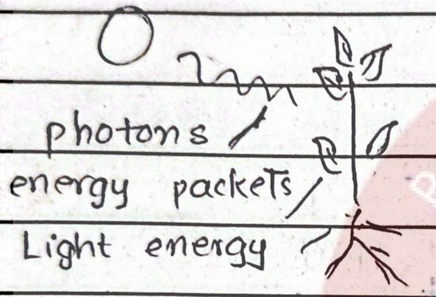
CHAPTER : 04

"BIOENENRGETICS"

→ Definition:

The transformation of energy from one form to another form in a living system.

In bioenergetics, the transformer of energy is plants.



$CO_2 + H_2O \xrightarrow{\text{Photosynthesis}} C_6H_{12}O_6 + O_2 \xrightarrow{\text{Respiration}} CO_2 + H_2O + E$

(chemical energy) (energy)

anabolism — catabolism → metabolism

E → ATP → mechanical (KE) → mechanical energy

→ BIOENERGETICS

MCQ (1) carbohydrates are taken by animals in the form of starch.

(2) carbohydrates are stored in animals bodies in the form of glycogen.

→ PHOTOSYNTHESIS:

→ photosynthesis is an amphibolic process. (means both anabolic and catabolic process).

→ catabolic in a sense that H_2O molecule splits in light rxn i.e photolysis of H_2O.

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→ photo part of photosynthesis is known as light rxn (occurs in the grana)

→ synthesis part of photosynthesis is known as dark rxn. (that occurs in stroma)
synthesis of glucose.

• Definition of Photosynthesis:

The redox process in which oxidation of water and reduction of CO_2 to glucose occur within the green plants.

• Reaction:

(Inorganic energy poor) (oxidation)

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2\uparrow + 6H_2O$$

(reduction)

photosynthetic reactants

organic Energy rich molecule

(photosynthetic products)

→ Inorganic poor energy molecules produces organic energy rich molecules.

→ ROLE OF LIGHT, WATER AND CO_2.

1) H_2O:

"Robin Hill"	"Van - Neil"
→ used chlorello algae	→ used sulphur bacteria

→ Exp - ①

$CO_2^{16} + H_2O^{18} \rightarrow C_6H_{12}O_6^{16} + O_2^{18}$

→ $CO_2 + H_2S \rightarrow C_6H_{12}O_6 + S\uparrow$

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→ Exp ②

$CO_2^{18} + H_2O^{16} \longrightarrow C_6H_{12}O_6^{18} + O_2^{16}\uparrow$

→ Hence experimentally, it was proved that 'O' comes from H_2O

2) CO_2:

→ 'C' from CO_2 act as a back bone for hydrocarbons.

3) SUNLIGHT:

→ 100% sunlight

→ 60% screened by ozone layer

→ 40% received by earth

→ Only 1% is used in photosynthesis.

→ Out of this 1% visible light is required for photosynthesis.

→ Visible Light :- the solar radiations sensitive to our eyes. (390 – 760 nm).

UV	← Visible Light →	Infra-red
powerful and damages leaves	(390 – 760 nm)	weak and can't be used in photosynthesis

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ACTION SPECTRUM vs ABSORPTION SPECTRUM

ACTION SPECTRUM	ABSORPTION SPECTRUM
→ diff. wavelength of light absorbed by photosynthetic pigments.	→ to measure the effectiveness of diff. wavelength of light.

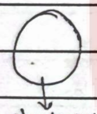
→ How is the effectiveness of light/absorption spectrum measured

Method - 01 : By means of spectrophotometer

Method - 02 : By the evolution of O_2 (greater the O_2 evolved, greater will be the effectiveness)

~~~~→ λ_1 glucose + O_2 ↑

~~~~~~→ λ_2 glucose + O_2 ↑


photosynthetic pigment

↳ Energy of the photon $\propto \frac{1}{\lambda}$

↳ chlorophyll absorbs → violet blue (390 – 460nm)
→ orange red (630nm – 700nm)
mathematical name

↳ carotenoids (500 – 600nm)
(accessory pigments)

carotene | xanthophyll (Yellow / brown)

BR

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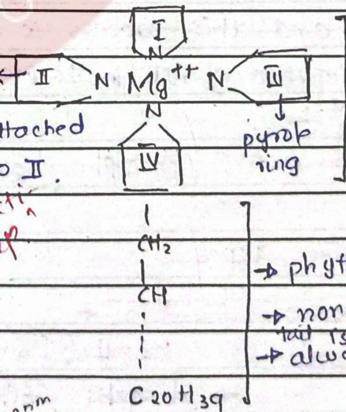
chlorophyll – a	chlorophyll – b
→ $C_{55}H_{72}O_5N_4Mg$	→ $C_{55}H_{70}O_6N_4Mg$
→ methyl group ($-CH_3$)	→ carbonyl group ($-CHO$)

chlorophyll

a, b, c, d, e

- a → main photosynthetic pigment → most abundant → universal photosynthetic pigment.
- b (present in some higher green plants, in some algae except diatoms)
- c, d, e → diatoms and red algae

→ Bacteriochlorophyll (present only in bacteria)



Functional group is always attached to ring no II.

which functional group?

pyrrole ring

→ Head
→ polar
→ collectively called tetrapyrrole ring / porphyrine ring

→ phytol tail
→ non-polar
→ tail is always attached ring no IV

390 – 460nm
630 – 700

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→ Head is composed of 35C and tail is composed of 20C

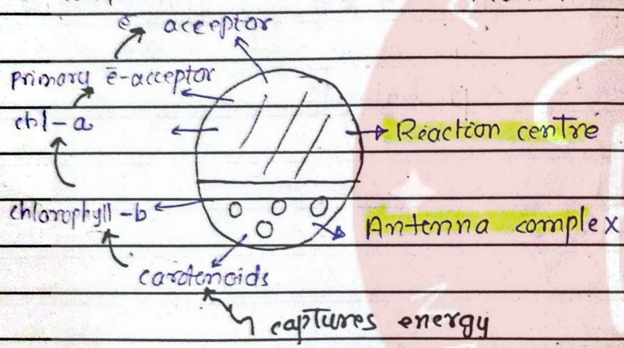
→ Head of the chlorophyll captures energy.

→ PHOTOSYSTEM I :-

→ unit of photosynthesis (especially for light rxn)

Photosystem

Antenna Complex | Reaction Centre



→ during this chain, the $\bar{e}$ releases energy which is used to form ATP and this process is called **photophosphorylation** (formation of ATP in the presence of light).

ADP + Pi ⟶ ATP (photophosphorylation)

Photosystem Types

PS I (P700) | PS-II (P680)

→ absorbs 700 nm (λ ~~light~~) | → absorbs 680 nm λ

PHOTOSYNTHESIS

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Steps of Photosynthesis

Light Rxn

- → light independent rxn
- → hills rxn
- → $\boxed{\text{Grana (occurance)}}$

Dark Rxn

- → calvin cycle
- → light independent rxn
- → C_3 - cycle (the first stable comp. formed is 3C
- → Carbon fixation + glucose synthesis
- → Benson-calvin cycle
- → $\boxed{\text{stroma (occurance)}}$

Products :-

→ H_2O
→ ATP
→ $NADPH_2$
→ O_2
] → light rxn

→ Glucose
→ O_2
] → dark rxn

Light Rxn

Light energy
H_2O

Non-cyclic photophosphorylation | Cyclic-photophosphorylation

PS-I + PS-II

(Use) | Non-cyclic | (Products)

Light energy ⟶ Non-cyclic ⟶ ATP

H_2O ⟶ ⟶ $NADPH_2$ and O_2

$\boxed{\text{Light Rxn}}$

Light energy (Use) → cyclic ⟶ ATP (products)

only PS-I
(abnormal pathway)

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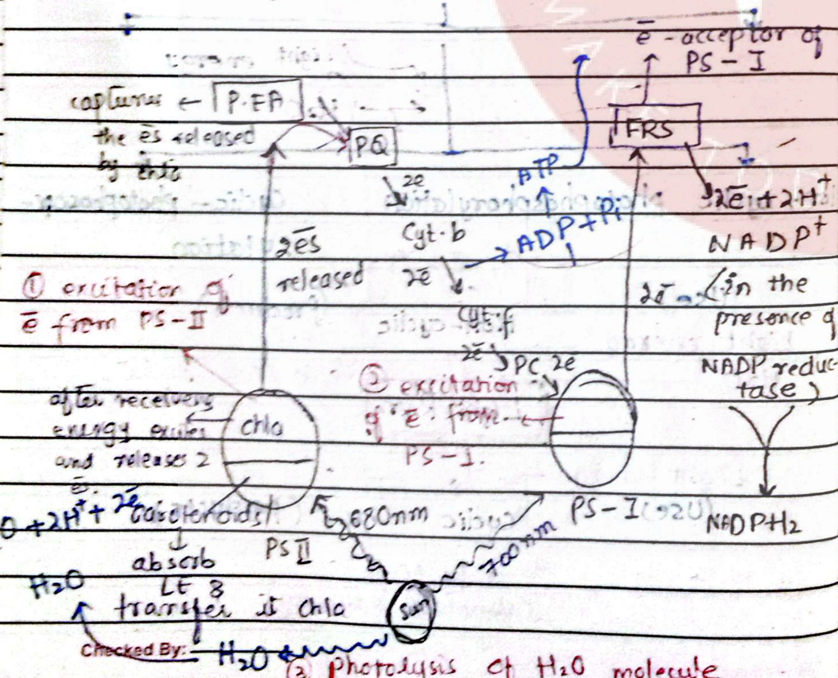
→ cyclic photophosphorylation. it's called abnormal pathway because it occurs when → low ATP production → more $NADPH_2$ production → Activity of PS-II is blocked.

LIGHT RXN:
NON CYCLIC ELECTRON PATHWAY:

→ also called Z-scheme (bcz the ēs revolve in zig-zag manner)
→ final product $NADPH_2$.
→ final ē acceptor $NADP^+$
→ The chl a recieves its lost ēs from the photolysis of water and fulfill its deficiency
→ The ēs from PS-II chl a and $2H^+$ ions from the photolysis of water are recieved finally by NADP in the presence of NADP reductase.



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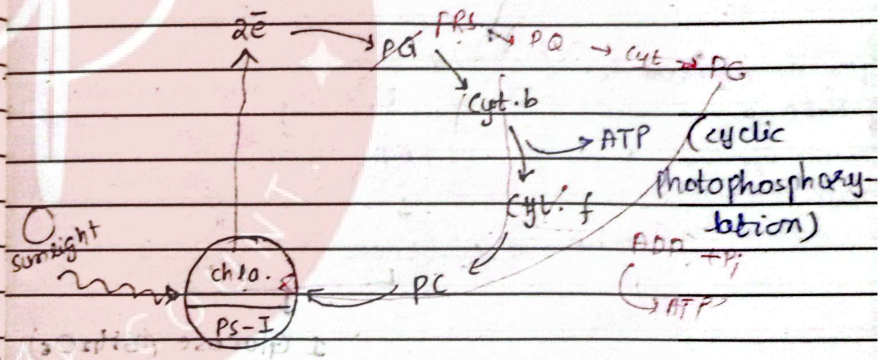
→ Two photon are required to excite 2ēs of chlorophyll a.
→ Non-cyclic Electron Pathway steps / non-cyclic photophosphorylation
↳ ① excitation of ē from PS-II
↳ ② excitation of ē from PS-I
↳ ③ photolysis of H_2O.

CYCLIC ELECTRON PATHWAY.
→ abnormal pathway
→ ēs revolve in cyclic manner
→ only PS-I is involved. The activity of PS-II is blocked when there is a low intensity of light i.e in the evening time.



CALVIN CYCLE / DARK RXN:
↳ steps
↳ ① Carbon fixation
↳ ② Reduction
↳ ③ Regeneration of RuBP

CALVIN ka CONA (6 words)
6 × 10
6
ATP 6×3
6×NADPH
12
18

→ Occurs in stroma of chloroplast

for 1 calvin cycle multiply it with 3.

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→ But in dark rxn, the energy is stored in the form of starch.

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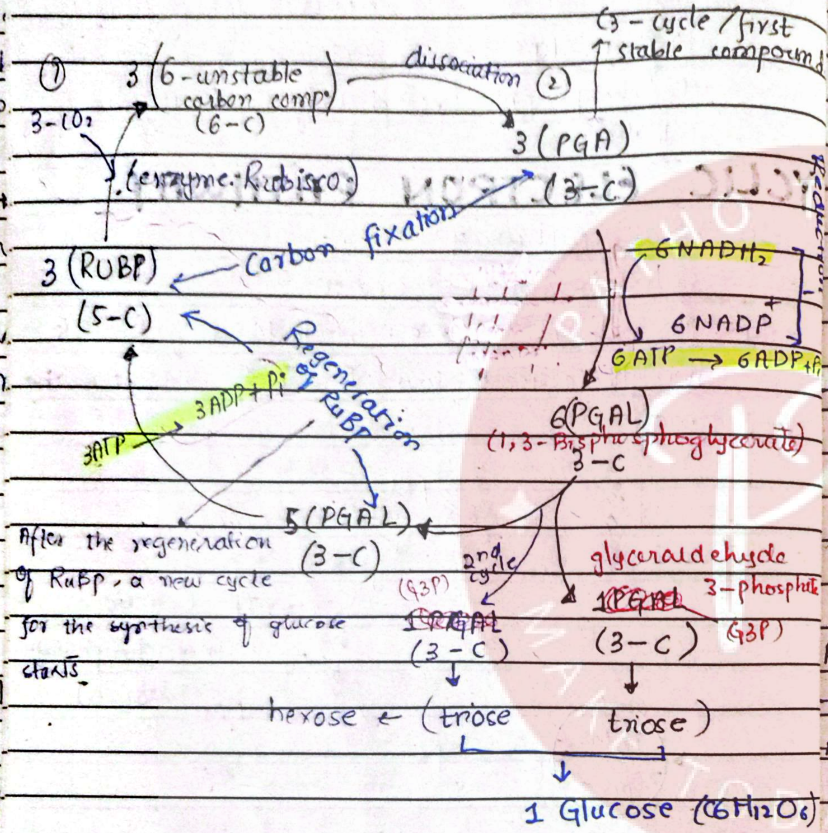
1) NADPH₂ and ATP → Products of light Rxn
↳ used in stroma in dark rxn.



2) 1 glucose formation requires 2 dark rxn.
3) 1 dark rxn needs → 9 ATP, 6 NADPH₂
3) (2 dark rxn needs) → 18 ATP, 12 NADPH₂
1 glucose molecule
4) excluding the 3rd step i.e regeneration of RuBP in which 3 ATP are used; then 1 glucose formation requires 15 ATP molecule.

15 → 6 + 3 → for one cycle → 1 3C compound
→ 6 → for the formation of 2nd 3C compound
→ Now the next '3' ATP are used for the initiation of next cycle ...

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Cyclic Photophosphorylation : 2 ATP
Non-cyclic Photophosphorylation : 1 ATP + 2 NADPH₂

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MCQ 3 glucose molecules require how much ATP and NADPH₂

Ans : 54 ATP + 36 NADPH₂

RESPIRATION

→ the redox process in which the organic food are broken down and energy is released.

→ $C_6H_{12}O_6 + O_2 \longrightarrow 6CO_2 + 12H_2O + ATP$
(glucose)
38 (total) 36 (net)

Types

Anaerobic Respiration
→ no. O₂ required
→ also called fermentation

Aerobic Respiration
→ O₂ is required.

Lactic Acid Fermentation
→ occurs in muscle cells and bacteria
(1st step)
→ Glycolysis (1st step)
Glucose → 2 Pyruvic Acid + 2 ATP)
Pyruvic acid + ATP → (Lactic Acid) end product

Alcoholic Fermentation
→ yeast, micro-organism
(1st step)
→ Glycolysis (1st step)
(Glucose → 2 Pyruvic acid + 2 ATP
↓
ethanol + CO₂
(alcohol)

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→ Due to which type of fermentation muscle fatigue occur
Lactic Acid fermentation.
(bcz lactic acid accumulates in the muscles and causes muscle fatigue).

↳ Aerobic Respiration

→ cellular respiration

Aerobic Respiration

Glycolysis	Linked reaction P.A.O	Kreb's cycle	Respiratory ETC
→ cytoplasm	→ mitochondrial matrix	→ mitochondrial matrix	cristae

→ GLYCOLYSIS:-

↳ common in aerobic as well as anaerobic organisms.

↳ $C_6H_{12}O_6 \xrightarrow{2ATP} 2(C_3H_4O_3) + 4ATP + 2NADH_2$

→ also called EMP (Embeden Myrof Parmas Pathway)

→ glycolysis is the anaerobic phase of aerobic respiration.

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→ steps of Glycolysis → Preparatory phase (investment phase) → 2ATP are used
→ Oxidative phase (pay off phase)

MCQ How many ATP are formed in glycolysis?
Total formed ATP are 4 and net gain is 2ATP.

Preparatory Phase

Glucose — 1st step: Phosphorylation of glucose
↓ ATP → ADP + Pi (bursting of ATP)
Glucose-6-phosphate (Phosphate attached at C-6)
↓ (glucose isomerized into fructose 6-phosphate).
Fructose-6-phosphate
↓ ATP → ADP + Pi
Fructose 1-6-Biphosphate (Pi at C1 and C6) (phosphorylation of fructose)

DHAP ⟵ Interconvertable ⟶ PG3 / G3P
(dihydroxyacetone phosphate) (3-C) (ketone) — (glyceraldehyde 3-Phosphate (3-C) (aldehyde).

→ For one preparatory phase in glycolysis, 2 oxidative phases are required.
→ In one oxidative phase, G3P is oxidized.
→ In the 2nd oxidative phase, DHAP → G3P → then Oxidized

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→ No investment of ATP in oxidative phase [illegible]
Inorganic phosphate is provided by cytoplasm.

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Oxidative Phase

oxidation

G_3P (phosphate attached only at 3C)

P_i → (from cytoplasm)

→ NAD^+ → $2NADH_2$ → reduction: 1st in 1st oxi. phase, 2nd in 2nd

↓

1, 3 - BPGA (phosphate attached at 1 and 3 position/C)

By

↓ $ADP + P_i \rightarrow 2ATP$ → 1 ATP produced during the oxi of G_3P; 2nd ATP produced during the oxi. of DHAP

↓

3 - PGA (C - C - C with P)

↓ (rearrangement)

2 - PGA

↓ → H_2O

phosphoenol pyruvate

↓ → 2ATP → 1 ATP in 1st oxidative phase; 2nd ATP in 2nd oxidative phase

2 (Pyruvic acid / pyruvate)

↳ 1 incomplete oxidation of glucose give rise to $2NADH_2$, 2 ATP, $2H_2O$ and 2 Pyruvic acid molecules.

↳ ~~So two oxidative phases give rise to,~~
~~1) 4 ATP~~ ~~3) 4 H_2O molecules~~
~~2) 4 $NADH_2$~~ ~~4) 4 pyruvic acid molecules~~ ✗

↳ **Products of Glycolysis:**

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1) 2 NADH₂ 2) $2H_2O$ 3) 2 ATP (net gain). 4ATP (total)

4) 2 Pyruvic acid.

↳ The ATP formed in glycolysis is called substrate level phosphorylation.

↳ Photosynthesis → photophosphorylation

↳ Kreb's cycle → substrate-level phosphorylation
+ Glycolysis

↳ Electron Transport chain → oxidative phosphorylation

LINKED RXN :-

→ Glycolysis ⟶ Kreb's cycle (mitochondrial matrix)
(citric acid cycle).

↓

LINKED RXN (mitochondrial matrix).

(Pyruvic Acid Oxidation)

$$2\ \text{Pyruvate}\ (C_3H_4O_3) + 2NAD^+ \xrightarrow{\text{Co.A}} 2\ \underset{(2-C)}{\text{Acetyl Co. A}} + 2NADH_2 + 2CO_2$$

(reduction)

oxidation

MNEMONIC FOR KREB'S CYCLE :

Our City Is Kept Safe and Sound from Murder

→ Kreb's cycle is also called citric acid cycle and tricarboxylic acid cycle.

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→ when the C number decreases from the ... next, then there is one ~~carbon~~ CO_2 released. (isocitrate → α-glutarate

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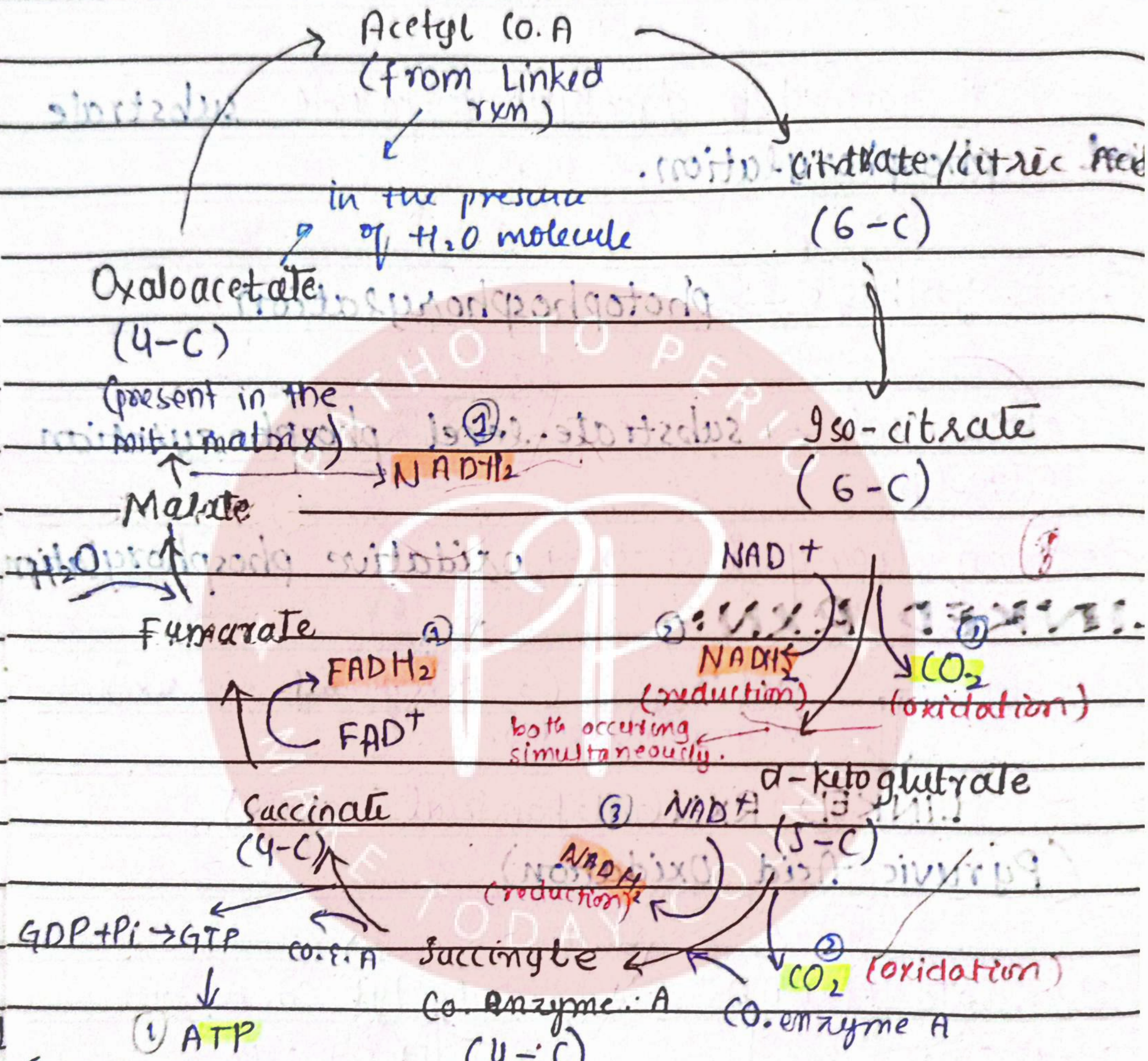
KREB's CYCLE

4 6[2] 5 4[2] 4[2]



(substrate level phosphorylation)

Glycolysis + Krebs cycle: (substrate level phosphorylation)

Products of Kreb's cycle:-

→ 1 Kreb's cycle = 1 ATP + 3 $NADH_2$ And 1 $FADH_2$ and $2CO_2$

→ 2 molecules of Acetyl Co.A were formed in the linked, so only 1 molecule is oxidized in one

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→ the $NADH_2$ in the cytoplasm form 2ATP bcs it loses 1 on its way to the mitochondria.

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Kreb's cycle.

→ 1 glucose molecule complete oxidation = 2 Kreb's cycle.

→ 2 Kreb's cycle = 2 ATP, 6 $NADH_2$ and 2 $FADH_2$ and 4 CO_2

* $NADH_2$ in cytoplasm is called external $NADH_2$ which give rise to 2ATP.
* $NADH_2$ in the mitochondrial matrix is called internal $NADH_2$ which give rise to 3ATP. They are either formed in the linked rxn or Kreb's cycle.

How many ATP are formed directly/indirectly in one Kreb's Cycle?

1 Kreb's cycle : 1 ATP (direct) ; $NADH_2$ = 3ATP, $FADH_2$ = 2ATP (forms ATP indirectly)

forms 3 ATP forms 2ATP

⇒ 1 Kreb's cycle : 1ATP 3×3 (9) 2×1 (2)

→ For 2 Kreb's cycle; 2 ATP, 6 $NADH_2$ and 2 $FADH_2$

6×3 $NADH_2$ 2×2 $FADH_2$

2 ATP (18 ATP 4ATP) indirect ATP

46 25 94

Total ATP formed in Respiration:-

1) Kreb's cycle : 2 ATP (direct), (22 ATP indirect from NADH₂ and FADH₂)
(total = 24 ATP)

2) In glycolysis → 2 $NADH_2$ were formed = 4 ATP
↓
4 ATP +

In glycolysis → 4 direct ATP were formed but the net gain was 2 ATP
(6 ATP) — 4 ATP from 2 $NADH_2$ and 2 ATP ~~from~~ directly.

3) In linked rxn → 2 $NADH_2$ were formed = 6 ATP
(6 ATP)

→ Hence ~~total~~ ATP ~~were~~ formed are 36 ATP (net gain) and total ATP (38 ATP).

RESPIRATORY ETC :

→ occurs in cristae

During the ETC the $NADH_2$ and $FADH_2$ formed during glycolysis, linked rxn and Kreb's cycle is oxidized by molecular oxygen and energy (ATP) is released.

↓

(Oxidative Phosphorylation)

$NADH_2 \rightarrow 2H^+$
↓
NAD^+ $\xrightarrow{\text{releases}}$ $2e^-s$ → Coenzyme Q $\xrightarrow{2e^-}$ Cyt. b $\xrightarrow{\uparrow ATP}$ Cyt. c
↓
ADP + Pi → ATP

$FADH_2$ → FAD^+

Cyt. c $\xrightarrow{2e^-}$ Cyt. a → Cyt. a_3 → ATP

final product
$H_2O = 2H^+ + \frac{1}{2}O_2$

→ the ATP formed by the oxidation of a chemical substance → oxidative phosphorylation

→ final electron acceptor in RTC is O_2.
→ final product in RTC is H_2O.

→ The ATP formed in RTC is indirect ATP bcz it is formed by the oxidation of coenzymes.

Energy Calculation:-

	$NADH_2$	$FADH_2$	ATP	Net ATP
Glycolysis	2 (formed) so ATP = 4 ATP	0	2/4 ATP (net / total)	6/8 ATP (net / total)
Linked Rxn:	2 $NADH_2$ formed so, ATP = 2×3 = 6	0	0	6 ATP
Kreb's cycle (2 Kreb's cycle)	6 $NADH_2$ formed so ATP = 6×3 = 18	2 $FADH_2$ formed so ATP = 2×2 = 4 ATP	2 ATP	24 ATP

Total ATP from 1 glucose = 36 / 38
36 (net) ↓ 2 were consumed in glycolysis; 38 (total)

→ Why does the oxidation of $NADH_2$ and $FADH_2$ does not occur in the cytoplasm?

It is bcz it requires O_2 which is present in mitochondria. It occurs in the cytoplasm but in prokaryotes

M T W T F S DATE: 20

MCQ For one maltose synthesis during photosynthesis how many ATP and $NADPH_2$ are required?

- Maltose is formed from two glucose molecules.
- Maltose = Glucose + Glucose
- for one glucose molecule 18 ATP and 12 $NADH_2$ are required. So for one maltose molecule;

18×2 and 12×2

$\boxed{= 36\ ATP \text{ and } 24\ NADH_2}$