO_2}}_{6C} \longrightarrow \underbrace{2 \times 3PGA\ (3C)}_{6C}$$

RUBP - Ribulose 1,5 - Bis phosphate

* The Calvin Cycle.

- It occurs in all photosynthetic Plants (C_3 or C_4) Pathways.
- It has 3 stages
1) Carboxylation
2) Reduction
3) Regeneration



→ G-3-P - Glyceraldehyde - 3 - Phosphate

→ 1 cycle uses = 3 ATP × 6 = 18 ATP

1 cycle uses = 2 NADPH 12 NADPH

* The C_4 Pathway. (Hatch and Slack Pathway)

C_4 Plants are special because

→ They Have a special type Of Leaf Anatomy (kranz)

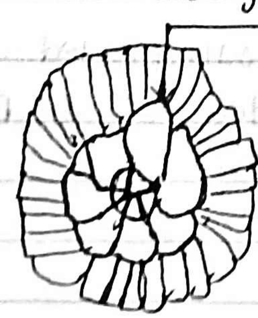
→ They tolerate higher temperature.

→ They Show a response to high light intensities.

→ They lack Photorespiration

→ They have greater productivity of biomass

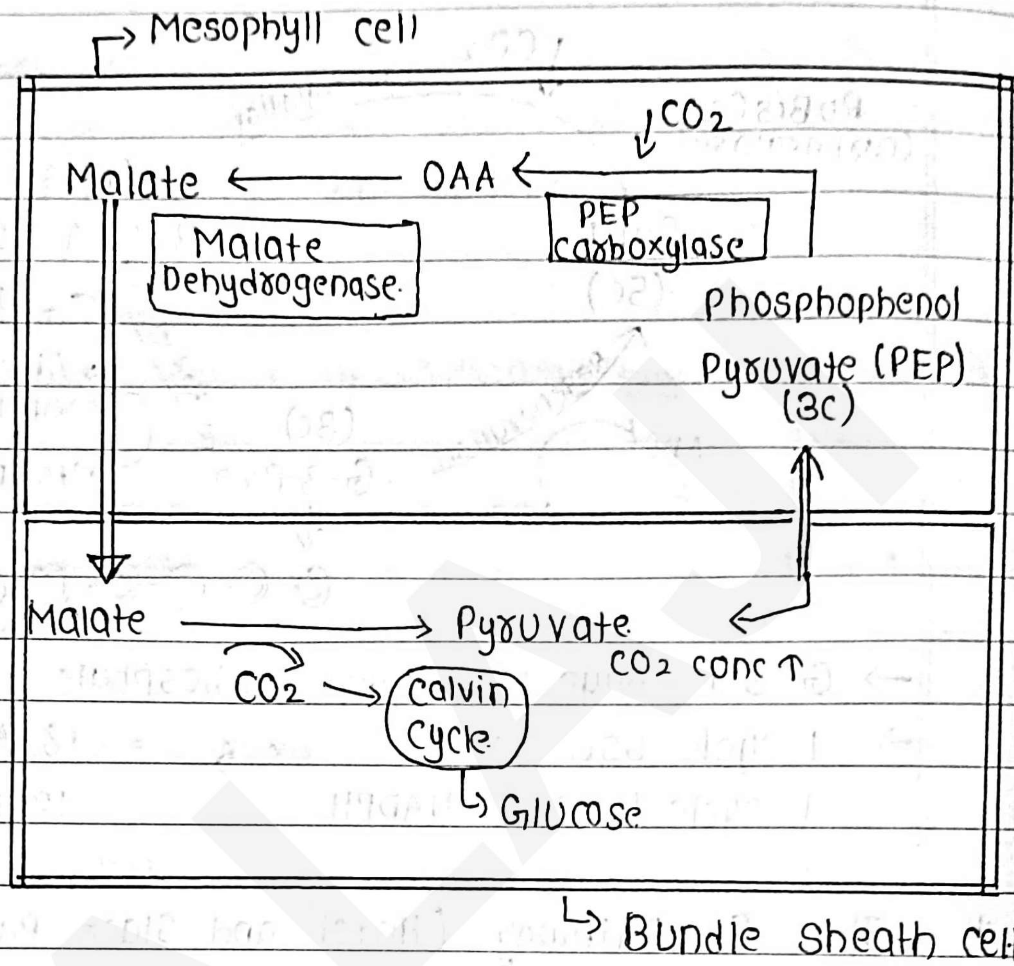
Kranz Anatomy.



→ Bundle sheath cells → Gas cannot enter/ move out these cells

- Cell Wall thick → Imperrious to gas → No intercellular spaces

- Large number of chloroplast



→ The primary CO_2 acceptor is a 3-carbon molecule Phosphophenol pyruvate. The enzyme Responsible for this fixation is PEP carboxylase or PEP case.

→ Mesophyll cells lack Rubisco Enzyme

→ It then forms other 4-carbon compounds like malic acid or aspartic acid in the mesophyll cells, itself, which are transported to the bundle sheath cells. In the bundle sheath cells these C_4 acids are broken down to release CO_2 and a 3-carbon molecule

→ The 3-carbon molecule is transported back to the mesophyll where it is converted to PEP again thus completing the cycle.

* CAM PATHWAY

Stomata
Night → Opens
Day → Closed
⟹ CO_2 - Fixation in night ⟹ Purpose - water Conservation

*	C_3 Plants	C_4 Plants
①	Photosynthesis occurs in mesophyll cells.	In mesophyll and bundle Sheath cells
②	Kranz anatomy is absent	Present.
③	RuBP is the primary CO_2 acceptor.	PEP is the Primary CO_2 acceptor
④	3-PGA, a (3C) compound is the first stable product	OAA, a (4C) compound is the first stable product.
⑤	Photorespiratory loss is high	Photorespiration is absent
⑥	High CO_2 compensation point (25-100 ml · CO_2 l^{-1})	Low CO_2 compensation point (0-10 ml. CO_2 l^{-1})
⑦	optimum temperature for photosynthesis is about 25°c.	About 35°C - 45°c
⑧	Photosynthetically less efficient and productivity low. E.g. Rice, wheat, bean, Potato	Photosynthetically more efficient and productivity high. E.g. Maize, Sugarcane, amaranth, sorghum

Date
Page

* PHOTORESPIRATION

- also called C_2-cycle / Glycolate Metabolism.
- Wasteful process [NO ATP, NADPH, NO sugar]
- Occurs in C_3 Plants.
- Occurs when CO_2 is low, O_2 is High.
- High light Intensity & High Temp (also Favourable)
- RuBisCo binds with O_2 [in place of CO_2]
- Does not occurs in C_4 plants because they have mechanism which include CO_2 at Enzyme site.

* Factors Affecting 'Photosynthesis'

Internal	External
Number, size, Age, Orientation of leaves	Light, Temp, water, CO_2 Conc^n.

→ Effect of light
- Plant capture light of range 400-700 nm [PAR]
- PAR - Photosynthetically Active Radiation
- At low light Intensity - Linear relation bet^n light & CO_2 Fixation
- At High Light Intensity - Rate does not show further increase.
- Photosynthesis saturation - at 10% of full sunlight
- Light increase beyond a point cause chlorophyll destruction

Effect of Temperature
- Dark Reaction - Temperature controlled [Enzymatic]
- Light Reaction - Less affected by Temperature.
- Temperature Optimum - C_3 (low), C_4 (High)

Effect of Water.
↳ water stress ⟶ Stomata closed ⟶ Reduced CO_2 availability ⟶ Photosynthesis decrease

* Carbon dioxide concentration.
- Major limiting factor for photosynthesis.
- CO_2 saturation [C_3 plants : beyond 450 $\mu l\ L^{-1}$
  C_4 plants : 360 $\mu l\ L^{-1}$
- Current availability of CO_2 is limiting to C_3 Plants.
- Increase concⁿ of CO_2 [= upto 0.05 %] can cause increased Photosynthesis (beyond this level, becomes damaging)
- For C_3 Plants [respond to High CO_2 concⁿ]

* Increased CO_2 ⟶ ↑sed Photosynthesis ⟶ High productivity (Green house crops) $\xrightarrow{eg}$ Tomato, Bell pepper