

A2 BIOLOGY 9700

PROSPERITY ACADEMY

Crash Course

ZUHA FATIMA

ENERGY AND RESPIRATION

COMPLETE NOTES



0331 - 2863334



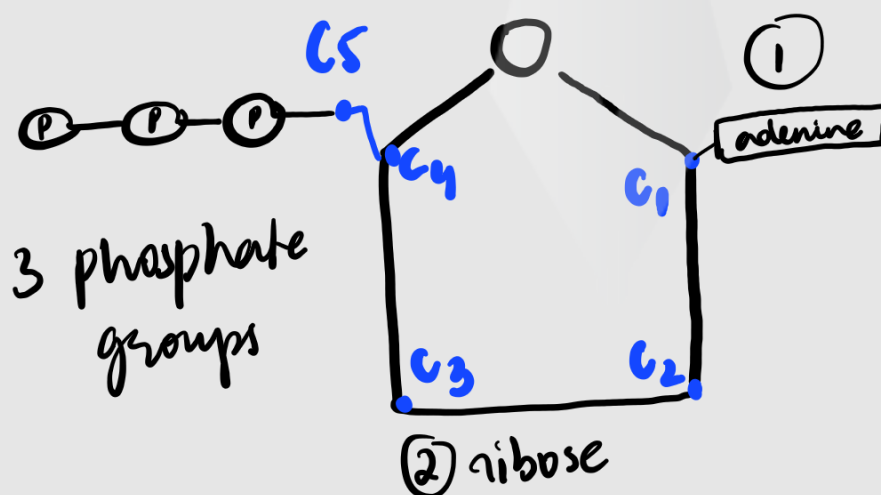
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Chap 12: Energy and Respiration

- energy is locked in organic / biological molecules (carbohydrates, proteins, lipids) which is released through respiration.
- All organisms require energy for their fundamental life processes.
- ATP (adenosine triphosphate) is the universal energy currency of cells.

Let's recall the structure of ATP

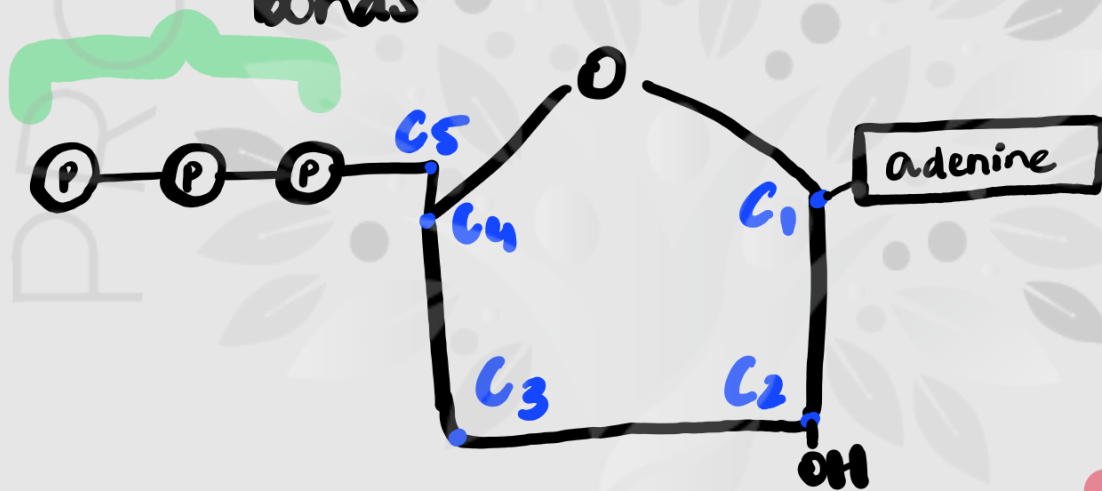


↓
adenosine
triphosphate

Structure of ATP: (i) Ribose (5C ^{pentose} sugar)
 (ii) Adenine (nitrogenous base)
 (iii) 3- Phosphate groups

a phosphorylated/ activated nucleotide

energy rich bonds



ribose + adenine = adenosine

ribose + adenine + P = AMP
 (adenosine mono)

ribose + adenine + P + P = ADP
 (adenosine di)

ribose + adenine + P + P + P = ATP

Energy requiring processes

- active transport / bulk transport
- movement / locomotion
 - ↳ (i) muscle contraction
 - (ii) movement of cilia / flagella
- transmission of nerve impulses ($\text{Na}^+ - \text{K}^+$ pump)
- homeostasis
- anabolic reactions
(eg: DNA replication, protein synthesis)
- bioluminescence (conversion of chemical energy into light energy)



ATP

Why is ATP the universal energy currency??

- energy in ATP is in its readily usable form.

① Small size (low mr)

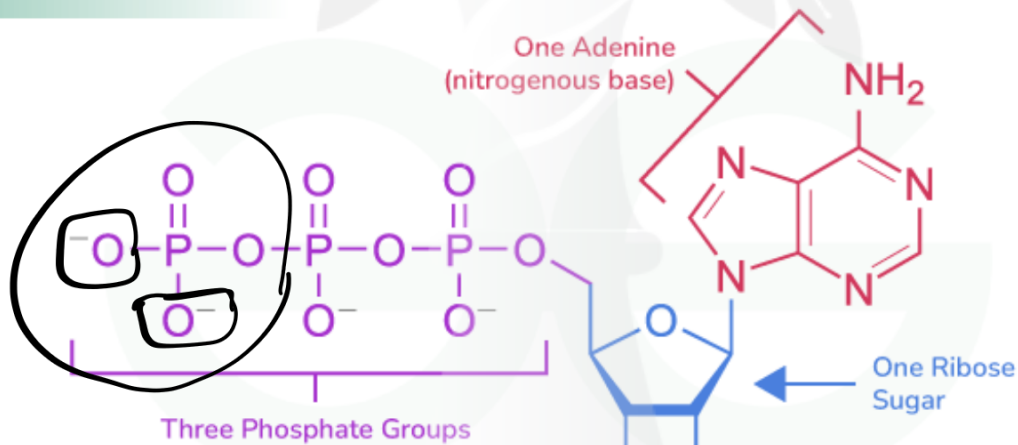
② Negatively charged
↓
ease of hydrolysis

③ releases large amount of energy

⑤ does not spontaneously hydrolyze (stable)

④ easily regenerated

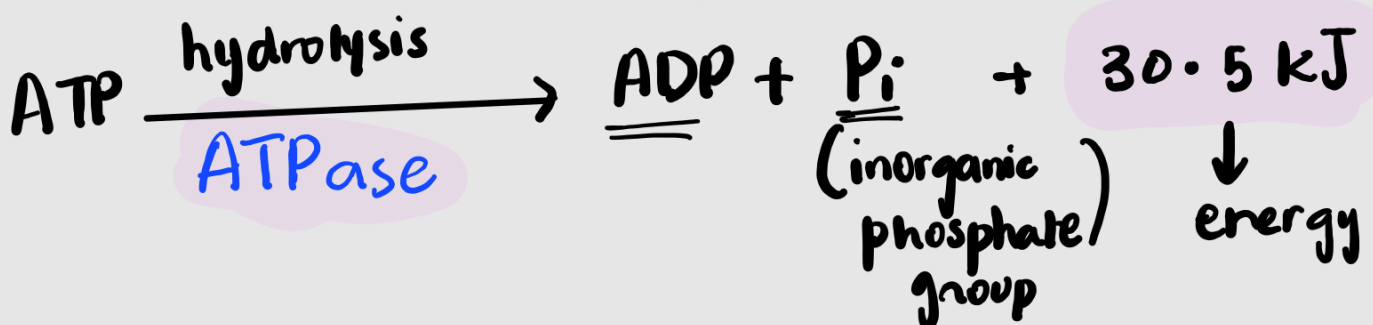
Structure of ATP



like charges $\Rightarrow$ repel

easier to break the bonds between phosphate groups

ATP- Adenosin Triphosphate

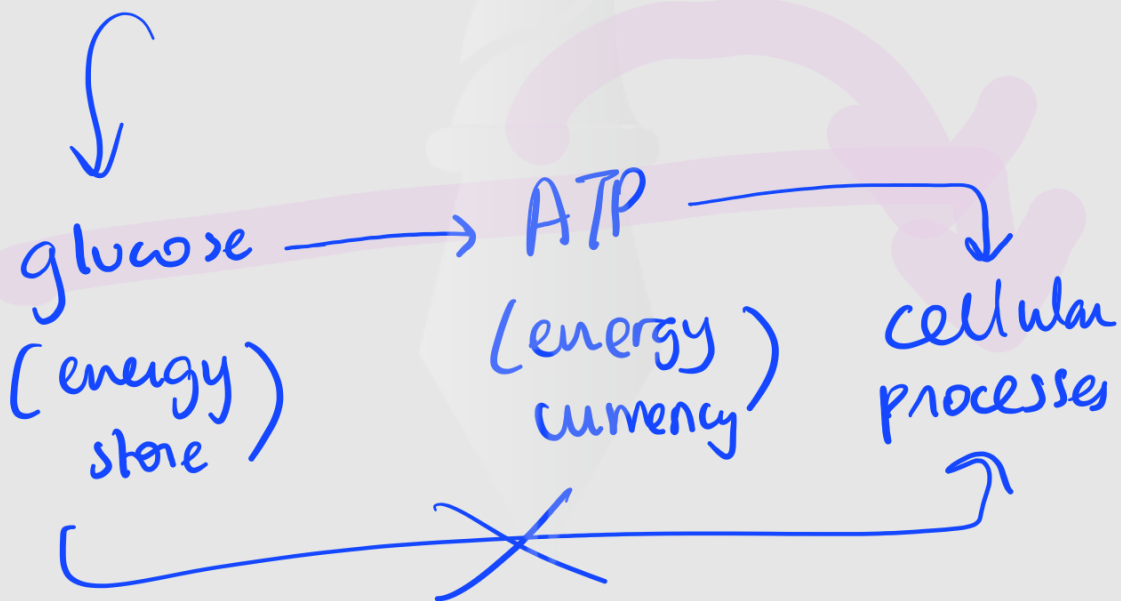


- ATP is continuously being hydrolysed in the cell for cellular processes.

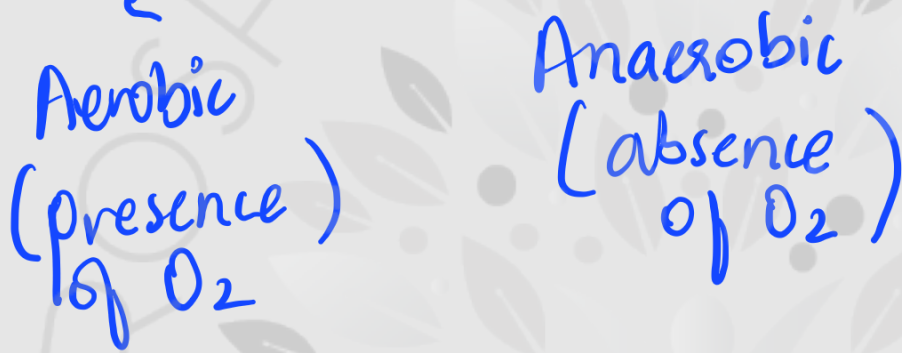
DOES THAT MEAN A CELL RUNS OUT OF ATP?



from organic
molecules'
respiration



Respiration: oxidation of food molecules to release energy in the form of ATP.



⇒ Eukaryotic cells

- | | | |
|-----------------------------|-------------|---------|
| ① Glycolysis | ⇒ cytoplasm | Glucose |
| ② Link reaction | } Matrix | lones |
| ③ Kreb's Cycle | | Killing |
| ④ Oxidative phosphorylation | | Oxygen |

(electron transport chain)

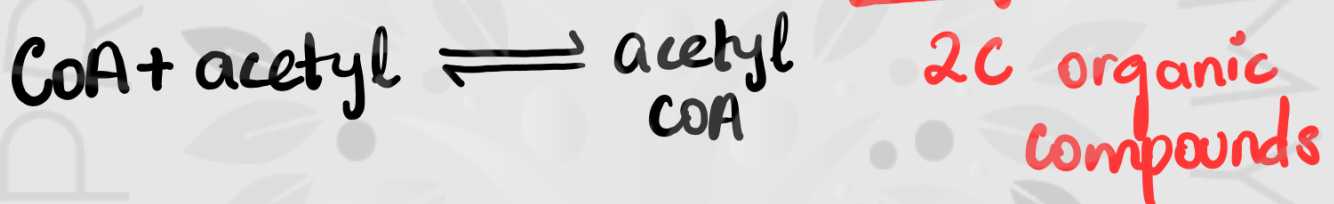
→ Inner memb of mitochondria /
Cristae

Coenzymes used in respiration

↳ Vitamin derivatives

- ① NAD^+ (nicotinamide adenine dinucleotide)
- ② FAD (flavin adenine dinucleotide)
- ③ Coenzyme A

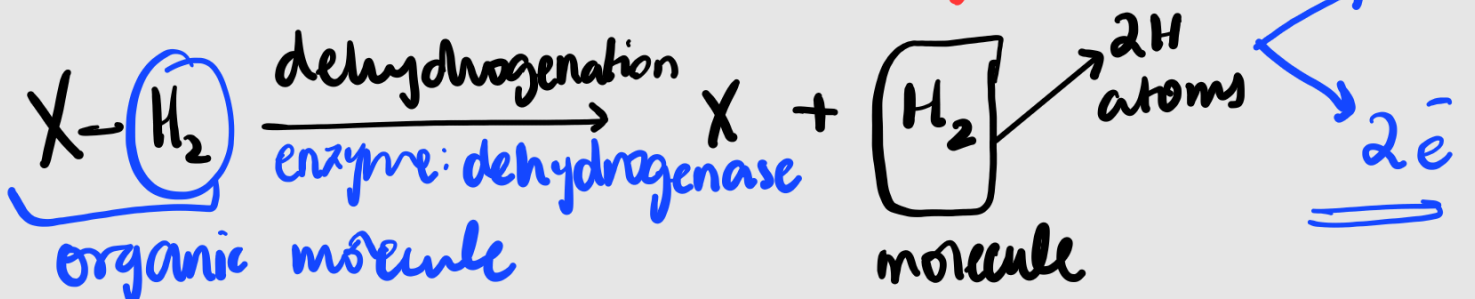
↳ serves as a carrier of acetyl group.



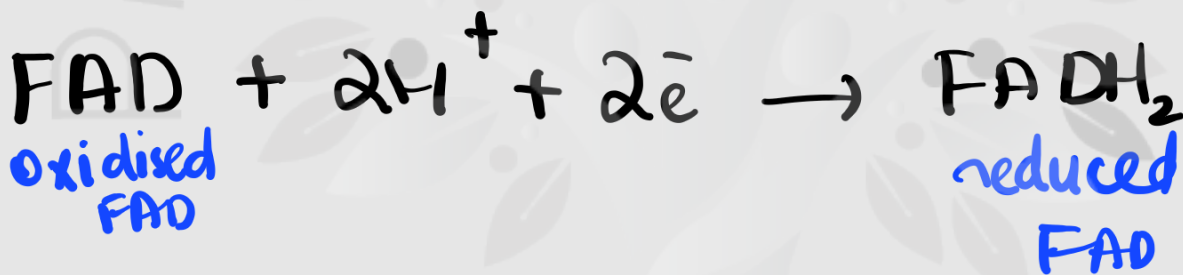
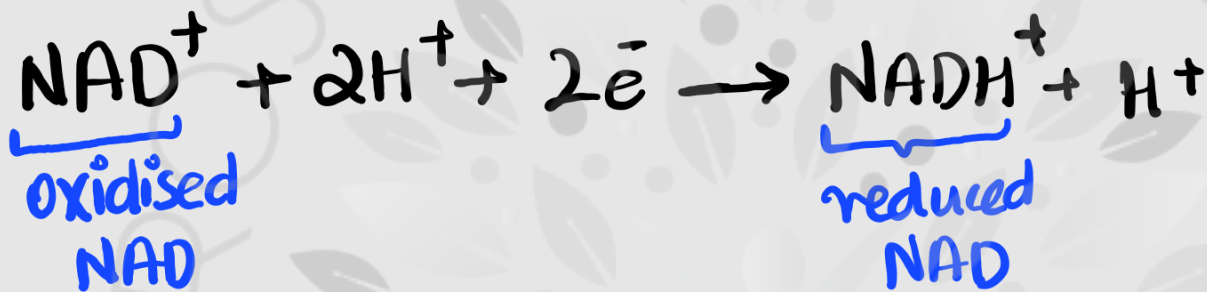
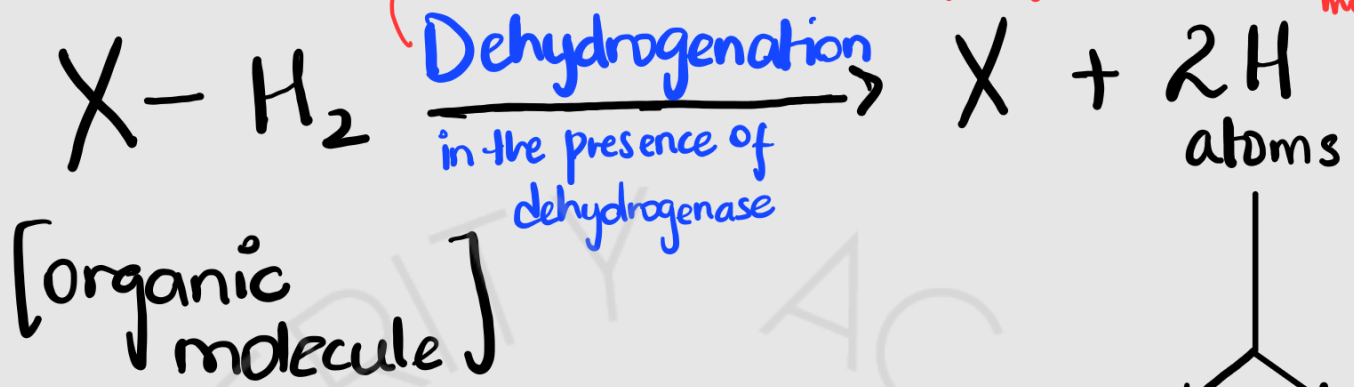
∴ NAD^+ and FAD

↳ Both are coenzymes for a group of enzymes called "DEHYDROGENASES"

↳ Both serve as hydrogen/proton carriers and electron carriers.

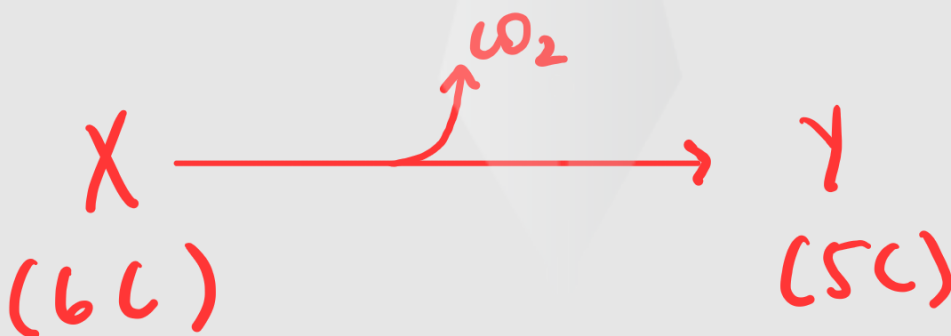


is a form of oxidation which involves the removal of hydrogen atoms from organic molecules



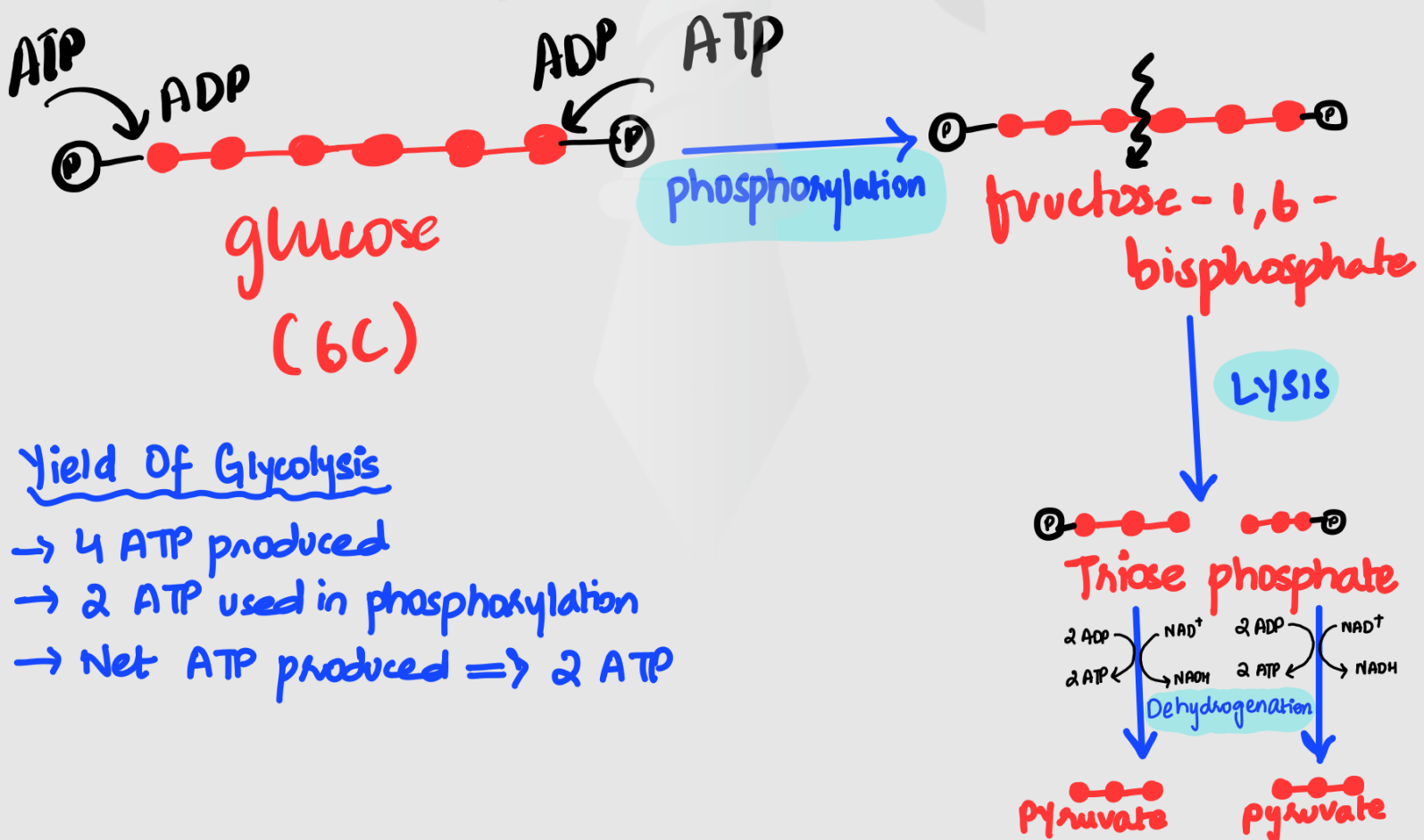
Decarboxylation

↳ removal of CO_2 from an organic molecule



Glycolysis

- takes place in the cytoplasm of the cell.
- means "splitting of sugars"
- oxygen independent process. → anaerobic resp
- can be subdivided into 3 stages:
 - (i) Phosphorylation → addition of P
 - (ii) Lysis
 - (iii) Dehydrogenation

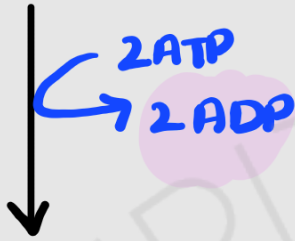


Yield Of Glycolysis

- 4 ATP produced
- 2 ATP used in phosphorylation
- Net ATP produced $\Rightarrow$ 2 ATP



glucose



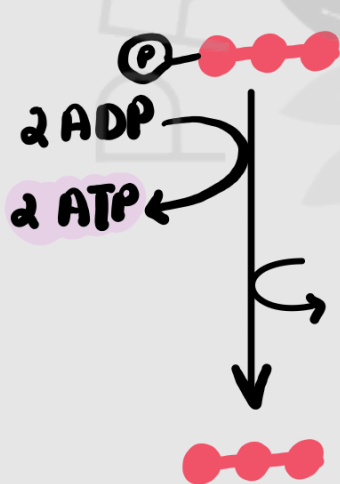
PHOSPHORYLATION



fructose - 1, 6 - bisphosphate



LYSIS



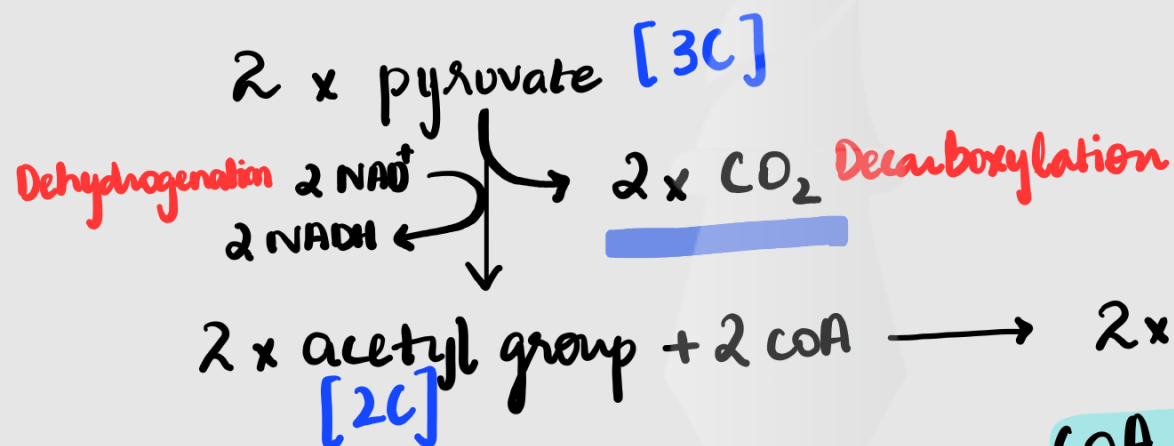
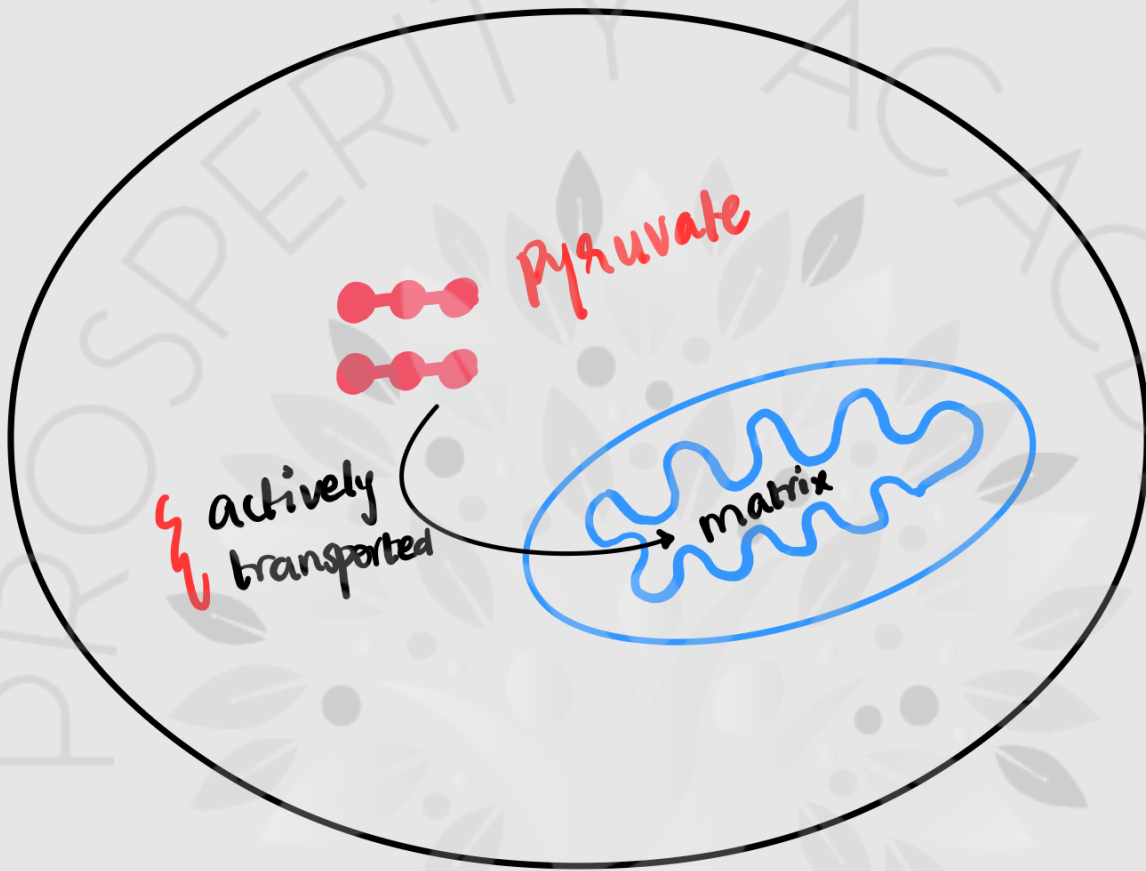
Triose phosphate x 2

DEHYDROGENATION

pyruvate x 2

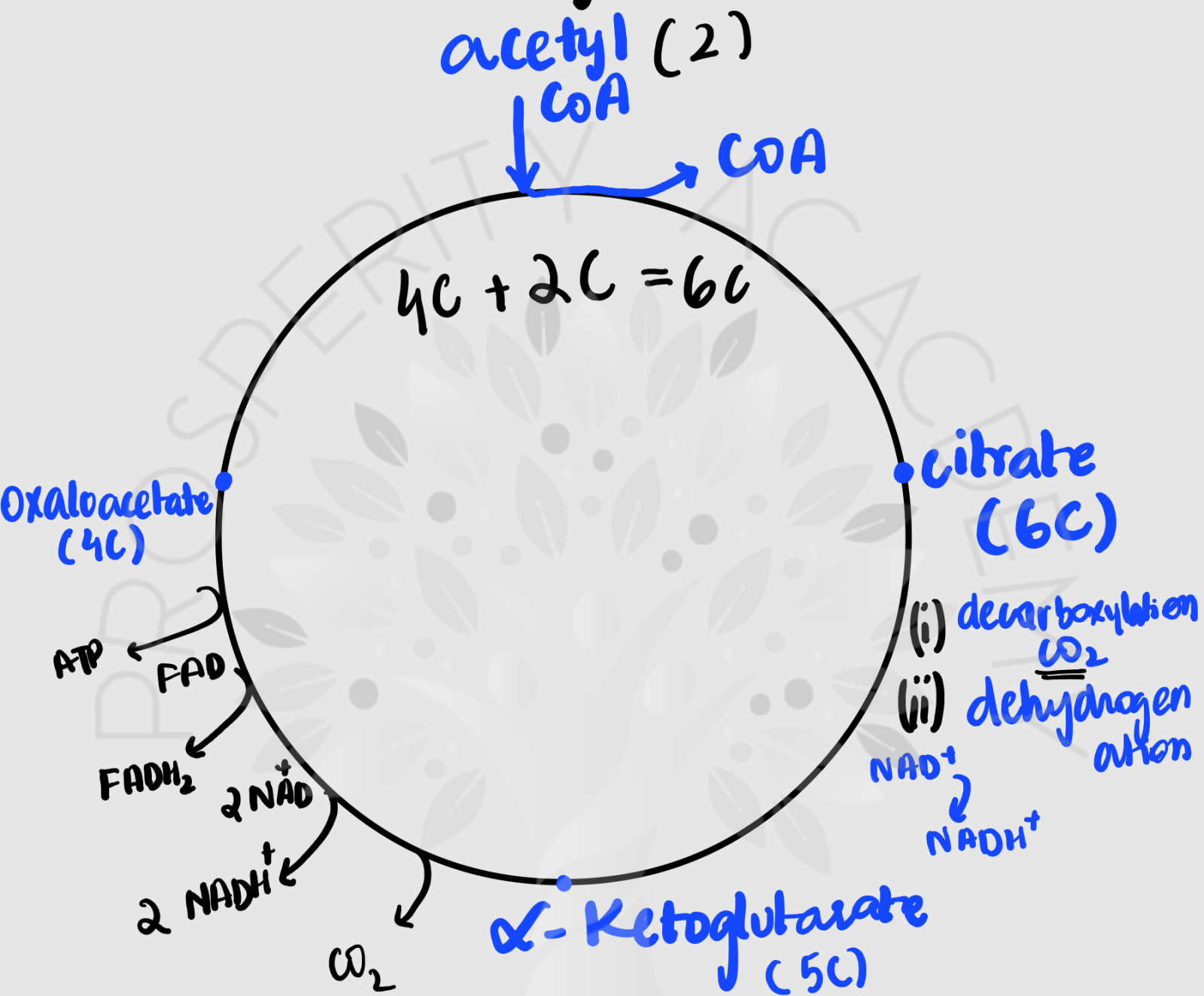
LINK REACTION

- occurs in the matrix of mitochondria



coA is a carrier of acetyl

Kreb's Cycle



In one cycle from 1 acetyl CoA

3 NADH

2 CO_2

1 $FADH_2$

1 ATP

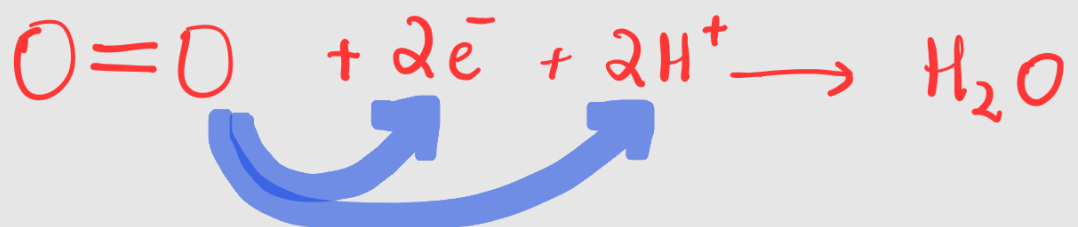
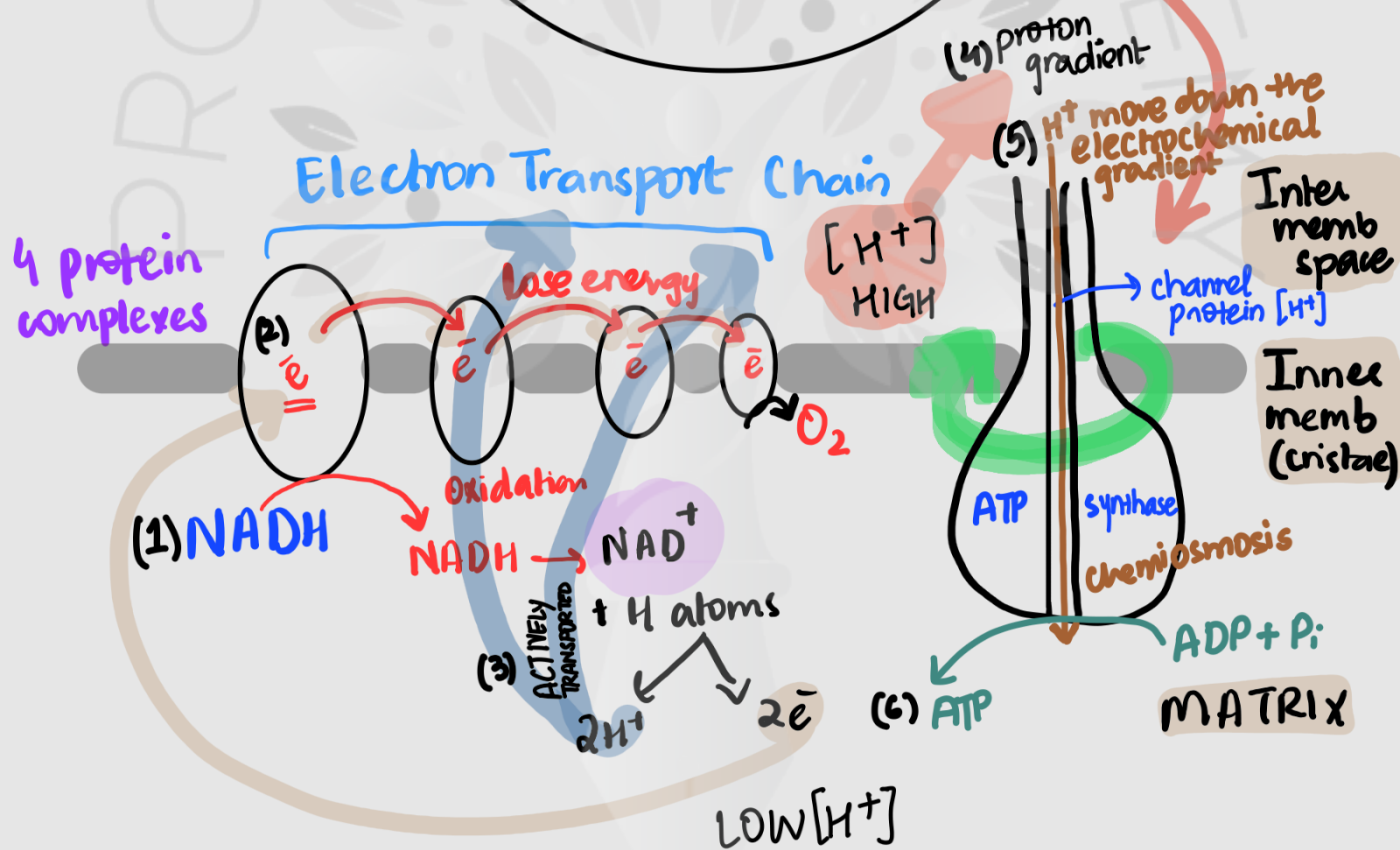
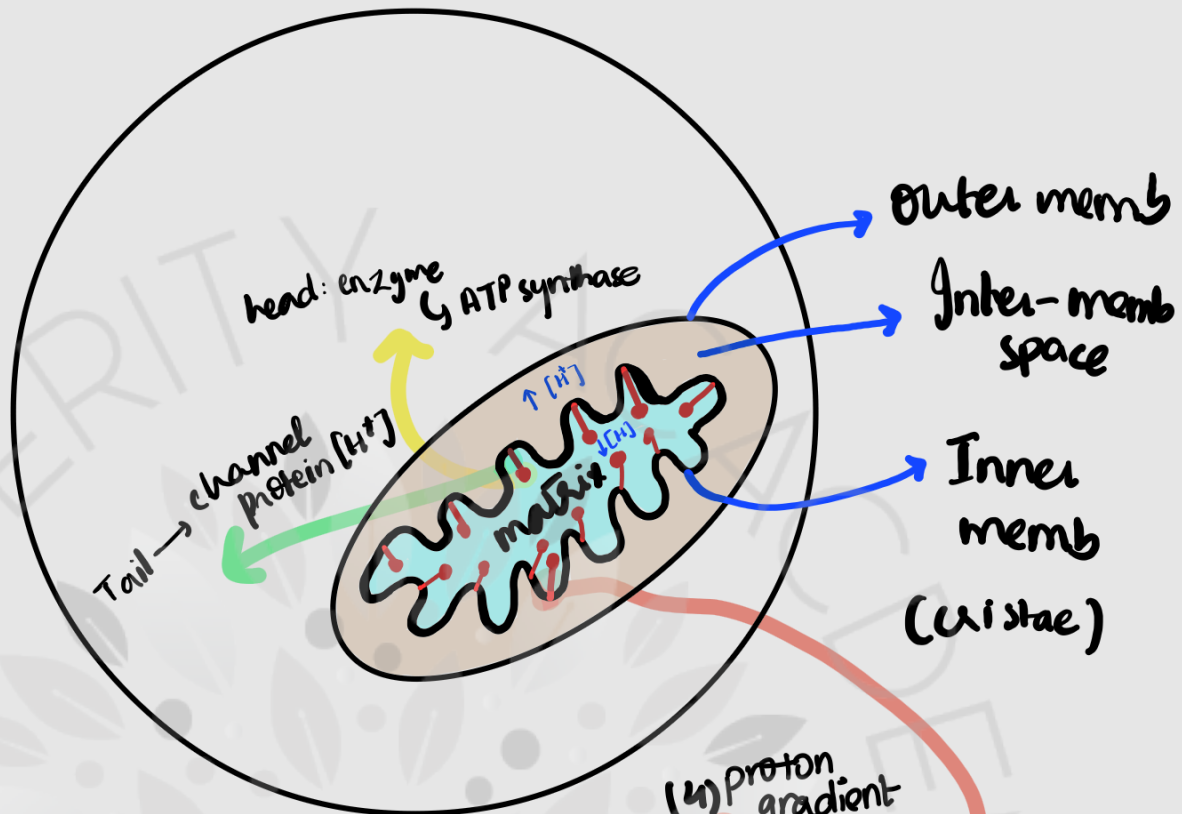
from 2 acetyl CoA

$3 \times 2 = 6$ NADH

$2 \times 2 = 4$ CO_2

$1 \times 2 = 2$ $FADH_2$

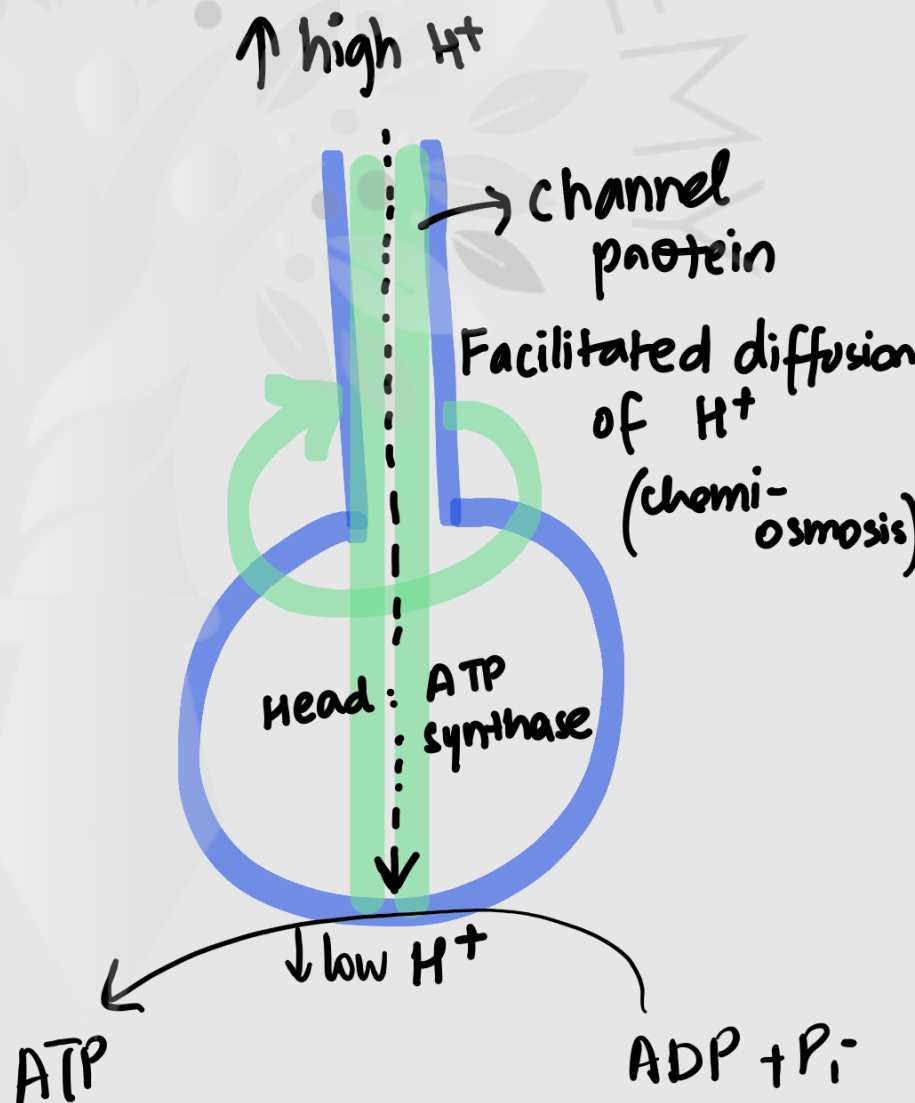
$1 \times 2 = 2$ ATP



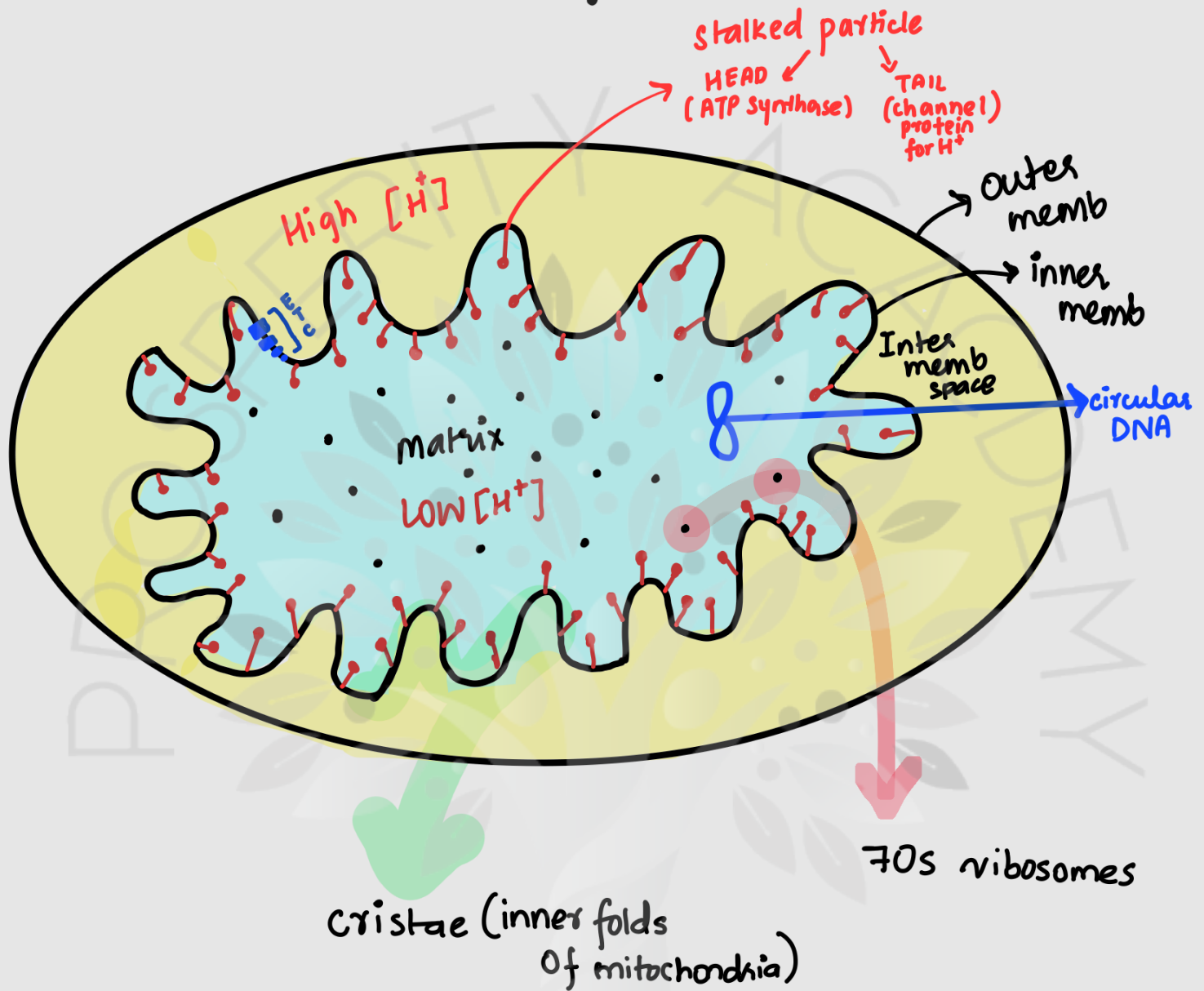
Oxidative Phosphorylation

- NADH gets oxidised at the ETC releasing hydrogen atoms.
$$\text{NADH} \longrightarrow \text{NAD}^+ + \text{H} \begin{matrix} \nearrow \text{H}^+ \\ \searrow e^- \end{matrix}$$
- Hydrogen atoms split to form protons and high energy electrons. The electrons are picked up by the ETC.
- The electrons lose energy as they move from one protein complex to another.
- This energy is used to transport H^+ from the mitochondrial matrix into intermembrane space creating a **proton gradient**.
- The electrons are eventually accepted by molecular oxygen (O_2) $\Rightarrow$ terminal electron acceptor
- $\frac{1}{2}\text{O}_2 + 2\text{H}^+ + 2e^- \longrightarrow \text{H}_2\text{O}$
- The protons move down the electrochemical gradient from the intermembrane into the matrix via channel protein of stalked particle. This releases energy which can be used to synthesize ATP via **chemiosmosis**.

- The stalked particles rotate combining ADP and P_i to form ATP using the enzyme **ATP synthase**.
- This process of producing ATP in the presence of proton motive force is known as **oxidative phosphorylation**.



Structural Features of Mitochondrion and functions

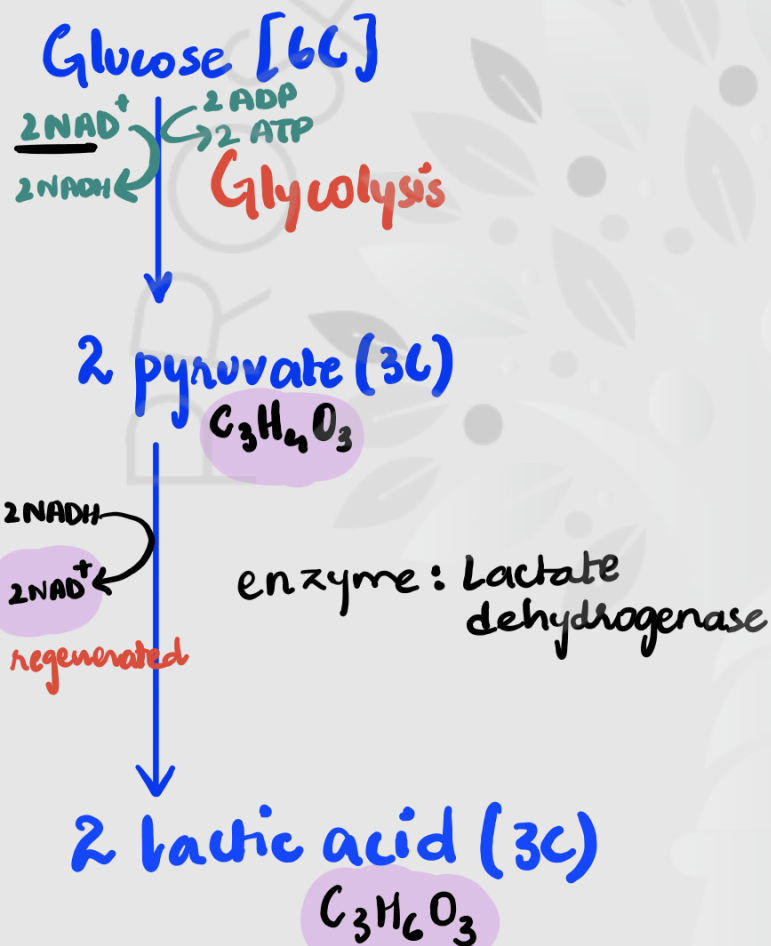


- circular DNA & 70S ribosomes: Protein synthesis for the enzymes needed in respiration & protein complexes.
- matrix: Site of Link reaction and Kreb's cycle
- Outer memb: allows entry of specific molecules such as pyruvate and reduced NAD $[NADH]$.
- Inner memb and Cristae: highly folded inner membrane provides a large surface area to accommodate ETC and stalked particles $[\Rightarrow]$ more oxidative phosphorylation & chemiosmosis = $\uparrow$ ATP Synthesis
- Intermembrane space: $\uparrow [H^+]$, creates a proton gradient for chemiosmosis

Anaerobic Respiration

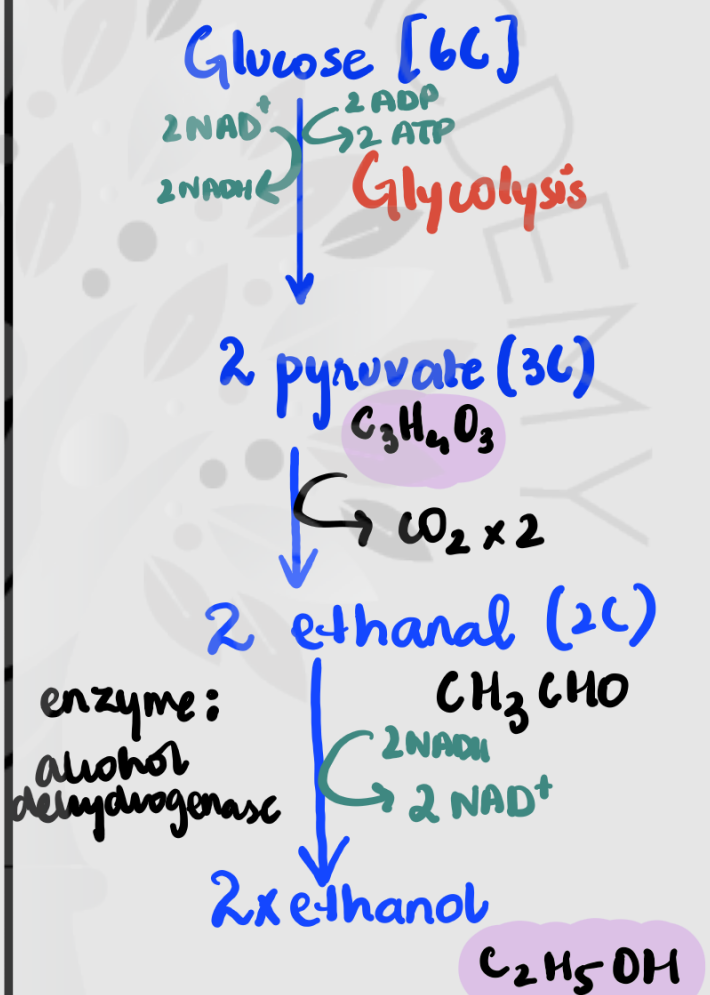
Lactate fermentation

(in mammals)



Ethanol fermentation

(in plants and yeast)



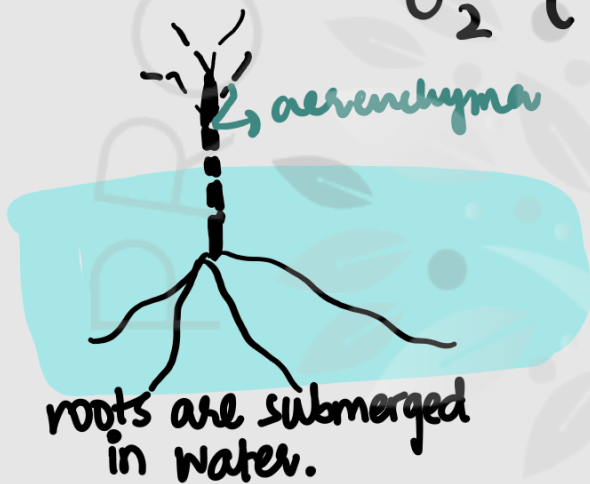
Fate of lactate in liver



Rice Plants



O_2 (barely soluble - almost insoluble)



Rice plants grow in flooded fields (paddies)

Adaptations to survive in paddies

- (i) Interconnected system of air spaces from roots to leaves called **AERENCHYMA** → ensures that O_2 may diffuse from the air towards the roots.
- (ii) **Anaerobic Respiration in roots for ATP production.** High ethanol conc. is toxic and thus "ethanol dehydrogenase" detoxifies ethanol.
- (iii) **Accelerated stem growth.**
↳ part of the rice plant is above water to allow uptake of air through stomata.

Respiratory Substrates, Energy Values & Respiratory Quotient.

(1) Respiratory Substrate: organic molecules that can be broken down to generate ATP.

carbohydrates lipids proteins

(2) Energy Values: amount of energy released per gram of a respiratory substrate.

1g of carbohydrates $\rightarrow$ 15.8 kJ

1g of proteins $\rightarrow$ 17 kJ

1g of lipids $\rightarrow$ 39.4 kJ

↳ long chain hydrocarbons

↳ more C-H bonds

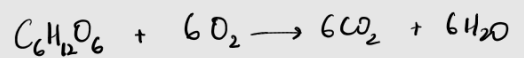
↳ more H atoms

more H^+ more e^-

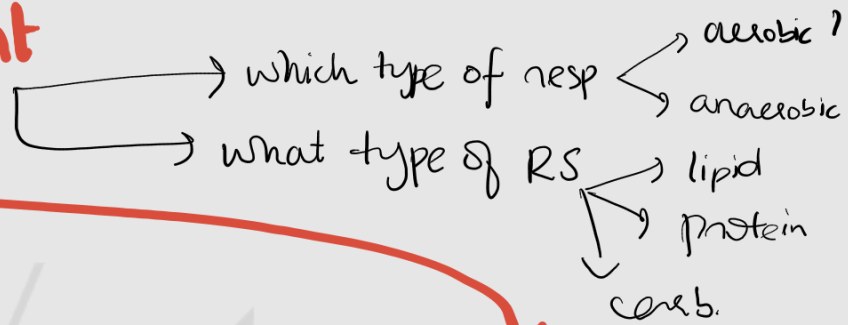
↑

↑ oxidative phosphorylation

↑ ATP synthesis



(3) Respiratory Quotient



ratio of the volume of CO_2 produced per unit time to the volume of O_2 consumed per unit time.

the ratio of the mols of CO_2 produced per unit time to the mols of O_2 consumed per unit time.

(Q) Significance of RQ values?

RQ $\Rightarrow$ 0.7 (lipids)

RQ $\Rightarrow$ 1.0 (carbs)

RQ $\Rightarrow$ 0.9 (proteins)

$$RQ = \frac{\text{amount of } CO_2 \text{ produced}}{\text{amount of } O_2 \text{ consumed}}$$

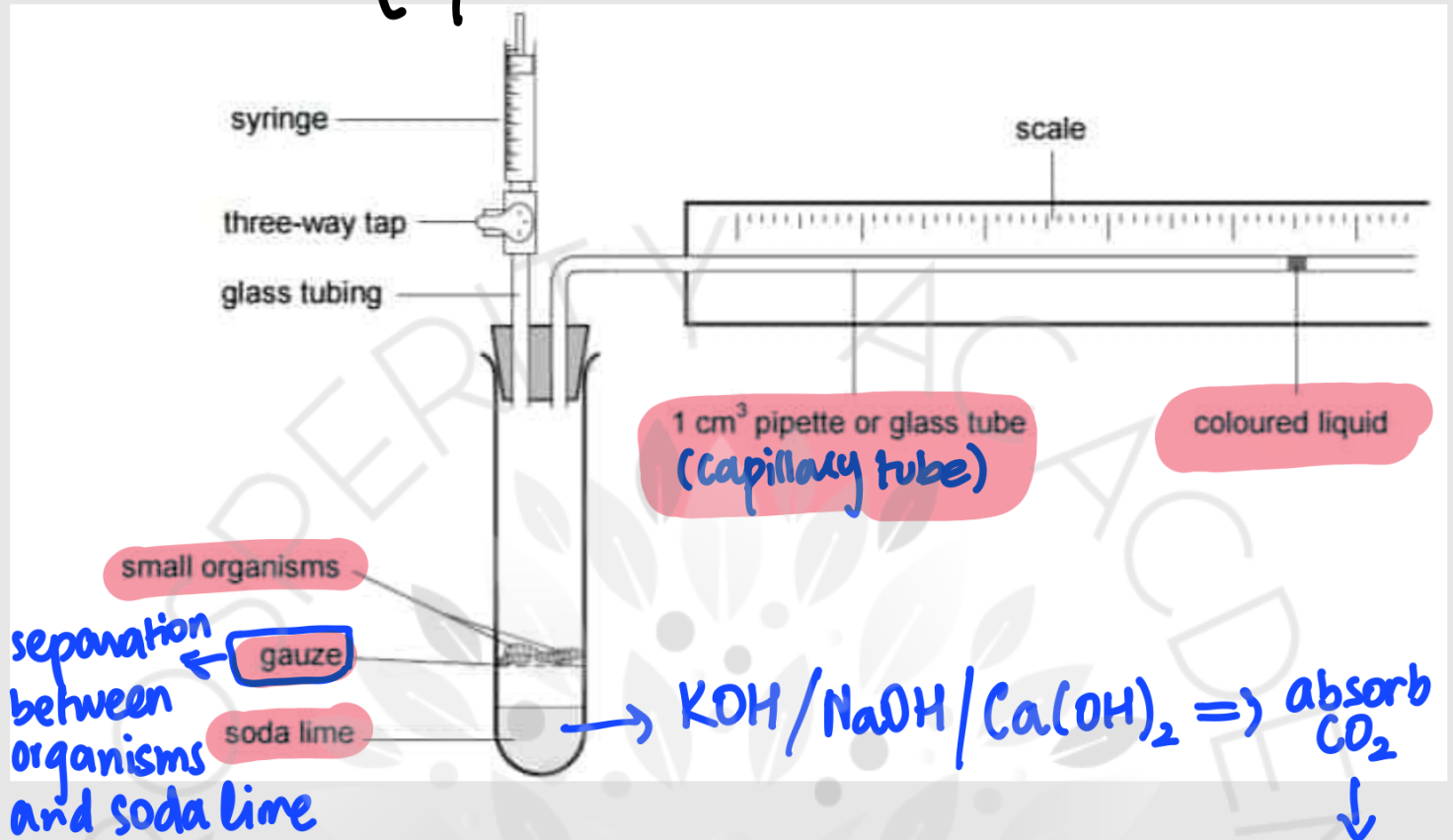


$$\frac{6}{6} = 1$$

aerobic resp $\Rightarrow$ RQ value ≤ 1

anaerobic resp $\Rightarrow$ RQ value $> \underline{\underline{1}}$

Respirometer



- results in decrease in air volume and air pressure in the experimental tube
- air from the surrounding move in (O_2 uptake for respiration) due to which the coloured liquid moves.

Volume of O_2 taken in = $\pi r^2 \times \text{distance moved by the coloured liquid.}$

$$\text{Rate} = \frac{\text{amount of reactant used} / \text{amount of product produced}}{\text{Time}}$$

$$\therefore \text{Rate} = \frac{\text{Vol of } \text{O}_2}{\text{time}}$$

Increase in temp $\rightarrow$ Increased rate of respiration

Increase in substrate conc. $\rightarrow$ Increased rate of respiration

(b) A respirometer can be used to measure the rate of respiration of germinating seeds.

Fig. 8.1 shows a respirometer.

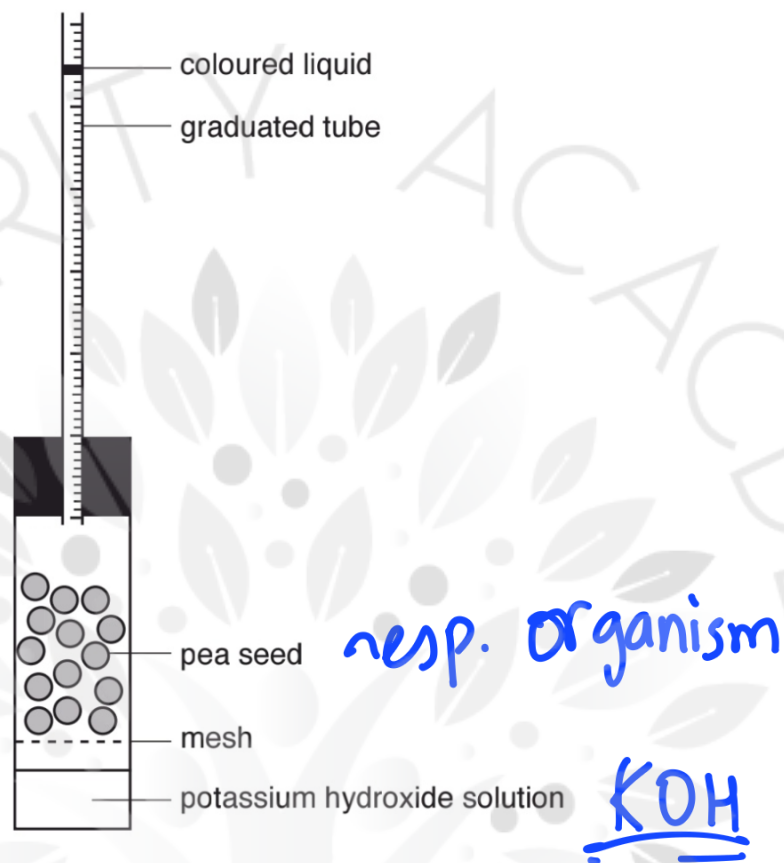


Fig. 8.1

(i) State the role of potassium hydroxide solution in the use of a respirometer.

absorbs CO_2

[1]

- (ii) As respiration takes place, oxygen is used by the seeds and the coloured liquid moves down the tube.

Describe the role of oxygen in aerobic respiration.

- ① Oxygen is used in the oxidative phosphorylation
- ② It acts as the terminal / final electron acceptor and combines with protons to form H_2O .
- ③ It ensures that the ETC is not blocked, for the OP to continue.

[3]

(c) Respirometers, as shown in Fig. 8.1, were used to investigate the effect of temperature on the rate of respiration of germinating pea seeds.

Four respirometers, **A**, **B**, **C** and **D** were set up:

- **A** and **B** in a water-bath maintained at 10°C.
- **C** and **D** in a water-bath maintained at 25°C.
- **A** and **C** each contained 30 germinating pea seeds.
- **B** and **D** each contained glass beads with a total volume equivalent to 30 pea seeds.
- The respirometers were left in the water-baths for 10 minutes.
- In each respirometer the position of the coloured liquid in the graduated tube was then marked (time 0 minutes).
- After 5 minutes the distance moved by the coloured liquid was measured.
- The volume of oxygen taken up was calculated for each respirometer.
- This was repeated after 10, 15 and 20 minutes.

Fig. 8.2 shows the results of the experiment.

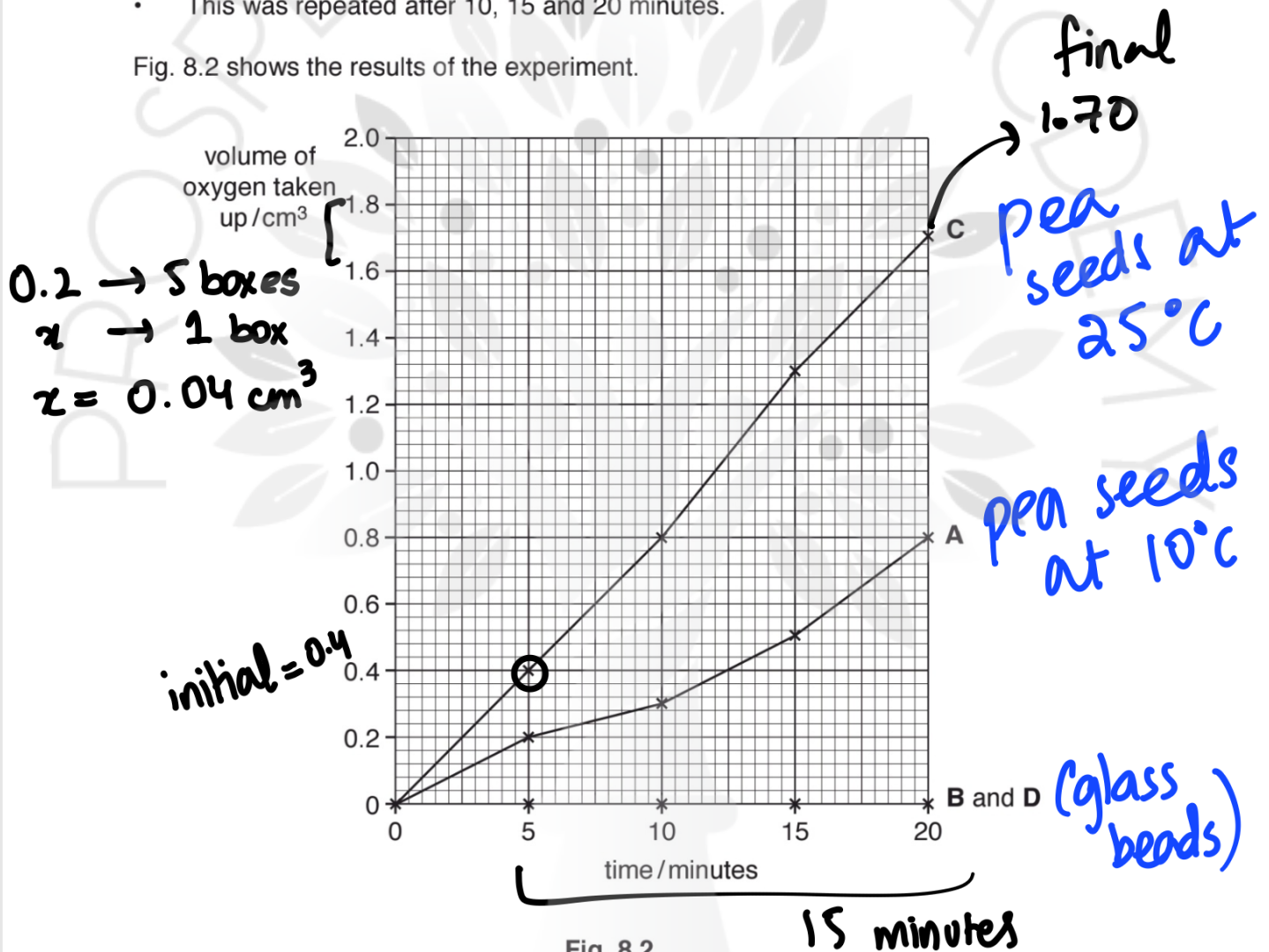


Fig. 8.2

(i) Suggest why the respirometers were left for 10 minutes before measurements were made.

to ensure that the temp of respirometer is same as the water bath. [1]

→ acclimatization

- (ii) Suggest why respirometers B and D were used in this investigation.

B and D are acting as control set ups which ensure that act as a standard base line for comparison.

[2]

- (iii) Calculate the rate of oxygen uptake in cm^3 per minute for respirometer C between 5 and 20 minutes.

Give your answer to two significant figures.

Show your working.

$$\text{rate} = \frac{\text{final V} - \text{initial V}}{\text{time}} = \frac{1.70 - 0.4}{15} = 0.087$$

answer $\text{cm}^3 \text{ min}^{-1}$ [2]

- (iv) Explain why there is an increased rate of respiration of germinating pea seeds between 10°C and 25°C .

As temp increases, the enzyme activity $\uparrow$, the KE increases, resulting in an $\uparrow$ frequency of effective collisions due to which more E-S complexes are formed.

[2]

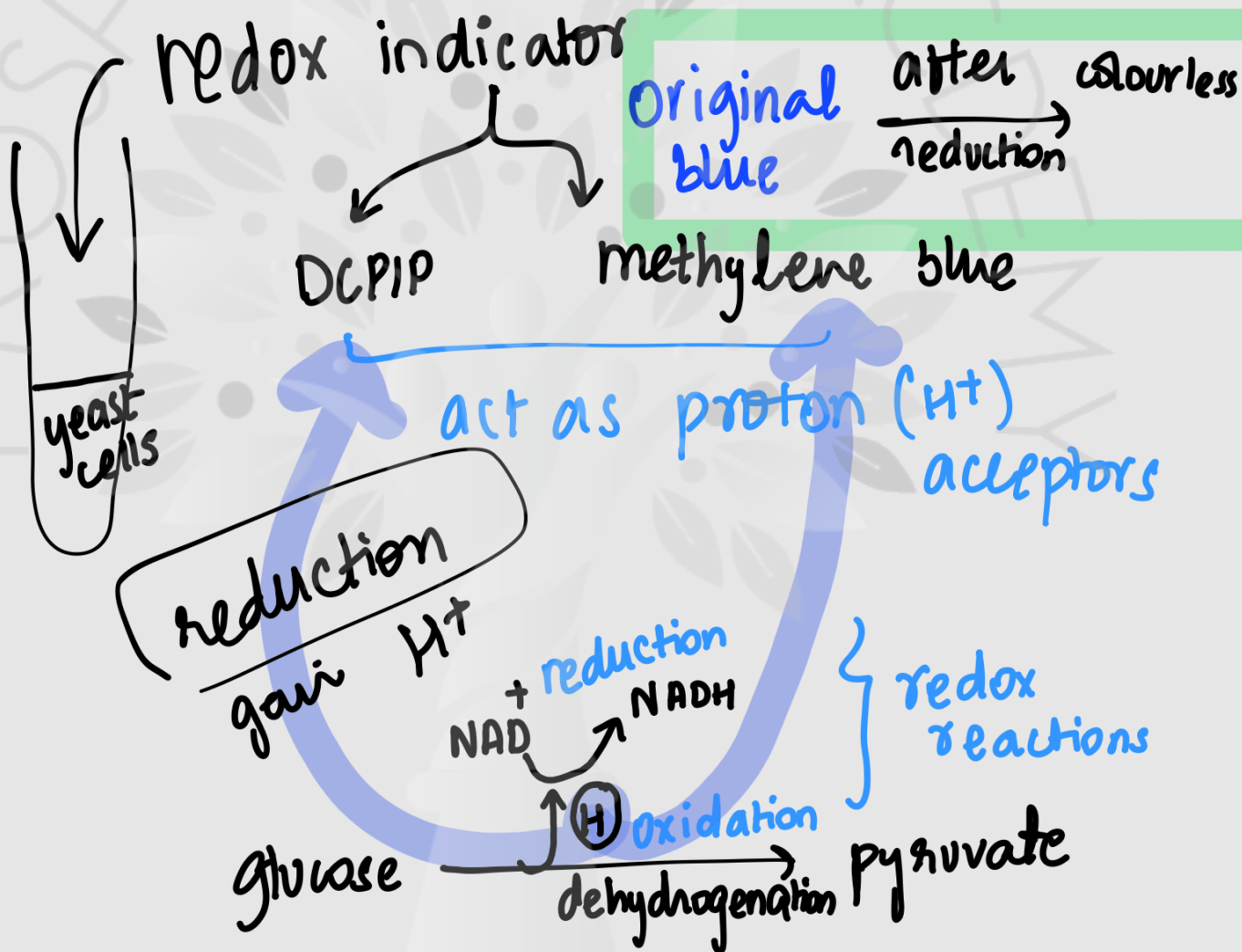
- (v) Suggest why carrying out the experiment with germinating seeds at 50°C could result in a lower rate of respiration than at 25°C .

At temperatures above the optimum temp, the enzyme undergoes denaturation, thus $\downarrow$ E-S complexes are formed.

[2]

[Total: 14]

- 13 describe and carry out investigations using redox indicators, including DCPIP and methylene blue, to determine the effects of temperature and substrate concentration on the rate of respiration of yeast
- 14 describe and carry out investigations using simple respirometers to determine the effect of temperature on the rate of respiration



Effect of temperature

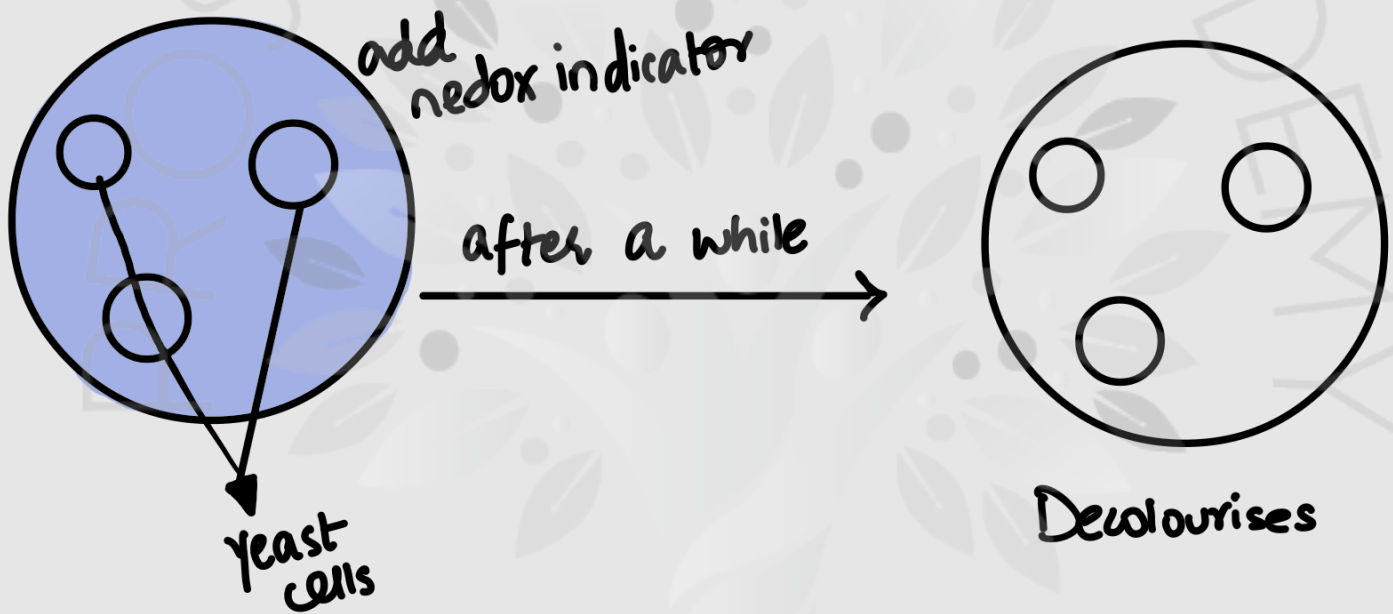
10°C	→	100 secs	fast rxn fast colour change
20°C	→	70 secs	

Redox Indicators $\Rightarrow$ change colour when they get oxidised or reduced.

DCPIP

methylene blue

original colour $\Rightarrow$ BLUE



- During respiration dehydrogenation takes place in Glycolysis, LR and KC. The H^+ released as a result of that can be accepted by DCPIP and/or methylene blue. This results in the reduction of DCPIP/methylene blue causing them to decolourise.
- Faster the rate of respiration, more hydrogens are released per unit time, and the faster the dyes are reduced/decourised.
- The rate of change from blue to colourless is a measure of the rate of respiration.