FREE NOTES · NCERT + NEET LEVEL

Photosynthesis in Higher Plants

Early experiments, site of photosynthesis, pigments, light reaction (Z-scheme, photophosphorylation, chemiosmosis), Calvin cycle, C4 pathway, photorespiration and factors affecting photosynthesis.

01 Early experiments
02 Site and pigments
03 Light reaction
04 Chemiosmosis and Calvin cycle
05 C4 pathway and photorespiration
06 Factors affecting photosynthesis
07 Extra + tricks
08 Important Q&A
09 Common mistakes
10 Practice (NEET style)
11 Quick revision

01 Early experiments

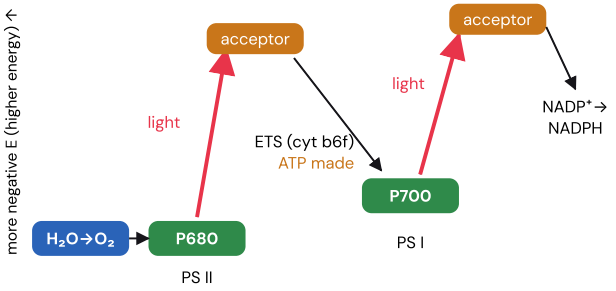
Scientist	Finding
Joseph Priestley (1770)	Mint plant restores air "spoilt" by a burning candle or mouse
Jan Ingenhousz	Sunlight needed; only green parts release O_2
Julius von Sachs (1854)	Glucose made, stored as starch in green parts
T.W. Engelmann	Action spectrum using *Cladophora* + aerobic bacteria: blue and red light most effective
Cornelius van Niel	Purple/green sulphur bacteria; O_2 comes from water (H_2O), not CO_2

Equation: $6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$ (light, chlorophyll).

02 Site and pigments

- Mesophyll cells; chloroplast **grana** (light reaction: traps light, makes ATP, NADPH) and **stroma** (dark reaction: enzymes fix CO_2).
- Chromatography of leaf pigments: chlorophyll *a* (bright/blue-green; chief pigment, reaction centre), chlorophyll *b* (yellow-green), xanthophylls (yellow), carotenoids (yellow to orange).
- Accessory pigments widen the absorption range and protect chlorophyll *a* from photo-oxidation.
- Action spectrum closely matches absorption spectrum of chlorophyll *a*: peaks in blue and red.

03 Light reaction

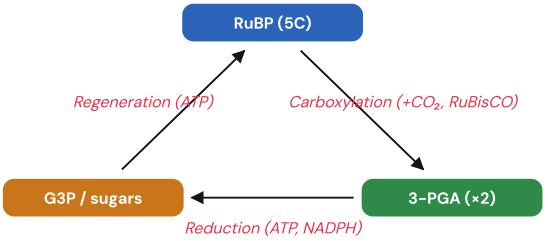


Z-scheme (non-cyclic electron flow)

- Light harvesting complexes (antennae) with reaction centres: **PS I** (P700) and **PS II** (P680).
- **Photolysis** of water at PS II (inner side of thylakoid membrane, Mn, Ca, Cl involved): $2H_2O \rightarrow 4H^+ + O_2 + 4e^-$.
- **Non-cyclic photophosphorylation**: both PS, makes ATP + NADPH. **Cyclic**: only PS I (stroma lamellae, which lack PS II and NADP reductase), makes only ATP; when only light > 680 nm is available.

04 Chemiosmosis and Calvin cycle

- **Chemiosmotic hypothesis**: proton gradient across thylakoid membrane (H^+ build up in lumen from photolysis, pumping by cyt b6f, and NADP reduction removing H^+ from stroma).
- H^+ flows back to stroma through **ATP synthase** (CF_o channel, CF_1 makes ATP).
- Calvin (using ^{14}C): first product in C3 plants is **3-PGA**. CO_2 acceptor is RuBP; enzyme **RuBisCO**.
- **For 1 glucose: 6 CO_2, 18 ATP, 12 NADPH** (6 turns; each CO_2 needs 3 ATP + 2 NADPH).



Three stages of the Calvin cycle

05 C4 pathway and photorespiration

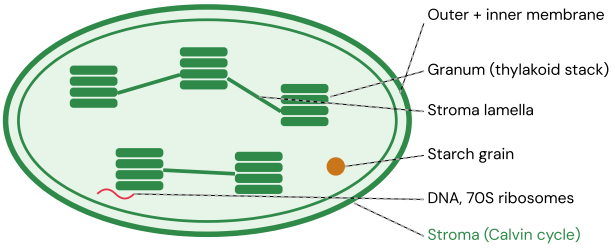
Feature	C3	C4
First product	3-PGA (3C)	OAA (4C)
Primary acceptor	RuBP	PEP (enzyme PEP case, in mesophyll)
Leaf anatomy	Normal	**Kranz anatomy**: large bundle sheath cells with many chloroplasts, thick walls, no intercellular spaces
Photorespiration	Present	Absent (CO_2 concentrated at RuBisCO)
Optimum temperature	20–25°C	30–40°C
Examples	Wheat, rice	Maize, sorghum, sugarcane

Photorespiration: RuBisCO binds O_2 instead of CO_2 (RuBP + O_2 → 1 PGA + phosphoglycolate); no ATP or sugar made, wasteful. C4 cycle: OAA → malate → bundle sheath → releases CO_2 → Calvin cycle; pyruvate returns to mesophyll.

06 Factors affecting photosynthesis

- **Blackman's law of limiting factors** (1905): rate is determined by the factor nearest its minimum value.
- Light: rate rises linearly at low intensity; at high light other factors limit; very high light damages chlorophyll.
- CO_2: major limiting factor (0.03–0.04% in air). C3 plants respond to higher CO_2 (greenhouse crops like tomato, bell pepper are grown in CO_2-enriched air); C4 saturate at ~360 µL/L.
- Temperature (dark reactions are enzymatic) and water (stress closes stomata, wilts leaves).

07 Extra + tricks



Structure of a chloroplast

Feature	C3	C4	CAM
First product	PGA	OAA	OAA (at night)
CO_2 fixation	Day, mesophyll	Day, mesophyll + bundle sheath (space separation)	Night (stomata open) + day Calvin (time separation)
Examples	Wheat, rice	Maize, sugarcane, sorghum, *Amaranthus*	Succulents: *Opuntia*, pineapple, *Bryophyllum*

- **Moll's half-leaf experiment**: half leaf inside bottle with KOH (absorbs CO_2) shows no starch ⇒ CO_2 is needed.
- Priestley: candle + mouse in bell jar; mint plant restored air. Ingenhousz: *Hydrilla* gives O_2 bubbles only in light.
- Trick: **C4 = 4 plants "MS-SA"**: Maize, Sugarcane, Sorghum, Amaranthus.

08 Important Q&A

Q1. Why are C4 plants more efficient in hot, dry conditions?

PEP case has no affinity for O_2 and CO_2 is concentrated in bundle sheath, so photorespiration is avoided; they tolerate high temperature and use water efficiently.

Q2. Where does the O_2 released in photosynthesis come from?

From water, by photolysis at PS II (van Niel; later confirmed by isotopes).

Q3. How many ATP and NADPH make one glucose in Calvin cycle?

18 ATP and 12 NADPH (6 turns).

09 Common mistakes

- Saying dark reaction happens only in dark (it is light-independent, happens in day).
- Writing first product of C4 as malate (it is OAA).
- Thinking cyclic photophosphorylation makes NADPH.
- Mixing PS I (P700) and PS II (P680).

10 Practice (NEET style)

1. CO_2 acceptor in C3?
2. Kranz anatomy is found in?
3. Photolysis is associated with?
4. Who proved O_2 comes from water?
5. Law of limiting factors?

ANSWERS

1) RuBP · 2) C4 plants (maize) · 3) PS II · 4) van Niel · 5) Blackman

11 Quick revision: 5 minutes before the exam

LIGHT REACTION

- Grana; PS II P680, PS I P700
- Non-cyclic: ATP + NADPH
- Cyclic: only ATP

CALVIN

- Stroma; RuBisCO
- First product 3-PGA
- 18 ATP + 12 NADPH per glucose

C4

- PEP case, OAA
- Kranz anatomy
- No photorespiration

SCIENTISTS

- Priestley mint
- Engelmann action spectrum
- Blackman limiting factors

Have a doubt? Ask the AI Doubt Solver at padhaiadda.netlify.app, or take the mock test on this chapter.