QUESTION

+ RUBD ⟶ Photorespiration

Statement I: In C_3 plants, some O_2 binds to RuBisCO, hence CO_2 fixation is decreased.
Statement II: In C_4 plants, mesophyll cells show very little photorespiration while bundle sheath cells do not show photorespiration.
In the light of the above statements, choose the correct answer from the options given below: [2024]

1. Both Statement I and Statement II are true
2. Both Statement I and Statement II are false
3. Statement I is true but Statement II is false
4. Statement I is false but Statement II is true

QUESTION

How many molecules of ATP and NADPH are required for $\boxed{\text{every molecule of } CO_2}$ fixed in the Calvin cycle? [2024]

1. 2 molecules of ATP and 3 molecules of NADPH
2. 2 molecules of ATP and 2 molecules of NADPH
3. 3 molecules of ATP and 3 molecules of NADPH
4. 3 molecules of ATP and 2 molecules of NADPH

$1 CO_2 \Rightarrow 3 ATP,$
$2 NADPH.$

QUESTION

Which of the following are required for the dark reaction of photosynthesis?

A. Light ✗

B. Chlorophyll ✗

C. CO_2 ✓

D. ATP ✓

E. NADPH ✓

Choose the correct answer from the options given below: [2024]

(1) A, B and C only

(2) B, C and D only

(3) C, D and E only ✓

(4) D and E only

QUESTION

The reaction center in PS II has an absorption maxima at (2023)

1. 700 nm
2. 660 nm
3. 780 nm
4. 680 nm

Chla

QUESTION

Which of the following combinations is required for chemiosmosis? (2023)

PQ

1. membrane, proton pump, proton gradient, ~~NADP synthase~~
2. proton pump, electron gradient, ATP synthase
3. proton pump, electron gradient, NADP synthase

Thylakoid PQ

4. membrane, proton pump, proton gradient, ATP synthase

QUESTION

Which one of the following is **not true** regarding the release of energy during ATP synthesis through chemiosmosis? It involves: (2022)

2e 2H+ NADPH+H+

1. Reduction of NADP to $NADPH_2$ on the stroma side of the membrane C
2. Breakdown of proton gradient — C ATP.
3. Breakdown of electron gradient
4. Movement of protons across the membrane to the stroma (lumen → stroma.)

QUESTION

What is the role of large bundle shealth cells found around the vascular bundles in C_4 plants? (2022)

1. To protect the vascular tissue from high light intensity X
2. To provide the site for photorespiratory pathway X
3. To increase the number of chloroplast for the operation of Calvin cycle ✓
4. To enable the plant to tolerate high temperature

QUESTION

Given below are two statements: (2022)

Statement I: The primary CO_2 acceptor in C_4 plants is phosphoenolpyruvate and is found in the mesophyll cells. C

Statement II: Mesophyll cells of C4 plants lack RuBisCO enzyme C

In the light of the above statements, choose the correct answer from the options given below.

1. Statement I is incorrect but Statement II is correct
2. Both Statement I and Statement II are correct
3. Both statement I and statement II are incorrect
4. Statement I is correct but Statement II is incorrect

QUESTION

Which of the following statements is incorrect? (2021)

1. Stroma lamellae have PS I only and lack NADP reductase. C
2. Grana lamellae have both PS I and PS II. C
3. Cyclic photophosphorylation involves both PS I and ~~PS II~~.
4. Both ATP and $NADPH + H^+$ are synthesized during noncyclic photophosphorylation. C

QUESTION

The first stable product of CO_2 fixation in *Sorghum* is: (2021)

(C-4).

1. Oxaloacetic acid ✓
2. Succinic acid
3. Phosphoglyceric acid
4. Pyruvic acid

QUESTION

In light reaction, plastoquinone facilitates the transfer of electrons from: (2020)

1. $Cytb_6f$ complex to PS-I
2. PS-I to $NADP^+$
3. PS-I to ATP synthase
4. PS-II to $Cytb_6f$ complex

PS-II → Pheo → PQ → $Cytob_6f$ → PC.

QUESTION

The oxygenation activity of RuBisCo enzyme in photorespiration leads to the formation of: (2020)

1. 1 molecule of 3-C compound (PGA)
2. 1 molecule of 6-C compound X
3. 1 molecule of ~~4-C~~ 3C compound and 1 molecule of 2-C compound
4. 2 molecules of 3-C compound X

QUESTION

During non-cyclic photophosphorylation, when electrons are lost from the reaction centre at PS II, what is the source which replaces these electrons? (2020-Covid)

1. Water
2. Carbon dioxide
3. Light
4. Oxygen

QUESTION

Which of the following statements is incorrect? (2020-Covid)

B.S.

1. In C_4 plants, the site of RuBisCO activity is ~~mesophyll~~ cell

RUBP C.

2. The substrate molecule for RuBisCO activity is a 5-carbon compound
3. RuBisCO action requires ATP and NADPH → dark rxn. G
4. RuBisCO is a bifunctional enzyme C

QUESTION

Which of the following is **not** a product of light reaction of photosynthesis? (2018)

1. ATP C
2. NADH
3. NADPH C
4. Oxygen C.

QUESTION

Phosphoenol pyruvate (PEP) is the primary CO_2 acceptor in: (2017-Delhi)

1. C_3 plants
2. C_4 plants
3. C_2 plants
4. C_3 and C_4 plants

QUESTION

With reference to factors affecting the rate of photosynthesis, which of the following statements is **not** correct? (2017-Delhi)

1. Light saturation for CO_2 fixation occurs at 10% of full sunlight
2. Increasing atmospheric CO_2 concentration upto 0.05% can enhance CO_2 fixation rate
3. C-4 ~~C_3~~ plants responds to higher temperatures with enhanced photosynthesis while ~~C_4~~ C-3 plants have much lower temperature optimum
4. Tomato is a greenhouse crop which can be grown in CO_2^- enriched atmosphere for higher yield

QUESTION

In a chloroplast the highest number of protons are found in: (2016 - I)

1. Stroma
2. Lumen of thylakoid
3. Inter membranal space
4. Antennae complex

QUESTION

The process which makes major difference between C_3 and C_4 plants is: (2016 - II)

1. Photorespiration
2. Respiration
3. Glycolysis
4. Calvin cycle

QUESTION

A plant in your garden avoids photorespiratory losses, has improved water use efficiency, shows high rates of photosynthesis at high temperatures and has improved efficiency of nitrogen utilisation. In which of the following physiological groups would you assign this plant? (2016 - I)

1. C_3
2. C_4
3. CAM
4. Nitrogen fixer

QUESTION

In photosynthesis, the light-independent reactions take place at: (2015 Re)

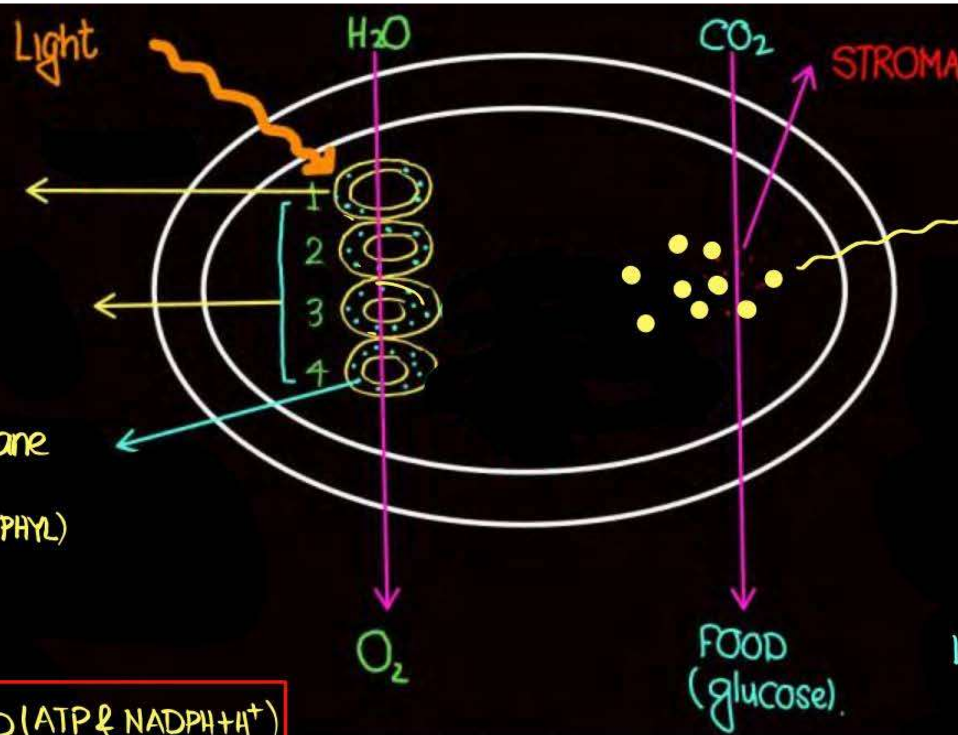
1. Photosystem-I
2. Photosystem-II
3. Stromal matrix ✓ dark rxn.
4. Thylakoid lumen

QUESTION

Anoxygenic photosynthesis is characteristic of: [OS] (2014)

1. Ulva E
2. Rhodospirillum (BACTERIA H_2S — S
3. Spirogyra E
4. Chlamydomonas E

PHOTOSYNTHESIS



LIGHT RX^n

grana → Thylakoid → membrane
↓
PIGMENTS (CHLOROPHYL)
↓
ABSORB LIGHT
↓
ENERGY FORMED (ATP & NADPH+H^+)

NO FOOD SYNTHESIS
(glucose)

DARK RX^n

→ STROMA
↓
UTILISED PRODUCT OF LIGHT RX^n IT DEPENDS UPON
(ATP, NADPH +H^+)

CO_2 ⟶ FOOD SYNTHESIS
(glucose)

⇒ indirectly depend upon light

LIGHT RX^n + DARK RX^n ⇝ PHOTOSYNTHESIS

* Definition:

LIGHT ENERGY CONVERT CHEMICAL ENERGY OF FOOD.

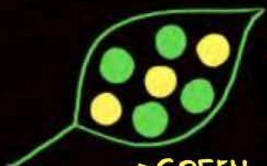
DARK RX^{n}

$$\boxed{6CO_2} + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} \boxed{\text{glucose}} + 6O_2 + 6H_2O$$

LIGHT RX^{n}.

EXPERIMENT

①



VERIGATED LEAF → GREEN ✓ / → NON GREEN X

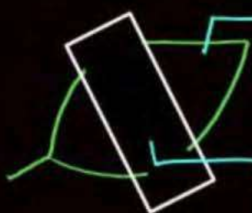
LIGHT → (STARCH TEST)

CHLOROPHYL ✓

GREEN PART	NON GREEN PART
⇒ Iodine sol^n	⇒ Iodine sol^n
⇒ BLUISH BLACK	X
⇒ STARCH ✓	X
↑ glucose ↓ PHOTOSYNTHESIS PRESENT	↑ NO GLUCOSE ↓ NO PHOTOSY.

* $\boxed{\text{ROLE OF GREEN PART (CHLOROPHYLL)}}$ ✓

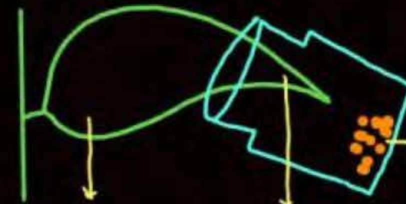
②



	I_2 SOL^n.	BLUISH BLACK	PHOTOSY
REGION: EXPOSED (LIGHT ✓)	✓	✓ Starch ✓	✓
REGION: COVERED WITH BLACK PAPER (LIGHT X)	✓	X, Starch X	X

* $\boxed{\text{ROLE OF LIGHT}}$ ✓

③ MOLL HALF LEAF EXP.



ROLE OF CO_2

	OUTSIDE THE TEST TUBE	INSIDE TUBE
⇒ LIGHT :	✓	✓
⇒ CO_2 :	✓	X
⇒ STARCH TEST :	BLUISH BLACK. PHOTO ✓	X X

④ PRIESTLEY EXP.

CANDLE & MOUSE ⇝ UTILISED O_2 ⇝ RELEASE CO_2 → CANDLE EXTINGUISHED / → MOUSE DEATH.

O_2 discovered

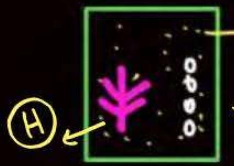
CANDLE & MOUSE RELEASE CO_2 ⇝ CO_2 TAKEN BY MINT

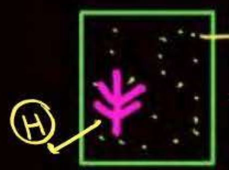
PLANT PURIFY AIR

$CO_2 \longrightarrow O_2$ → CANDLE DO NOT EXTINGUISHED / → MOUSE SURVIVE

⑤ Ingenhousz

⇒ Exp : aquatic plant (Hydrilla)





	LIGHT	GAS(O_2)	PHOTOSYNTH.
BRIGHT LIGHT	✓	✓	✓
DARK	X	X	X

⑥ VON SACH :

AS PLANT GROW ⟶ glucose accumulation increase

glucose synthesis ⤳ green part (chlorophyll)

glucose $\xrightarrow{\text{stored}}$ starch

green pigment Chlorophyll ⤳ present in CHLOROPLAST

NOTE : By 19th century.

$$CO_2 + H_2O \xrightarrow[\text{CHLOROPHYL.}]{\text{LIGHT}} (CH_2O)$$

Carbohydrate (glucose).

⑦ Van NIEL.

PURPLE SULPHUR } ⟶ PHOTOSYNTHETIC BACTERIA
GREEN SULPHUR }

$$CO_2 + 2H_2A \xrightarrow[\text{(}O_2\text{ NOT RELEASED)}]{\text{NON-OXYGENIC}} \boxed{(CH_2O)} + 2A + H_2O$$

Reduction

$2H_2A$ ↓ Release H atom (oxidisable compound) BINDS WITH CO_2

$2H_2S$

(CH_2O): Carbohydrate synthesis / glucose

2A: 2S

PLANTS

BUT DIDN'T PROOF.

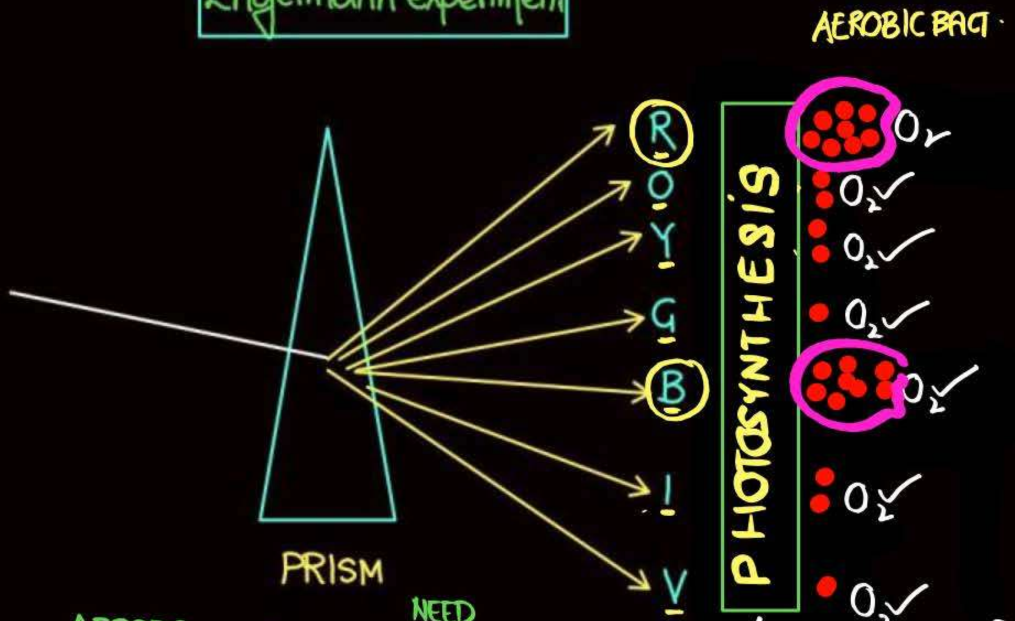
⇒ $H_2O \longrightarrow \frac{1}{2}O_2$

⇒ O_2 COMES FROM H_2O NOT CO_2.

⑧ RUBAN, KAMAN

$$CO_2^{16} + H_2O^{18} \longrightarrow O_2^{18}$$

Engelmann experiment



AEROBIC BACTERIA ⟶ GROW ⟶ NEED O_2

↓ CLADOPHORA (GREEN ALGAE)

PLANT: PIGMENTS → BLUE, RED → MAX. ABSORB ⟶ $\boxed{\text{ABSORPTION SPECTRUM.}}$

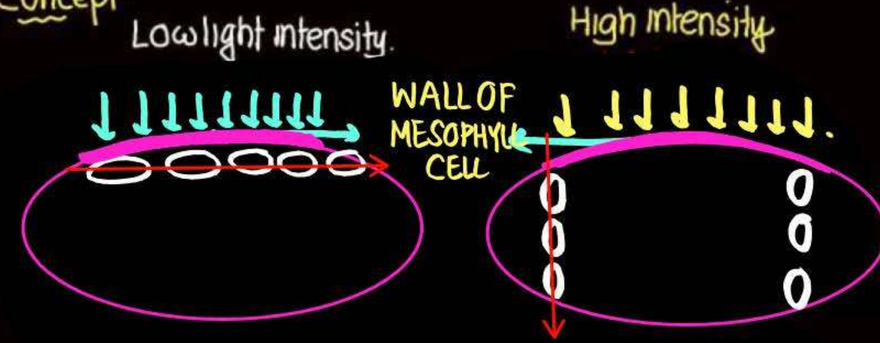
CO_2 FIXT^N / PHOTOSYNTHESIS / O_2 EVOLVED: $\boxed{\text{ACTION SPECTRUM}}$

BLUE, RED.

1st.

WHERE DOES PHOTOSYNTHESIS TAKES PLACE

Concept.



CHLOROPLAST: LIGHT:

↓ BETTER UTILISE

arrangement

Parallel to Wall of Mesophyll Cell.

Prependicular to Wall of Mesop cell.

HOW MANY TYPES OF PIGMENT

PAPER CHROMATOGRAPHY
↓
PIGMENTS OF LEAF COMES ON PAPER.

Chlorophyll a /main/UNIVERSAL → BLUISH GREEN

chlorophyll b : YELLOWISH GREEN / OLIVE GREEN.

Carotene : YELLOW/YELLOW TO ORANGE
+
Xanthophyll → YELLOW
↓
Carotenoids

ABSORPTION SPECTRUM.

ACTION SPECTRUM:

If we compare absorption spectrum of Chla with action spectrum.
so it overlap at some Region BUT NOT OVERLAP COMPLETELY.

DURING PHOTOSYNTHESIS LIGHT ALSO ABSORB BY.

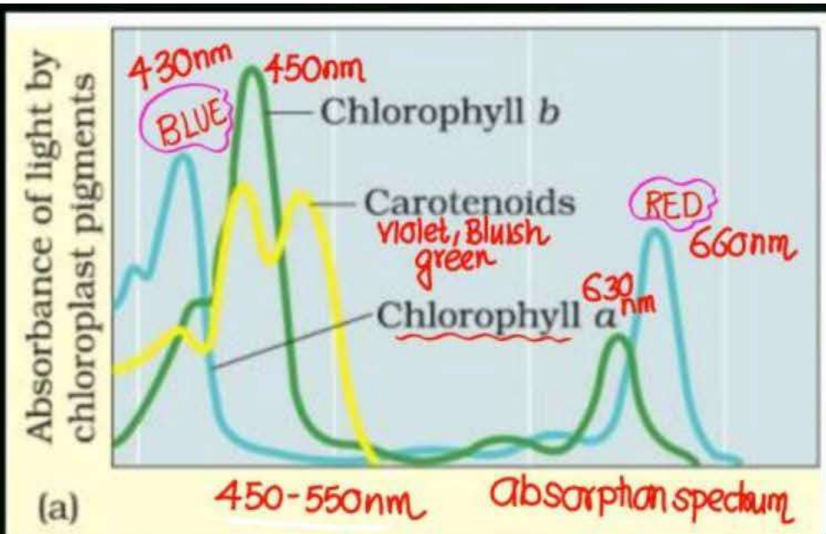
Chl b, Carotenoid → accessory pigments.
↓
also participate in PHOTOSYNTHESIS (INDIRECTLY)

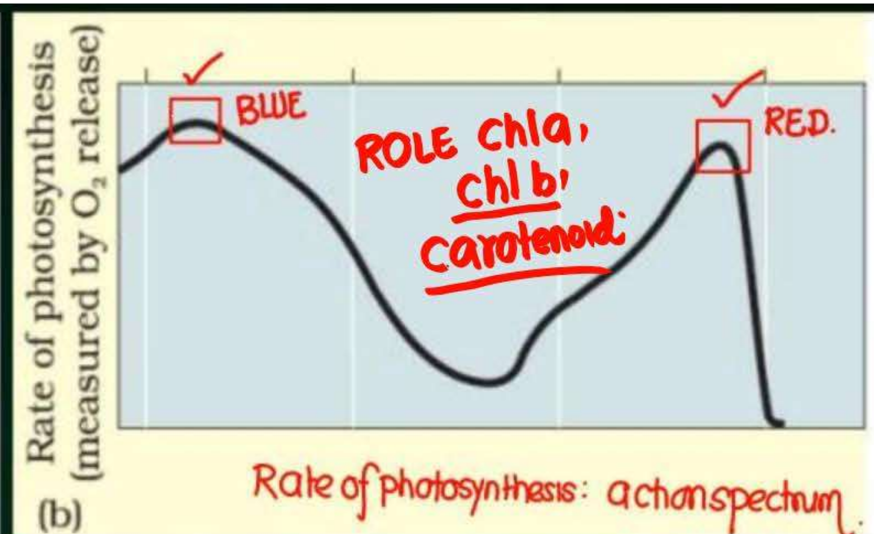
?

Chl a (main pigment) (DIRECTLY PARTICIPATE)

?

WAIT





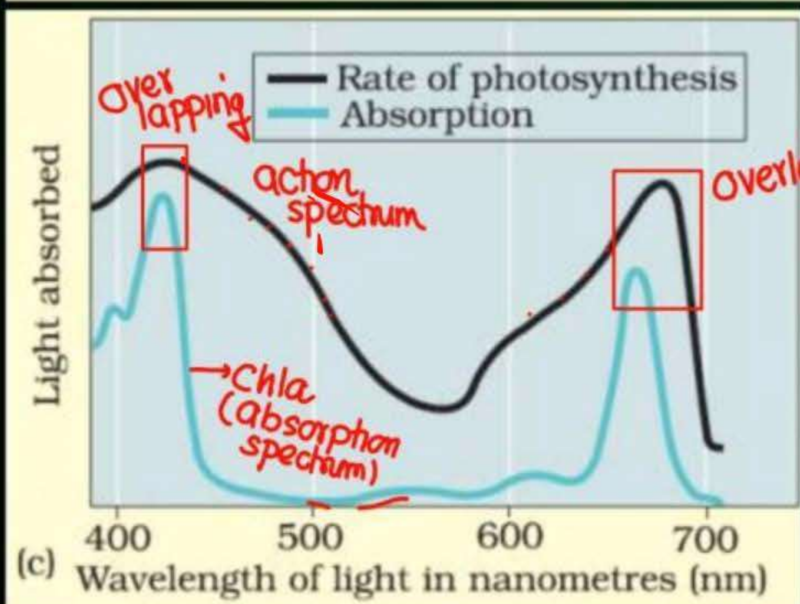


Figure 11.3a Graph showing the absorption spectrum of chlorophyll *a*, *b* and the carotenoids

Figure 11.3b Graph showing action spectrum of photosynthesis

Figure 11.3c Graph showing action spectrum of photosynthesis superimposed on absorption spectrum of chlorophyll *a*

LIGHT

Chla Chl b

carotenoid

Chloroplast

↓

Rate of photosy.

(CO_2 Fixt^n)

or

O_2 evolution

↓

Check.

(action)

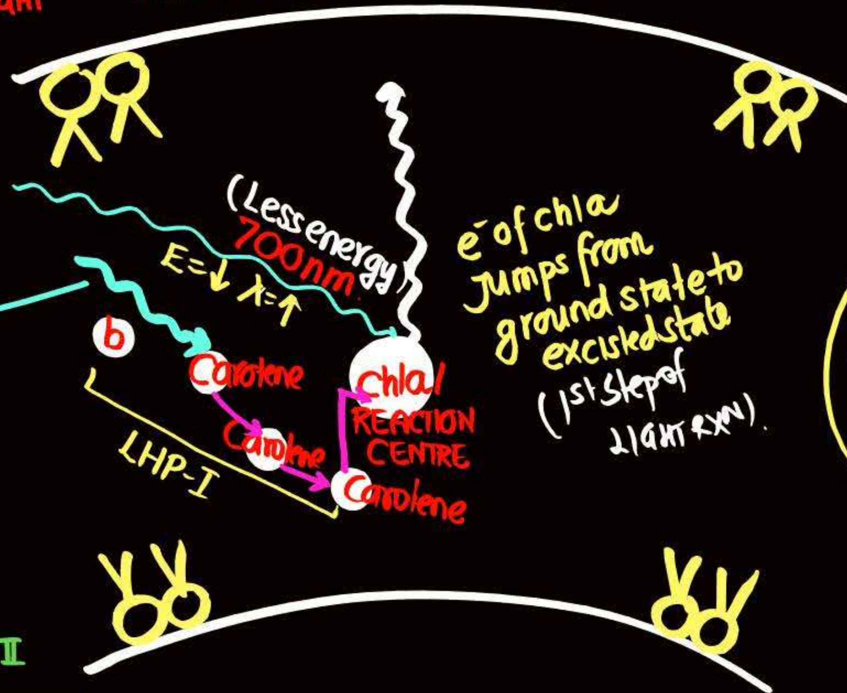
spectrum

PHOTOSYSTEM-I/PS-I

PHOTO → LIGHT

SYSTEM → PIGMENTS

grana
↓
Thylakoid
↓
membrane
↓
PIGMENTS



450nm
550nm
580nm

2nd discovered.

PS-II

- RC/chla (680nm)
- LHC-II
  - LHP-II
  - PROTEIN

NOW CHL a gets sufficient energy.

PS-I 1st discovered

- Reaction centre/ chla /single molecule.
  - $E = \frac{hC}{\lambda}$ (700nm↑)
- LIGHT HARVESTING COMPLEX (LHC-I)
  - LIGHT HARVESTING PIGMENT (LHP-I)
  - PROTEIN

energy TRANSFER.

Chlb
Carotene
Xanthophyll

→ access. pigment/ antenna molecule.

Shorter wavelength
LIGHT ABSORB
ENERGY HIGH.

LIGHT RX^N

$$ADP + iP \xrightarrow{LIGHT} ATP$$

$\boxed{\text{PHOTO PHOSPHORYLATION.}}$

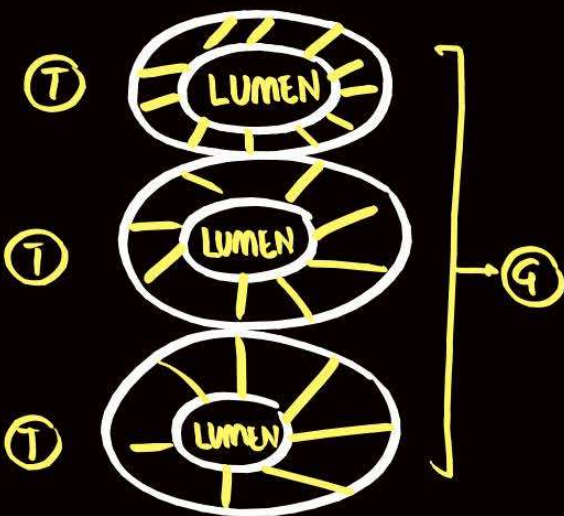
NON-CYCLIC

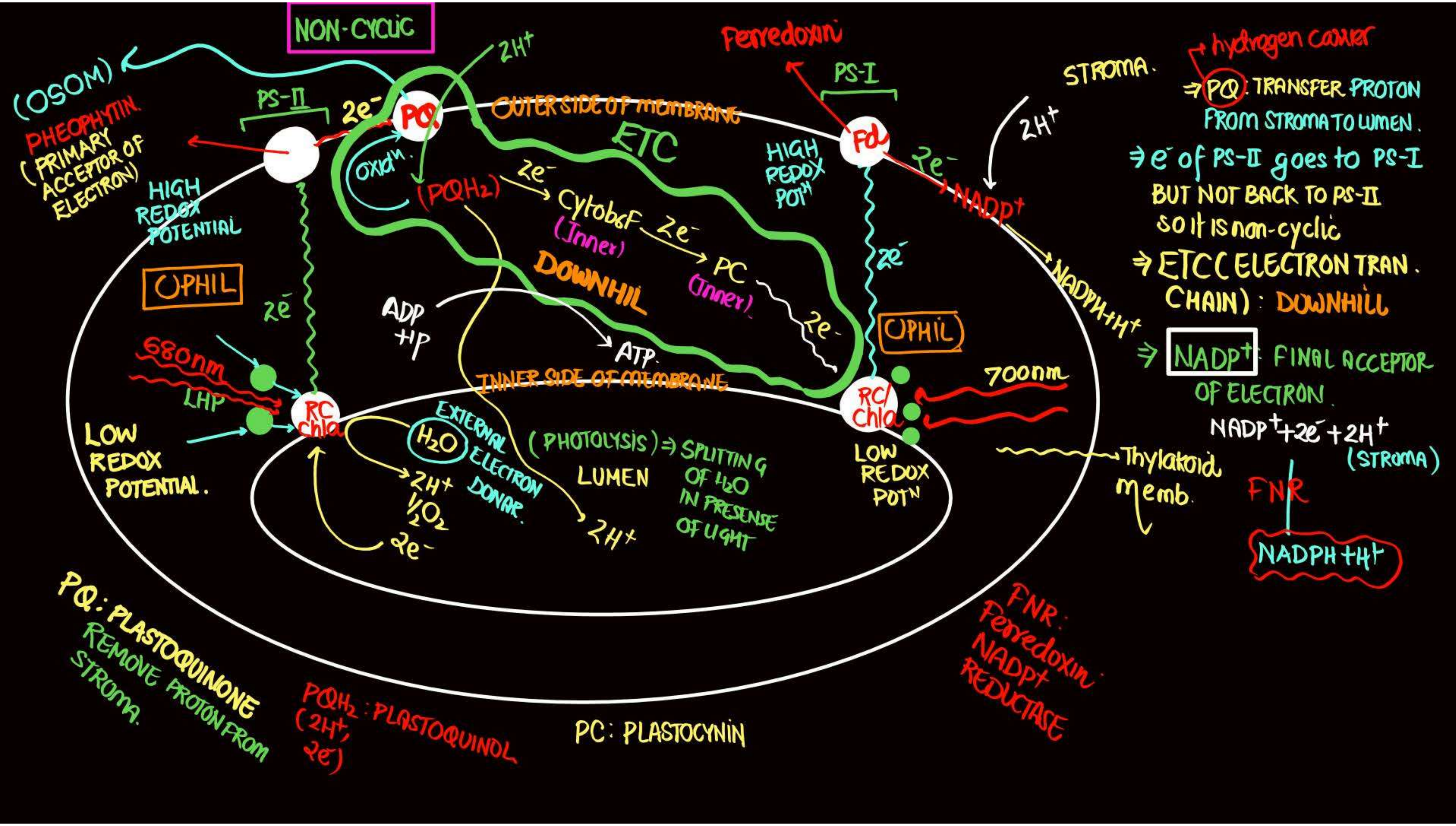
(grana)

↓

Thylakoid

CYCLIC




NON-CYCLIC
(OSOM)
PS-II
PHEOPHYTIN
(PRIMARY ACCEPTOR OF ELECTRON)
HIGH REDOX POTENTIAL
2e⁻
PQ
2H⁺
OUTER SIDE OF MEMBRANE
ETC
Oxidⁿ
(PQH₂)
2e⁻
Cytob6F
(Inner)
2e⁻
PC
(Inner)
DOWNHIL
UPHIL
ADP +P
ATP
2e⁻
INNER SIDE OF MEMBRANE
680nm
LHP
RC chla
LOW REDOX POTENTIAL.
H₂O
EXTERNAL ELECTRON DONAR.
2H⁺
½O₂
2e⁻
(PHOTOLYSIS) ⇒ SPLITTING OF H₂O IN PRESENSE OF LIGHT
LUMEN
2H⁺
Ferredoxin
PS-I
Fd
HIGH REDOX POTⁿ
2e⁻
2e⁻
NADP⁺
NADPH+H⁺
UPHIL
RC/ Chla
700nm
LOW REDOX POTⁿ
STROMA.
2H⁺
hydrogen carrier
⇒ PQ: TRANSFER PROTON FROM STROMA TO LUMEN.
⇒ e⁻ of PS-II goes to PS-I BUT NOT BACK TO PS-II SO it is non-cyclic
⇒ ETC (ELECTRON TRAN. CHAIN): DOWNHILL
⇒ NADP⁺: FINAL ACCEPTOR OF ELECTRON.
NADP⁺+2e⁻+2H⁺ (STROMA)
FNR
NADPH+H⁺
Thylakoid memb.
PQ: PLASTOQUINONE
REMOVE PROTON FROM STROMA.
PQH₂: PLASTOQUINOL (2H⁺, 2e⁻)
PC: PLASTOCYNIN
FNR: Ferredoxin NADP⁺ REDUCTASE

Non-cyclic

* SITE : GRANA
* Flow of e^- : PS-II to PS-I
* primary acceptor : PHEOPHYTIN
* External e^- donor : H_2O
* H_2O splitting : LUMEN
* PQ Remove $2H^+$ from stroma, TRANSFER TO LUMEN
* O_2 evolution. (H_2O splitting) at PS-II Photolysis)

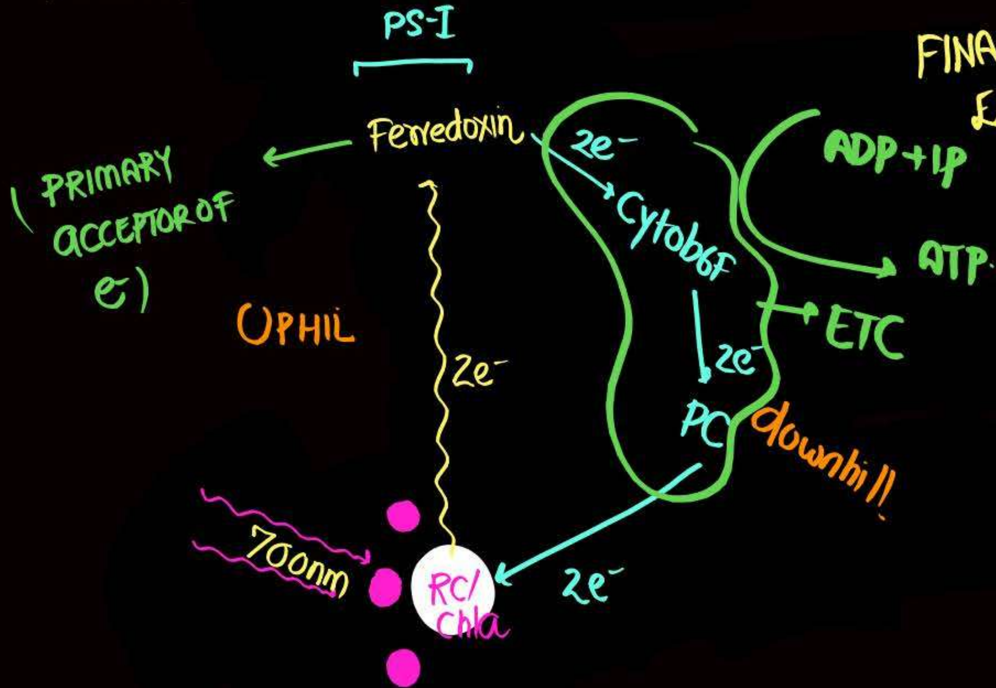
PQ

* e^- of PS-II Transfer to PS-I
* Cytob6F, PC : Inn. side of membrane.
* $NADP^+$ Reductase enzyme (FNR), PQ, Phaeophytin, $NADP^+$: OS of Thyl. membrane.

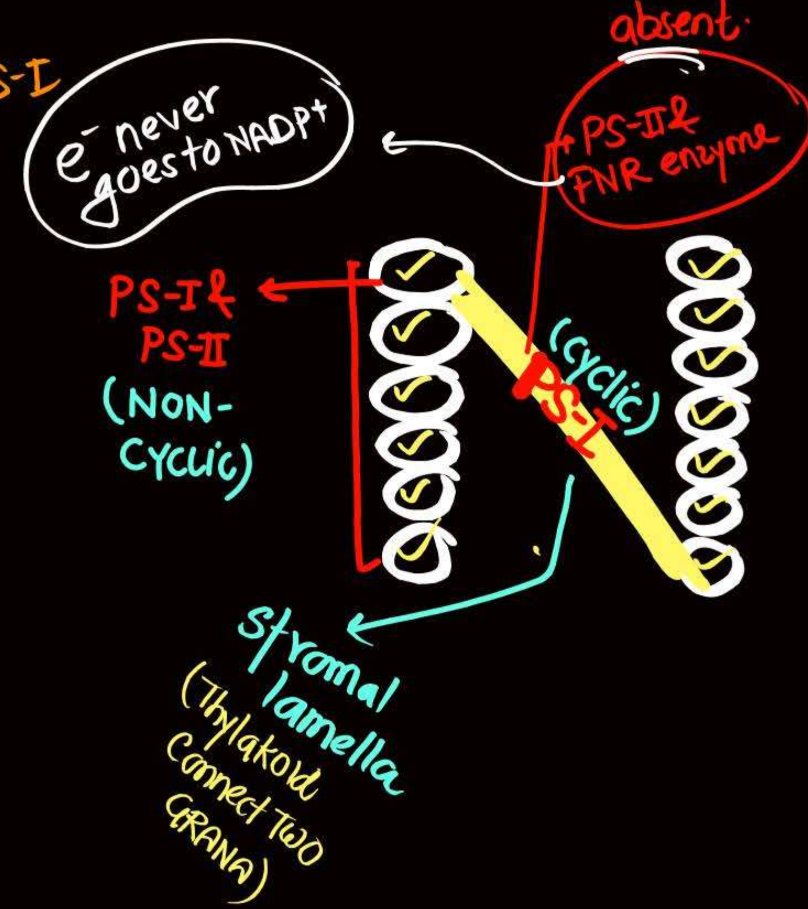
* Final acceptor of e^- : $NADP^+$

CYCLIC PHOTOPHOSPHORYLATION

* SITE: STROMAL LAMELLA.
* ONLY PS-I PRESENT

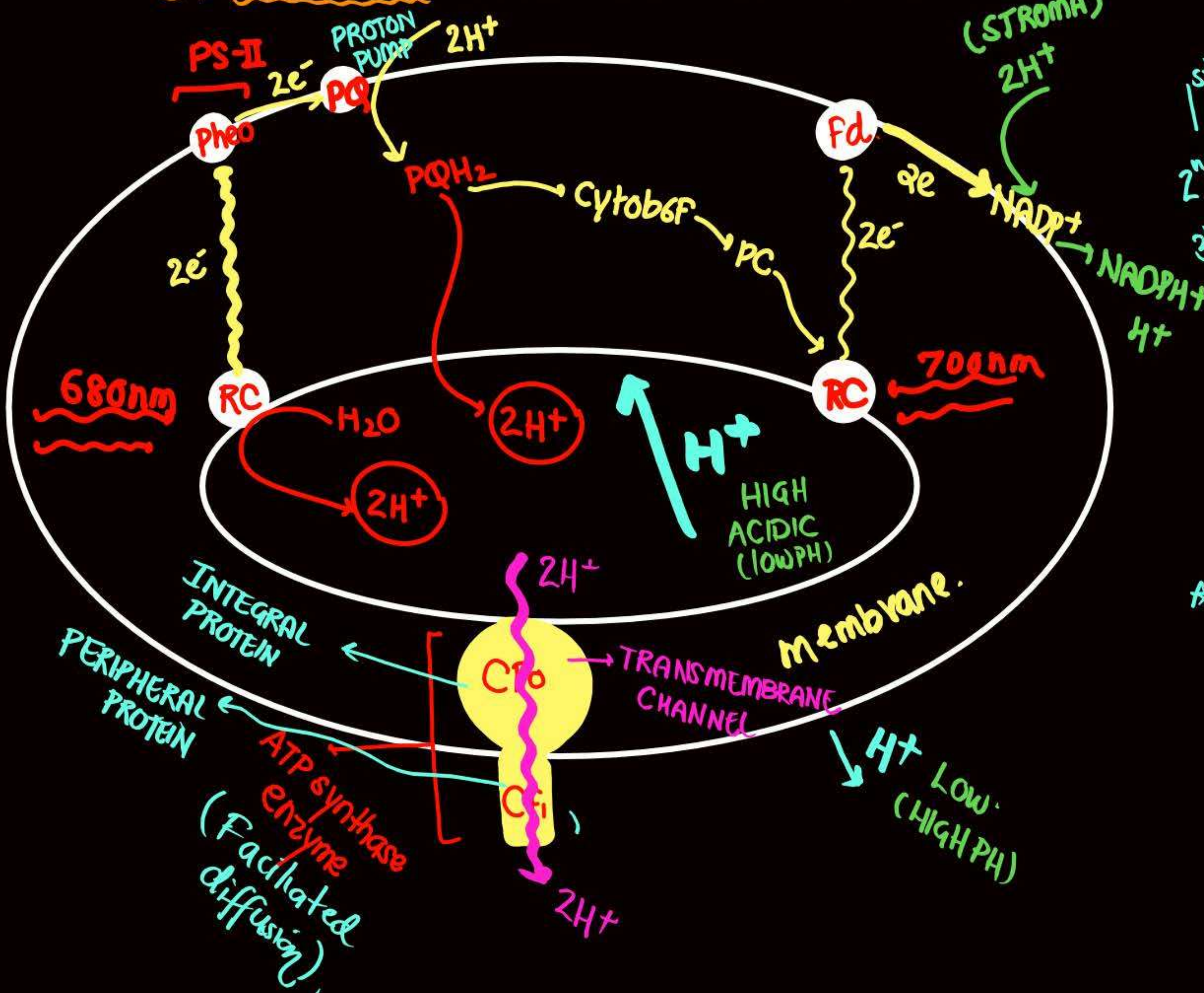


FINAL ACC. OF ELECTRON: PS-I



	NON-CYCLIC	CYCLIC
SITE	GRANA	STROMAL LAMELLA.
PHOTOSYSTEM	PS-II & PS-I	PS-I
External e^- donor (H_2O)	PRESENT	ABSENT (mov. of e^- is cyclic)
FINAL Electron acceptor	$NADP^+$	PS-I
PHOTOLYSIS / O_2 evolⁿ	✓ ✓	X X.
$NADPH + H^+$	yes.	NO
ATP synthesis	yes (ETC)	yes (ETC)
primary acceptor of e^-	Pheophytin	ferredoxin
Z- scheme	yes.	NO
Ferredoxin. NADP Reductase (FNR)	PRESENT	ABSENT

CHEMIOSMOTIC HYPOTHESIS (ATP FORMN) → Peter MITCHELL.



PROTON ACCUMULATION IN LUMEN INCREASE COMPARE TO STROMA.

1st ★ $H_2O \xrightarrow{\text{PHOTOLYSIS}} 2H^+$

2nd ★ PQ TRANSFER PROTON FROM STROMA TO LUMEN.

3rd ★ $NADP^+$ REMOVE PROTON FROM STROMA

PROTON GRADIENT FORMED ACROSS MEMBRANE

↓

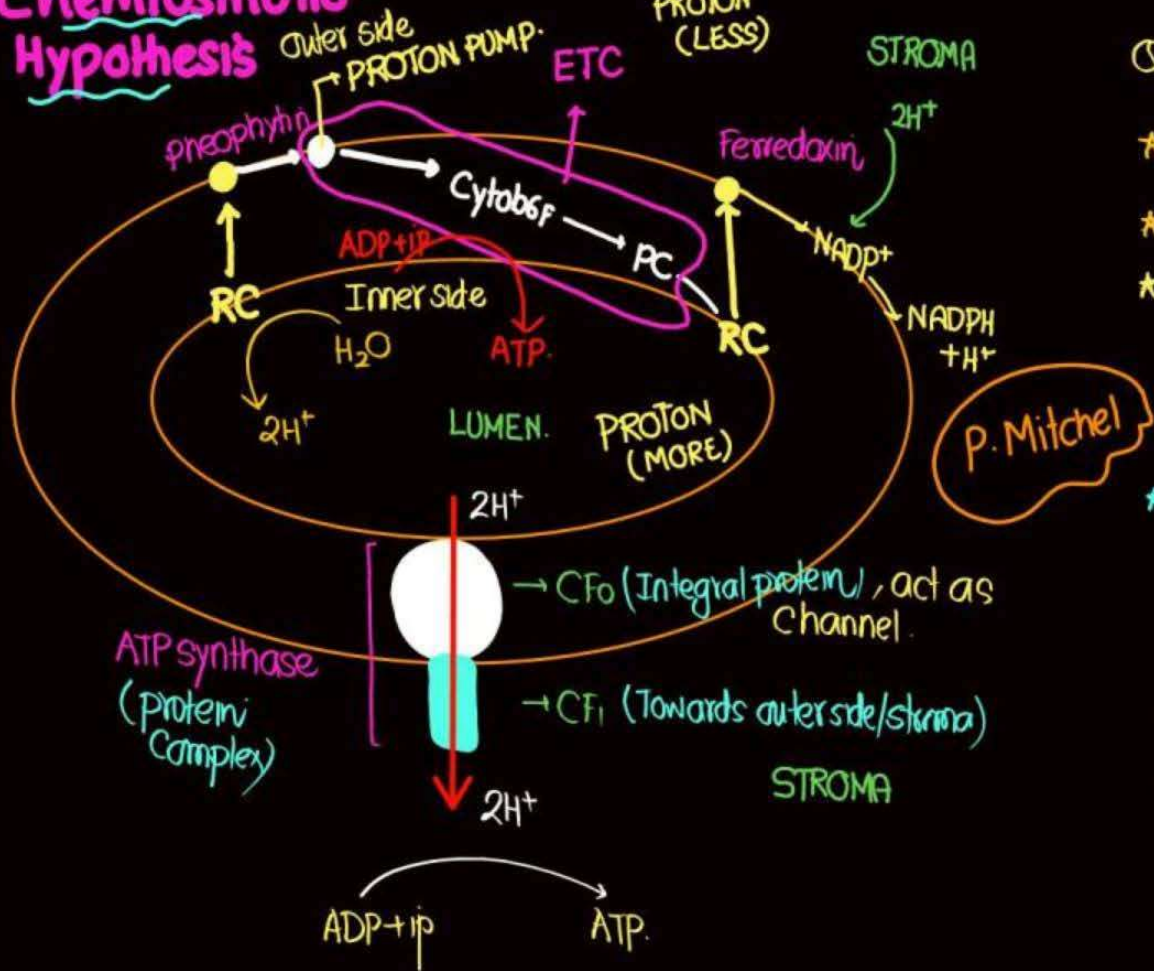
NOW NEED TO BREAK PROTON GRADIENT (LUMEN TO STROMA)

HIGH TO LOW (DOWNHILL) (ALONG CONN: PASSIVE TRANSPORT

★ AS PROTON MOVE THROUGH ATP synthase (from stroma to LUMEN) there is conformational change in CF_1 part

$ADP + ip \xrightarrow{2H^+} ATP \text{ synthesis}$

Chemiosmotic Hypothesis



Reason

Q Proton accumulation increase in Lumen of Thylakoid compare to Stroma

★ $H_2O \xrightarrow{\text{PHOTOLYSIS}} 2H^+$.

★ PQ Transfer H^+ from stroma into LUMEN.

★ H^+ of stroma Bind with $NADP^+$ to form $NADPH + H^+$ so H^+ conn decrease in Stroma.

PROTON GRADIENT FORMED ACROSS THYLAKOID MEMBRANE

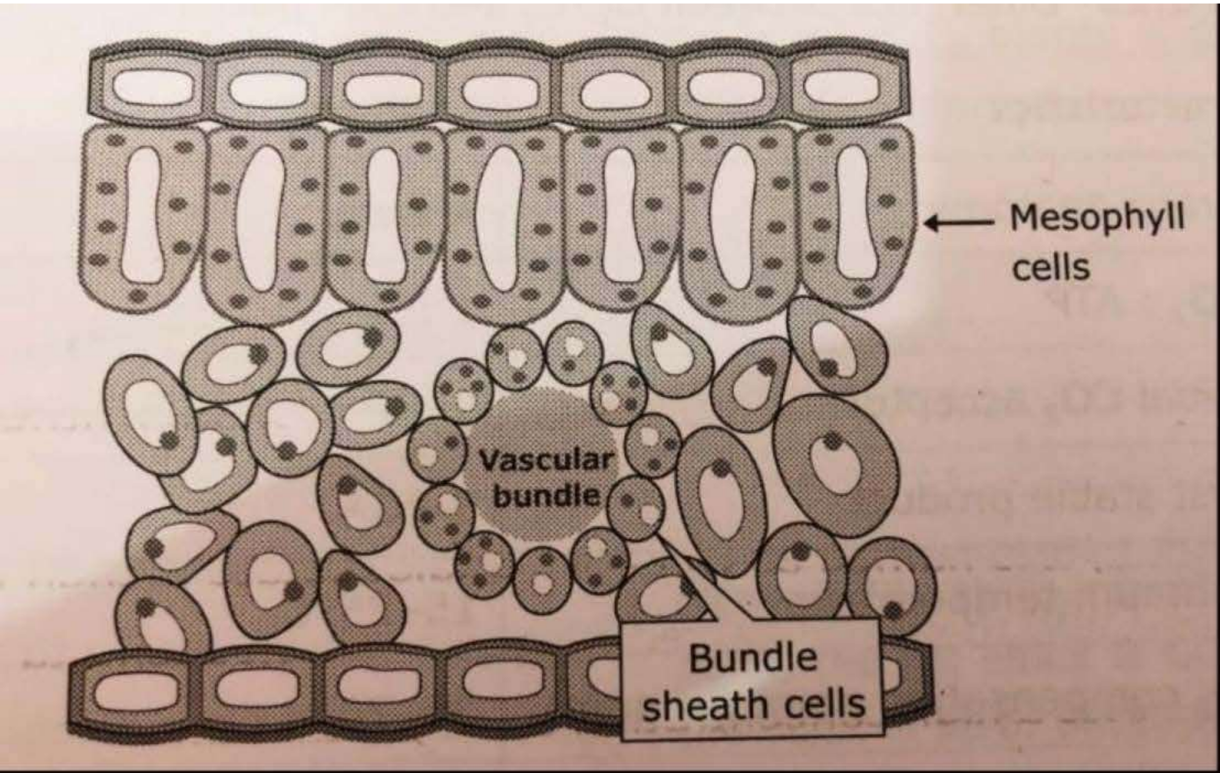
★ LUMEN: PH: LOW, H^+ more & STROMA: PH: HIGH: H^+ less.

YOU HAVE TO BREAK PROTON GRADIENT

so proton moves from LUMEN TO STROMA. (HIGH TO LOW conn", PASSIVE TRANSPORT

★ CF: Coupling factor.

★ As proton pass through this Complex, there is Conformational change in CF1 (Catalytic site) & energy of proton utilised in synthesis of ATP from ADP & ip. (Photophosphorylation)


Mesophyll
cells
Vascular
bundle
Bundle
sheath cells

PRODUCT OF LIGHT RX^n

O_2, ATP, NADPH FORMED. → 18 ATP, 12 NADPH.

6 TURN OF C-3 cycle

$6CO_2$ ($Fixt^n$) $\xrightarrow{\text{DARK } RX^N}$ One mole of glucose.

18 ATP, 12 NADPH CONSUMED.

$1CO_2$ ($Fixt^n$) $\xrightarrow{\text{DARK } RX^N}$

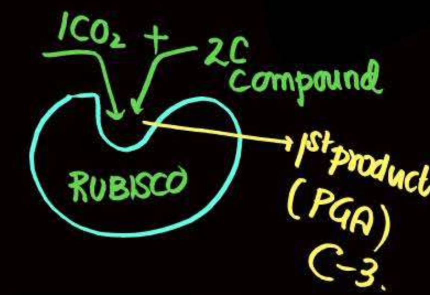
(1 TURN OF C-3 cycle)

3 ATP, 2 NADPH CONSUMED.

CALVIN CYCLE (FOOD SYNTHESIS)

DARK RX^N.

CALVIN-CYCLE/C-3.cycle : FOOD SYNTHESIS (glucose)



Earlier it was Believed

CO_2 + ~~PRIMARY ACCEPTOR of CO_2~~ $\xrightarrow{\text{RUBISCO}}$ $\boxed{\text{3-PHOSPHOGLYCERIC ACID (C-3)}}$ → FIRST PRODUCT

1C ~~2C compound~~

WRONG

RIGHT CONCEPT

(RIBULOSE 1,5 BISPHOSPHATE RUBP

CO_2 + 5C ketose sugar $\xrightarrow{\text{RUBISCO}}$

1C 5C PRIMARY acceptor.

2 molecule

3-PHOSPHOGLYCERIC (C-3)

3C + 3C → 6C

RUBISCO ENZYME → most abundant enzyme in earth.

GOOD BOY.

Carboxylase activity ✓

$\underbrace{RUBP + CO_2}_{RUBISCO} \xrightarrow[\text{of RUBP.}]{\text{Carboxylation}}$ C-3 cycle start (CO_2 FIXT^N).

$CO_2 \uparrow$
$O_2 \downarrow$

Oxygenase activity ✓

O_2 con ↑
CO_2 con ↓
around RUBISCO

$\underbrace{RUBP + O_2}_{RUBISCO} \xrightarrow[\text{RUBP.}]{\text{Oxygenation of}}$ NO FIXT^N OF CO_2.
NO GLUCOSE
Carbon loss.

PHOTORESPIRATION

BAD BOY

BIFUNCTIONAL ENZYME.

Ribulose 1,5 BISPHOSPHATE
CARBOXYLASE
OXYGENASE

CALVIN CYCLE (BIOSYNTHETIC PHASE).

$1CO_2 \longrightarrow$ FIX $\longrightarrow$ 1 TURN OF CYCLE

$6CO_2 \longrightarrow$ FIX $\longrightarrow$ 6 TURN OF CYCLE

$H_2O \rightarrow CO_2$ (1C)

+

C–C–C–C–C

1 mol : Ribulose 1,5 Bis PHOSPHATE / RUBP

1 mol : 5C

(PRIMARY ACCEPTOR OF CO_2)

① Carboxylation of RUBP (most crucial step)

RUBISCO (CARBOXYLASE).

NO INVOLMENT OF ENERGY.

3-PGA (2 mole) ⇒ 3C + 3C ⇒ $\boxed{6C}$, 1 Phosphate.

FIRST PRODUCT

② REDUCTION: 2ATP & 2NADPH CONSUMED

2ATP → 2ADP + 2P

1, 3 BISPHOSPHOGLYCERIC ACID ⇒ 3C + 3C ⇒ $\boxed{6C}$ 2 Phosphate

$2NADPH + H^+ \rightarrow 2NADP^+$

3- Phosphoglyceraldehyde ⇒ 3C + 3C ⇒ $\boxed{6C}$

(TRIOSE PHOSPHATE)

5C ← → 1C

1 TURN OF C-3 CYCLE

3ATP, 2NADPH CONSUMED

③ REGENERATION OF RUBP

CRUCIAL STEP.

TO CONTINUE 2nd TURN OF C-3 cycle.

ATP → ADP.

1 TURN / $1CO_2$ FIX :

3 ATP, 2NADPH.

CALCULATION

$1\ CO_2$ FIX/1 TURN OF CYCLE : Red^n : 2 ATP, 2 NADPH

Reg^n : 1 ATP

3 ATP, 2 NADPH

$6CO_2$/6 TURN OF C-3 CYCLE : Red^n : $6\times2 = 12$ ATP , $6\times2 = 12$ NADPH

Reg^n : $6\times1 = 6$ ATP

18 ATP, 12 NADPH.

1 TURN/$1CO_2$ FIX $\longrightarrow$ 1C

6 TURN/$6CO_2$ FIX $\longrightarrow$ 1C + 1C + 1C + 1C + 1C + 1C $\longrightarrow$ one molecule of glucose.

1st 2nd 3rd 4th 5th 6th.

C-4 cycle/Hatch & slack pathway

FOOD SYNTHESIS (THROUGH CALVIN CYCLE)

* Earlier Believed 1st product during food synthesis: 3PGA (C-3)
* BUT ONE DAY: SUGARCANE, MAIZE, 1st PRODUCT: OAA (C-4), OXALOACETIC ACID NOT 3-PGA.
* We Found alternate pathway: C-4 cycle./C-4 plants.
* Dry Tropical Region/High light intensity/High Temperature adapted, 30-40°C. → PHOTOSYNTHESIS HIGH.
* C-4 plant: KRANZ ANATOMY (LEAF): SPECIAL TYPE OF ANATOMY.

KRANZ → German WORD → WREATH/ARRANGEMENT OF

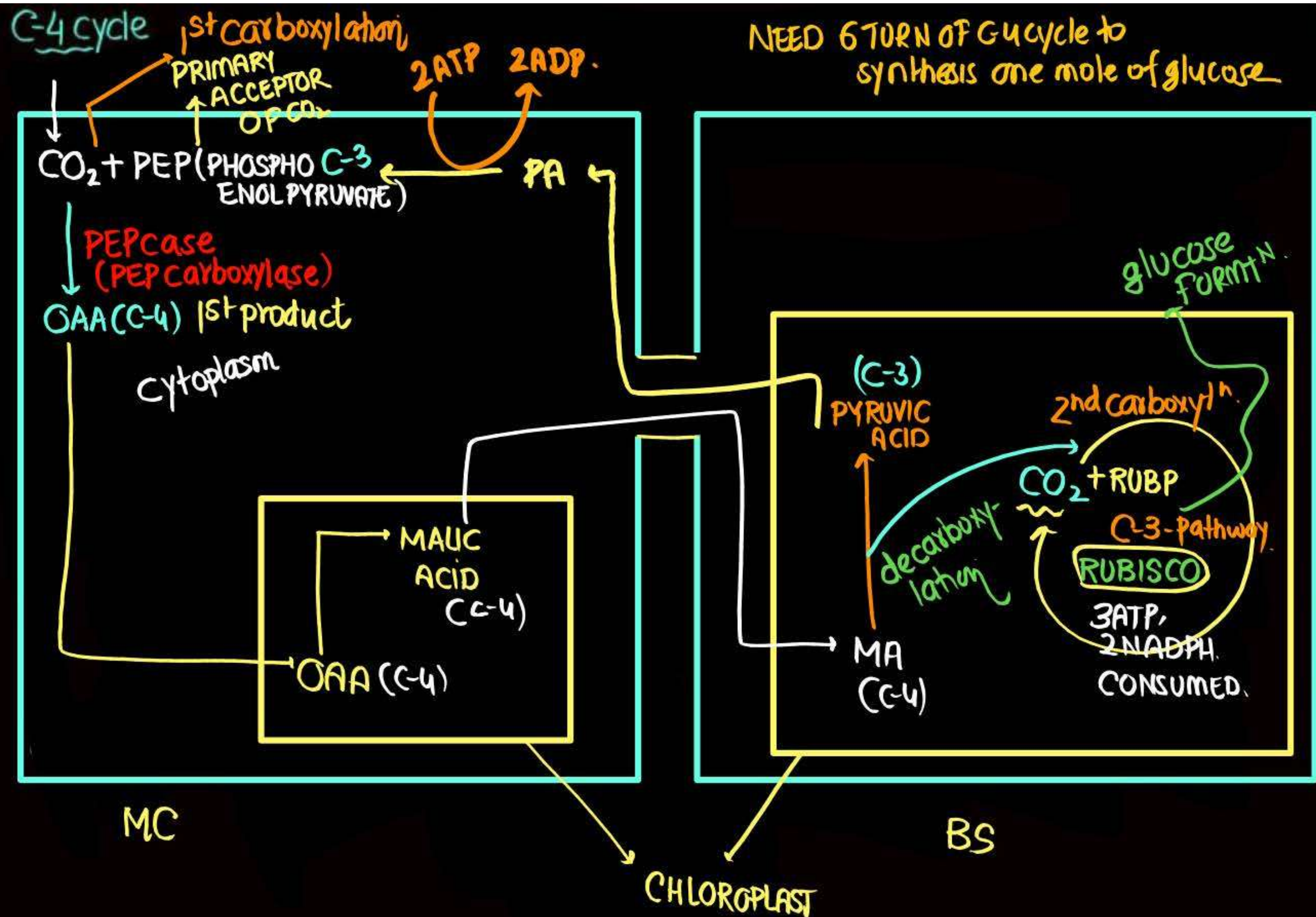
arrangement of BUNDLE SHEATH CELL AROUND VASCULAR BUNDLE.

DIMORPHIC CHLOROPLAST.

	Mesophyll cell	BUNDLE SHEATH CELL
Chloroplast (size, number)	small, less in number	LARGE IN NO. LARGE IN SIZE

NOTE: C-3 Chloroplast (Mesophyll cell): MONOMORPHIC

BUNDLE SHEATH CELL → several layers around Vascular BUNDLE
Intercellular space absent
THICK CELL WALL (IMPERMEABLE TO GASE)



1 TURN OF C-4 cycle: MC & BS
($1CO_2$ FIXT^n) 2 ATP 3ATP, 2NADPH

5 ATP, 2NADPH.

1 TURN OF C-3 cycle: 3ATP, 2NADPH

	C-3 Plant	C-4 Plant
RUBISCO	Mesophyll cell	BUNDLE SHEATH
CARBOXYLATION	1st (Mesophyll cell)	1st: MC 2nd: BS.
MAIN ENZYME	RUBISCO	PEPcase
1st product	3PGA, C-3	OAA, C-4.
Primary acceptor	RUBP, C-5	PEP, C-3.
6 TURN/$6CO_2$ FIX	18ATP 12NADPH NEED	30ATP, 12NADPH NEED.

★ Sorghum, sugarcane, maize (monocot)
BUT also in DICOT : C-4 cycle.

★ Wheat, RICE : C-3 plant → C-3 cycle.

★ C-3 plant : C-3 cycle ✓

★ C-4 plant : C-3 pathway present.

All photosynthetic plant have C-3 pathway.

★ C-3 pathway part of C-4 cycle. TRUE

★ 6 TURN OF C-4 cycle need to FIX 6 CO_2 & FORM one molecule of glucose.

C-4 Better than C-3 plant

★ PHOTORESPIRATION ABSENT IN C-4 PLANT / NO LOSS OF CO_2.
HIGH YIELD / PRODUCTIVITY PRESENT.

★ C-4 : INTRACELLULAR CO_2 CONCENTRATING MECHANISM

MA → PA → CO_2

conc^n always HIGH AROUND RUBISCO
SO IT ALWAYS BEHAVE AS CARBOXYLASE NOT OXYGENASE.

affinity of PEPcase > RUBISCO
FOR CO_2.

Q. Total No. of ATP Require for formation of 2 Maltose through C-4 cycle.

1 MALTOSE : 2 GLUCOSE
2 MALTOSE : 4 GLUCOSE
1 GLUCOSE : 30 ATP, 12 NADPH NEED.

= 4×30 120 ATP
= 4×12 = 48 NADPH.

PHOTORESPIRATION.

intake of O_2.

⇒ LIGHT PRESENSE (DAY TIME)

⇒ GREEN CELLS.

⇒ $O_2\uparrow$ $CO_2\downarrow$ RUBISCO → act as oxygenase

$$\underset{(5C)}{RUBP} + O_2 \xrightarrow[\text{oxygenase}]{\text{RUBISCO}} \underset{(1\text{mole } 3C)}{3PGA} + \underset{(1\text{mol})\ 2C}{\text{Phosphoglycolate}}$$

→ NOT ENTER INTO C-3 cycle

⇒ NO FIXᵗⁿ OF CO_2

⇒ CARBON LOSS

⇒ NO SUGAR SYNTHESIS

⇒ ATP, NADPH (ENERGY CONSUMED)

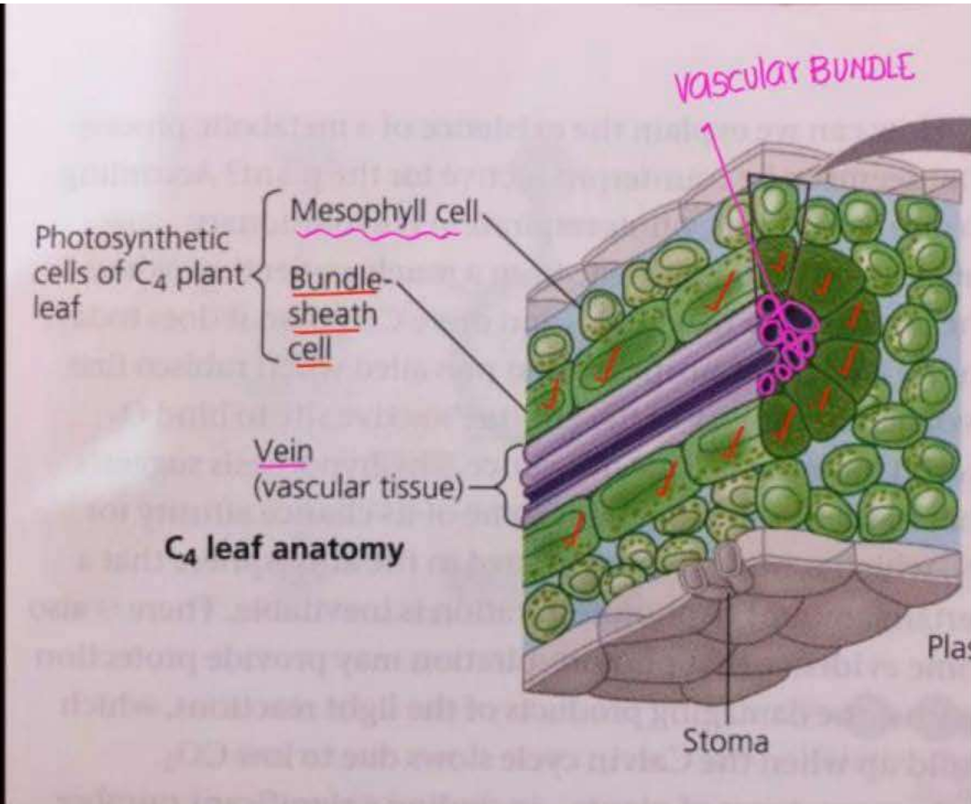
⇒ WASTEFUL PROCESS.

⇒ CO_2, NH_3 Released

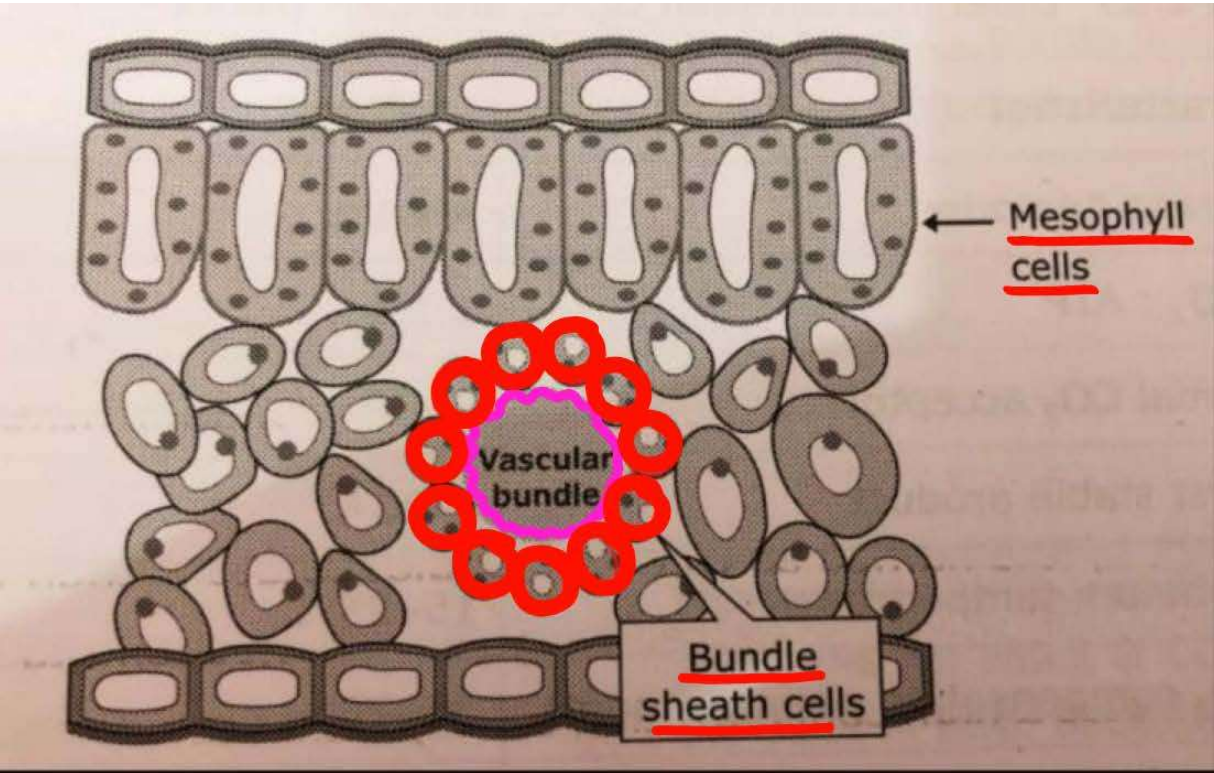
Chloroplast
peroxisome
mitochondria

HIGH TEMP/
HIGH LIGHT INTENSITY
$O_2\uparrow$ $CO_2\downarrow$

→ C-3 plant (PHOTORESPIRATION)



C_4 leaf anatomy



Mesophyll
cells
Vascular
bundle
Bundle
sheath cells

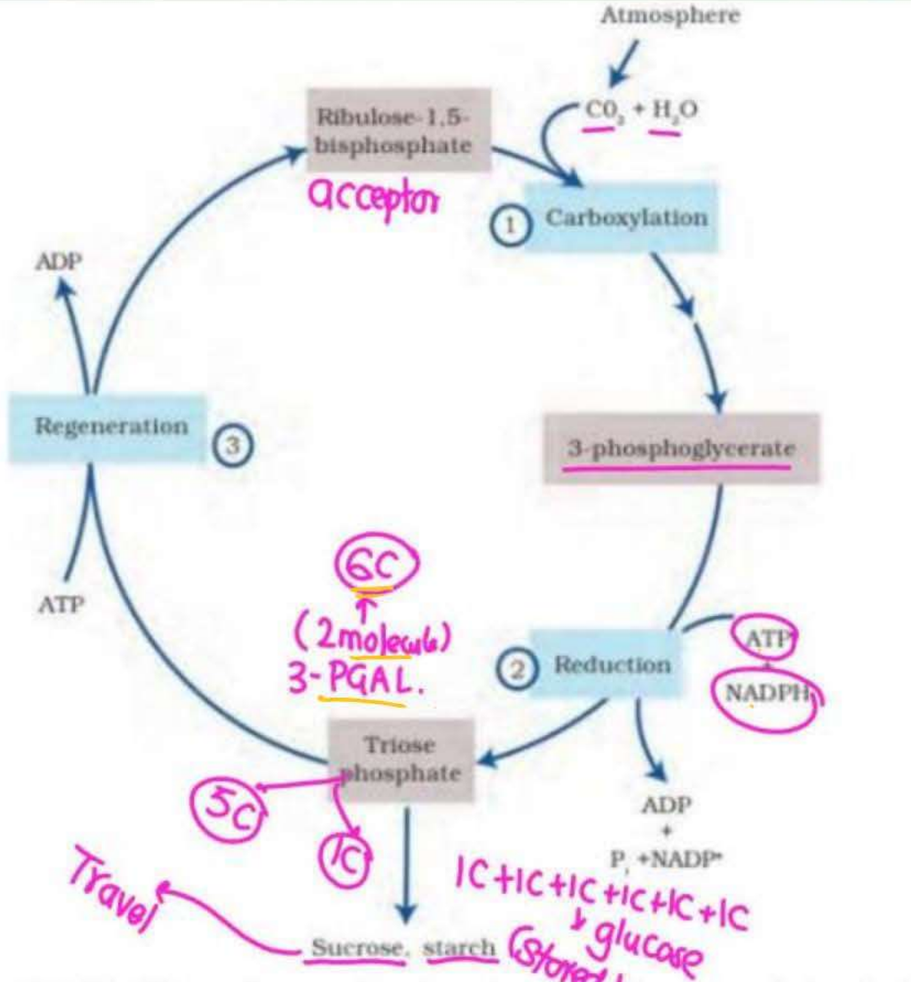


Figure 11.8 The Calvin cycle proceeds in three stages : (1) carboxylation, during which CO_2 combines with ribulose-1,5-bisphosphate; (2) reduction, during which carbohydrate is formed at the expense of the photochemically made ATP and NADPH; and (3) regeneration during which the CO_2 acceptor ribulose-1,5-bisphosphate is formed again so that the cycle continues

Red^n: glucose formed.

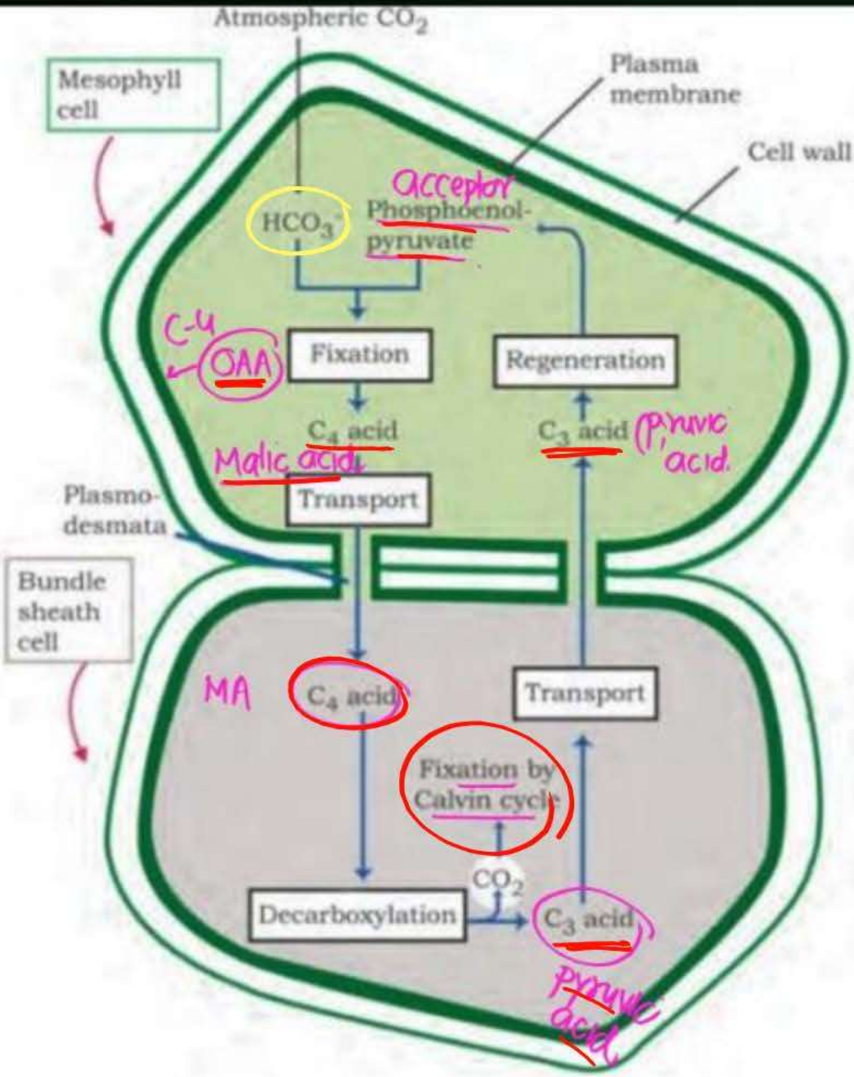


Figure 11.9 Diagrammatic representation of the Hatch and Slack Pathway

11.10 Factors affecting Photosynthesis

Rate ↑ : yield ↑
Rate ↓ : yield ↓

An understanding of the factors that affect photosynthesis is necessary. The rate of photosynthesis is very important in determining the yield of plants including crop plants. Photosynthesis is under the influence of several factors, both internal (plant) and external. The plant factors include the number, size, age and orientation of leaves, mesophyll cells and chloroplasts, internal CO_2 concentration and the amount of chlorophyll. The plant or internal factors are dependent on the genetic predisposition and the growth of the plant. ⇒ good : productivity High

(Internal Factor)

number ↑
chloroplast ↑
Photosynthesis ↑

Photosyn ↑

To get proper sunlight : Photosyn ↑

genetic makeup of Plant (DNA/chromosome)

Leaf No ↑, size ↑ → Chloroplast Number ↑ → Photosynthesis ↑

↑ age/Leaf old/mature : photosy ↑

age : More : Leaf very old : Senescence Start (chlorophyll destruction) ⇒ death of Leaf

The external factors would include the availability of sunlight, temperature, CO_2 concentration and water. As a plant photosynthesises, all these factors will simultaneously affect its rate. Hence, though several factors interact and simultaneously affect photosynthesis or CO_2 fixation, usually one factor is the major cause or is the one that limits the rate. Hence, at any point the rate will be determined by the factor available at sub-optimal levels.

Below expectation
Limiting

Rate of Rx^n.
↑
determine
↑
Limiting ← sugar X (minimum)

चाय
Milk ✓
पत्ती ✓
अदरक ✓
sugar X
(minimum)

Water ✓
CO_2 ✓
Chlorophyll ✓

Cloudy day (Light) X

Rate of photosy: determine By Limiting factor: Light ✓

You need optimal level
You do not need sub-optimal level

Bioyoyoyoyu

When several factors affect any [bio] chemical process, Blackman's (1905) **Law of Limiting Factors** comes into effect. This states the following: *If a chemical process is affected by more than one factor, then its rate will be determined by the factor which is nearest to its minimal value: it is the factor which directly affects the process if its quantity is changed.*

light
Temp
CO_2
$\boxed{H_2O}$ X.
Chlorophyll

H_2O
sub-optimum level / Limiting.

If you supply $H_2O \longrightarrow$ Things will Be fine/ok.

This too shall pass

Chlorophyll↑

For example, despite the presence of a green leaf and optimal light and CO_2 conditions, the plant may not photosynthesise if the temperature is very low. This leaf, if given the optimal temperature, will start photosynthesising.

11.10.1 Light

400-700nm (PAR: Photosynthetic active Radiation) (Blue, Red)

We need to distinguish between light quality, light intensity and the duration of exposure to light, while discussing light as a factor that affects photosynthesis. There is a linear relationship between incident light and CO_2 fixation rates at low light intensities. At higher light intensities, gradually the rate does not show further increase as other factors become limiting (Figure 11.10). What is interesting to note is that light saturation occurs at 10 per cent of the full sunlight. Hence, except for plants in shade or in dense forests, light is rarely a limiting factor in nature. Increase in incident light beyond a point causes the breakdown of chlorophyll and a decrease in photosynthesis.

Rate of photosynthesis

H_2O, Chlorop, CO_2

(Photo-oxidation).
Maximum intensity of light
↓
Chlorophyll destruction

dark Region grow (Sciophytes)

[redacted]

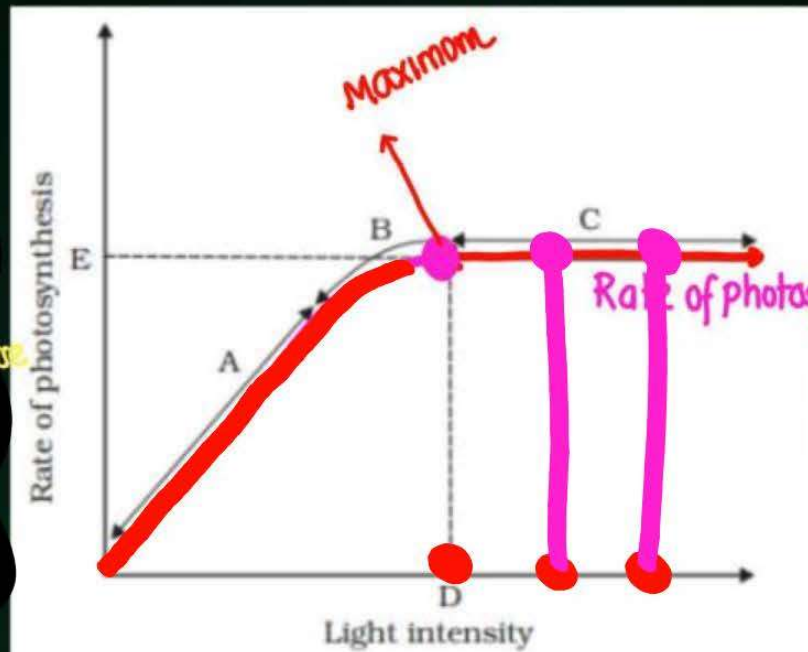


Figure 11.10 Graph of light intensity on the rate of photosynthesis

Rate of photosy : constant

If you increase more intensity of Light, other Factors Become limiting.

11.10.2 Carbon dioxide Concentration

Carbon dioxide is the $\boxed{\text{major limiting factor}}$ for photosynthesis. The concentration of CO_2 is very low in the atmosphere (between 0.03 and 0.04 per cent). Increase in concentration upto 0.05 per cent can cause an increase in CO_2 fixation rates; beyond this the levels can become damaging over longer periods.

Rate of Photosyn ↑

CO_2 ↑ (more increase)
Other factors Become limiting.

The C_3 and C_4 plants respond differently to CO_2 concentrations. At low light conditions neither group responds to high CO_2 conditions. At high light intensities, both C_3 and C_4 plants show increase in the rates of photosynthesis. What is important to note is that the C_4 plants show saturation at about 360 µlL^{-1} while C_3 responds to increased CO_2 concentration and saturation is seen only beyond 450 µlL^{-1}. Thus, current availability of CO_2 levels is limiting to the C_3 plants. Not for C-4 plant

	C-3	C-4
low light intensity CO_2 High	NO (SAD)	NO (SAD)
Light intensity (High) CO_2 can High	Happy	Happy

C-4 : 360 , can Respond at low CO_2

C-3 : 450 . Respond at High CO_2.

The fact that C_3 plants respond to higher CO_2 concentration by showing increased rates of photosynthesis leading to higher productivity has been used for some greenhouse crops such as tomatoes and bell pepper. They are allowed to grow in carbon dioxide enriched atmosphere that leads to higher yields.

grow in High CO_2 conc. Rate of photosynthesis

No Need for C_4 plant
CO_2 not limiting.

Temp effect

dark > Light
Rxn Rxn
↓
enzymatic Controlled.

11.10.3 Temperature

C-3cycle/C-4cycle Temp↑ : enzyme inactive

The dark reactions being enzymatic are temperature controlled. Though the light reactions are also temperature sensitive they are affected to a much lesser extent. The C_4 plants respond to higher temperatures and show higher rate of photosynthesis while C_3 plants have a much lower temperature optimum. 30-40C.

The temperature optimum for photosynthesis of different plants also depends on the habitat that they are adapted to. Tropical plants have a higher temperature optimum than the plants adapted to temperate climates. C-4 30-40C.

11.10.4 Water

Even though water is one of the reactants in the light reaction, the effect of water as a factor is more through its effect on the plant, rather than directly on photosynthesis. Water stress causes the stomata to close hence reducing the CO_2 availability. Besides, water stress also makes leaves wilt, thus, reducing the surface area of the leaves and their metabolic activity as well.

dry

Water: indirectly Control.

$H_2O \downarrow$ (soil) ⇒ To minimise Transpiration → Stomata Closed → No avail of CO_2 → Rate of Photosynthesis decrease.