Aakash + BYJU'S NOTES

Respiration in Plants

Key Takeaway

1. Respiration
2. Glycolysis
3. Anaerobic respiration
4. Aerobic respiration
5. Oxidative decarboxylation

6 Krebs cycle

Electron transport system 7

8 Respiratory balance sheet

Respiratory quotient 9

Summary

Respiration

- The **breaking of the C-C bonds** of the substrates (complex compounds) **through oxidation** within the cells, leading to a **release of** a considerable amount of **energy**, is known as respiration.
- The process of respiration occurs inside a living cell. Hence, this process is also known as **cellular respiration**.
- **Location of respiration**: Cytoplasm and mitochondria
- Cellular respiration involves:
  - Breakdown of **substrates**
  - Release of **energy** in the form of **ATP**
- Cellular respiration occurs **inside living cell**.

Respiratory Substrates

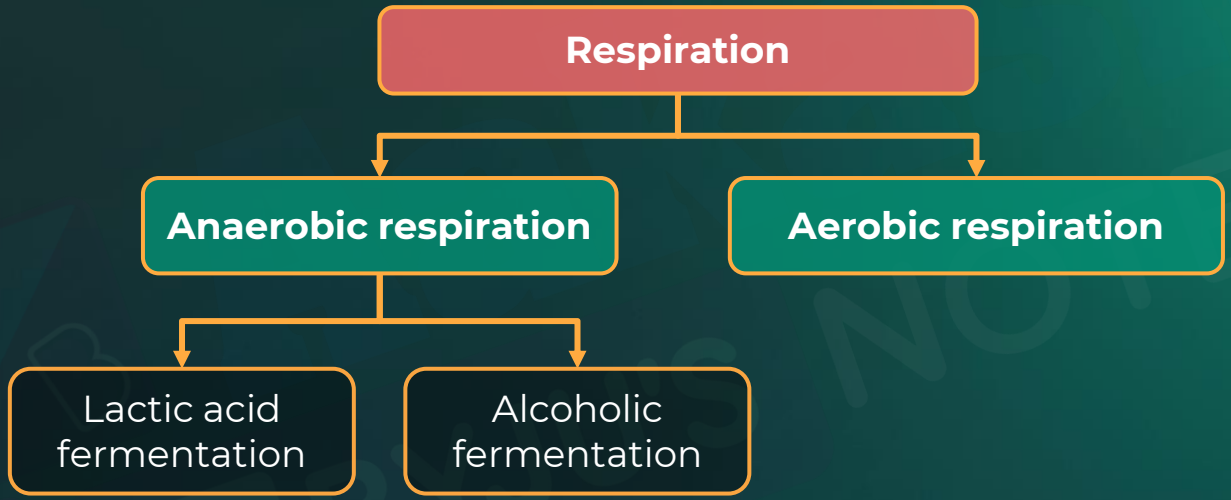
- Definition: Those organic substances which are oxidised during respiration to release energy inside the living cells are termed **respiratory substrates**.
- Example: Carbohydrate (primary), fats & proteins
- **ATP** acts as the **energy currency** of the cell.
- The energy trapped in ATP is **utilised in various energy-requiring processes** of the organisms.

Types of Respiration

Based on the availability of oxygen

Characteristics	Aerobic respiration	Anaerobic respiration
Breakdown of glucose	Occurs in the presence of oxygen	Occurs in the absence of oxygen
Occurs in	Cytoplasm, mitochondria and aerobic microbes	Cytoplasm and anaerobic bacteria

Types of Respiration



Breathing in Plants

Apertures responsible for gaseous exchange in plants

Stomata

- Present on the surface of leaves
- Their opening and closing facilitates gaseous exchange

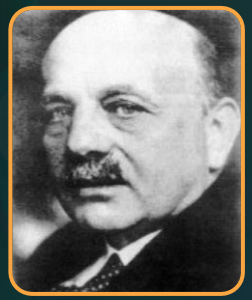
Lenticels

- Present in thick woody stem and root
- Have loosely packed parenchyma cells that facilitate gaseous exchange

Glycolysis

Glucose ⟶ **2x Pyruvic acid + Energy**

It is a metabolic pathway consisting of several steps.
Each step is catalysed by an enzyme.



Gustav **E**mbden

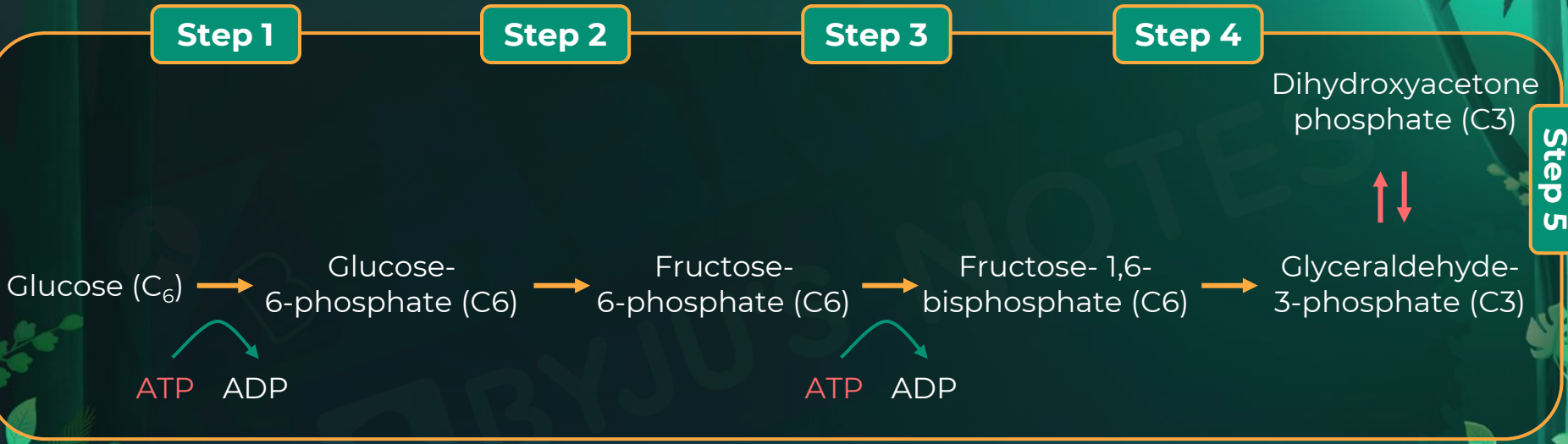
Otto **M**eyerhof

J. **P**arnas

EMP pathway

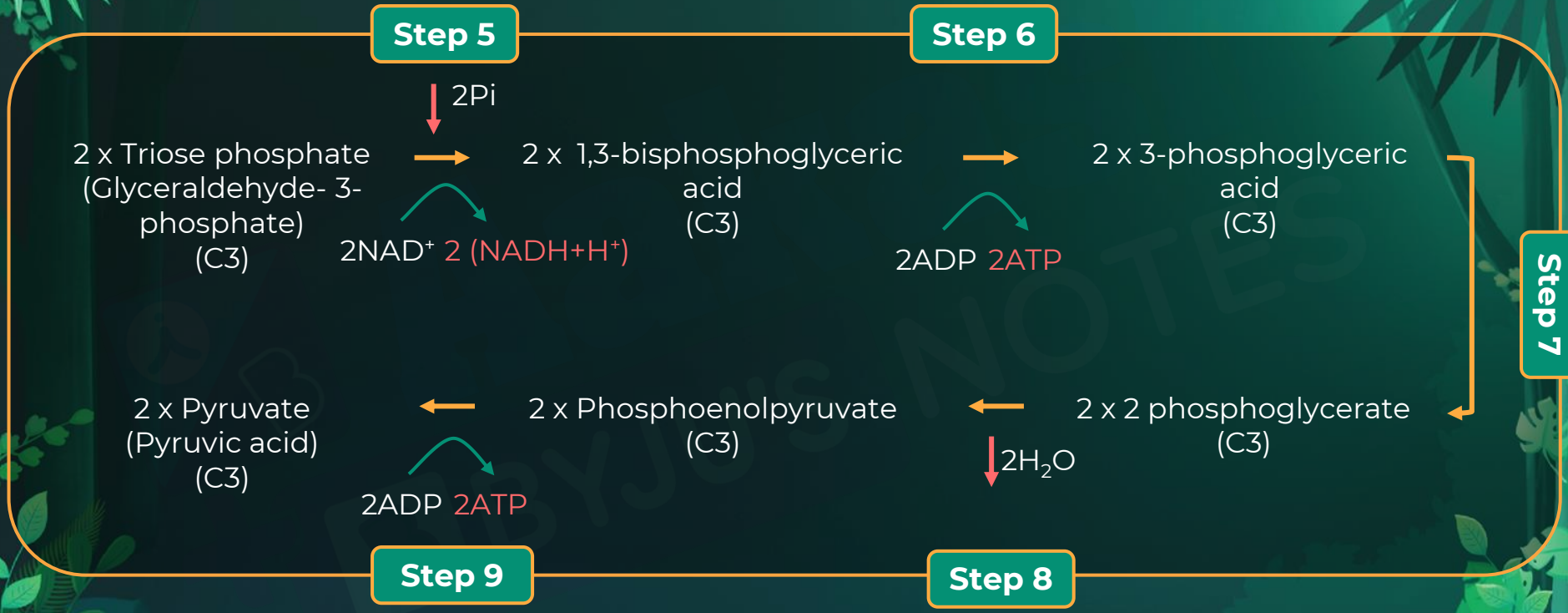
- First phase of **cellular respiration**
- **Glyco** = Sugar, **Lysis** = Splitting
- Also called EMP pathway
- Common to most living cells
- Does not require **oxygen**
- Glucose is **partially** oxidized
- Takes place in the **cytoplasm**

Glycolysis: Preparatory stage



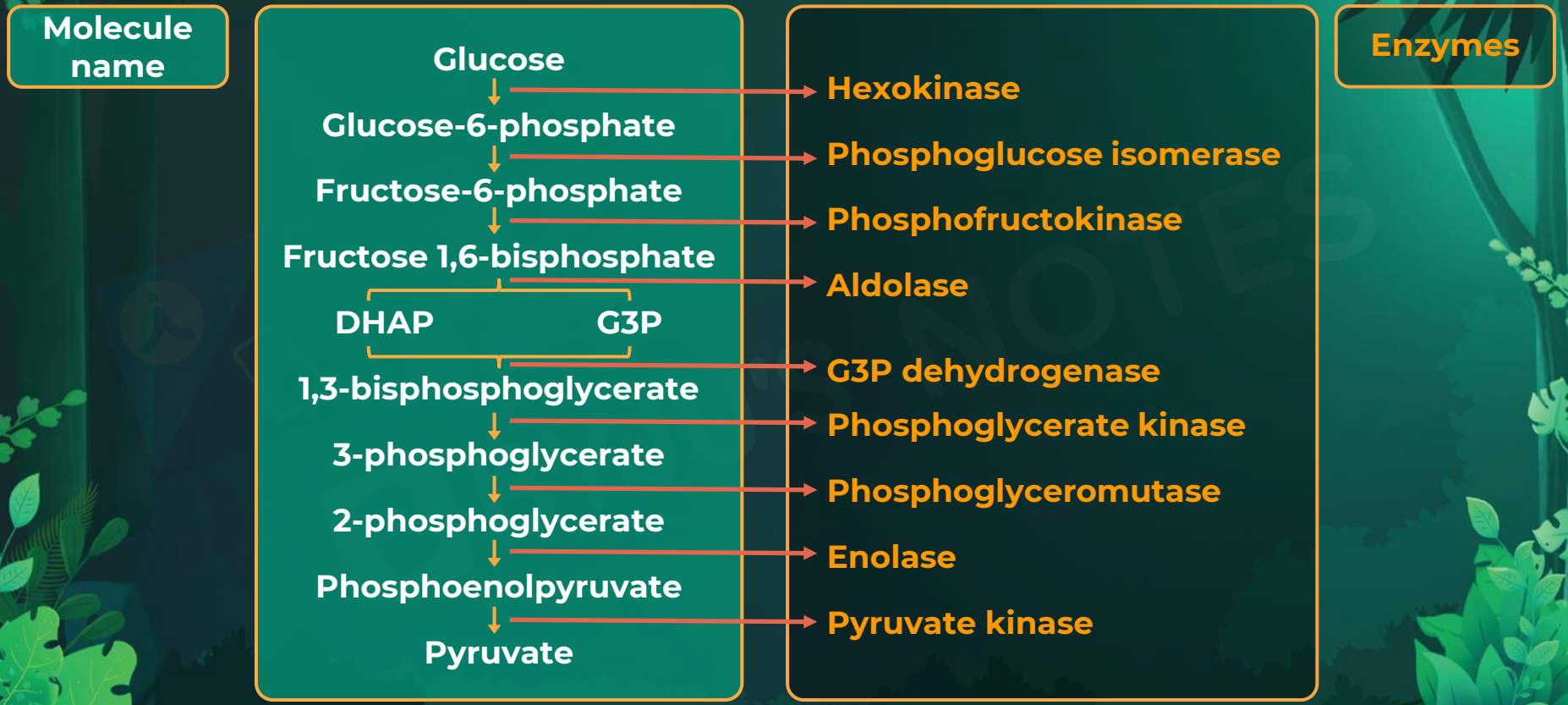
Preparatory stage

Glycolysis: Payoff stage



Payoff stage

Glycolysis: Enzymes Involved

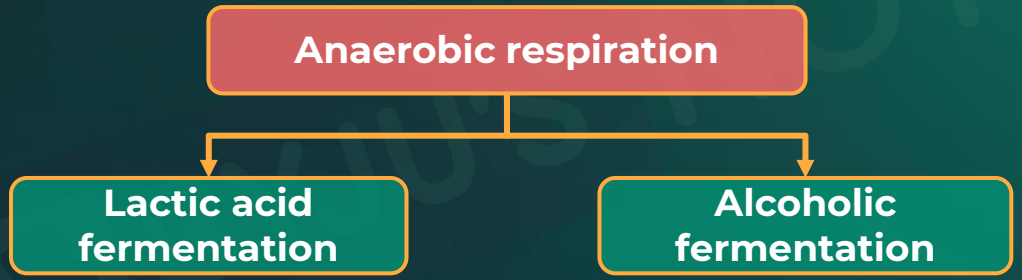


Glycolysis: Net Gain

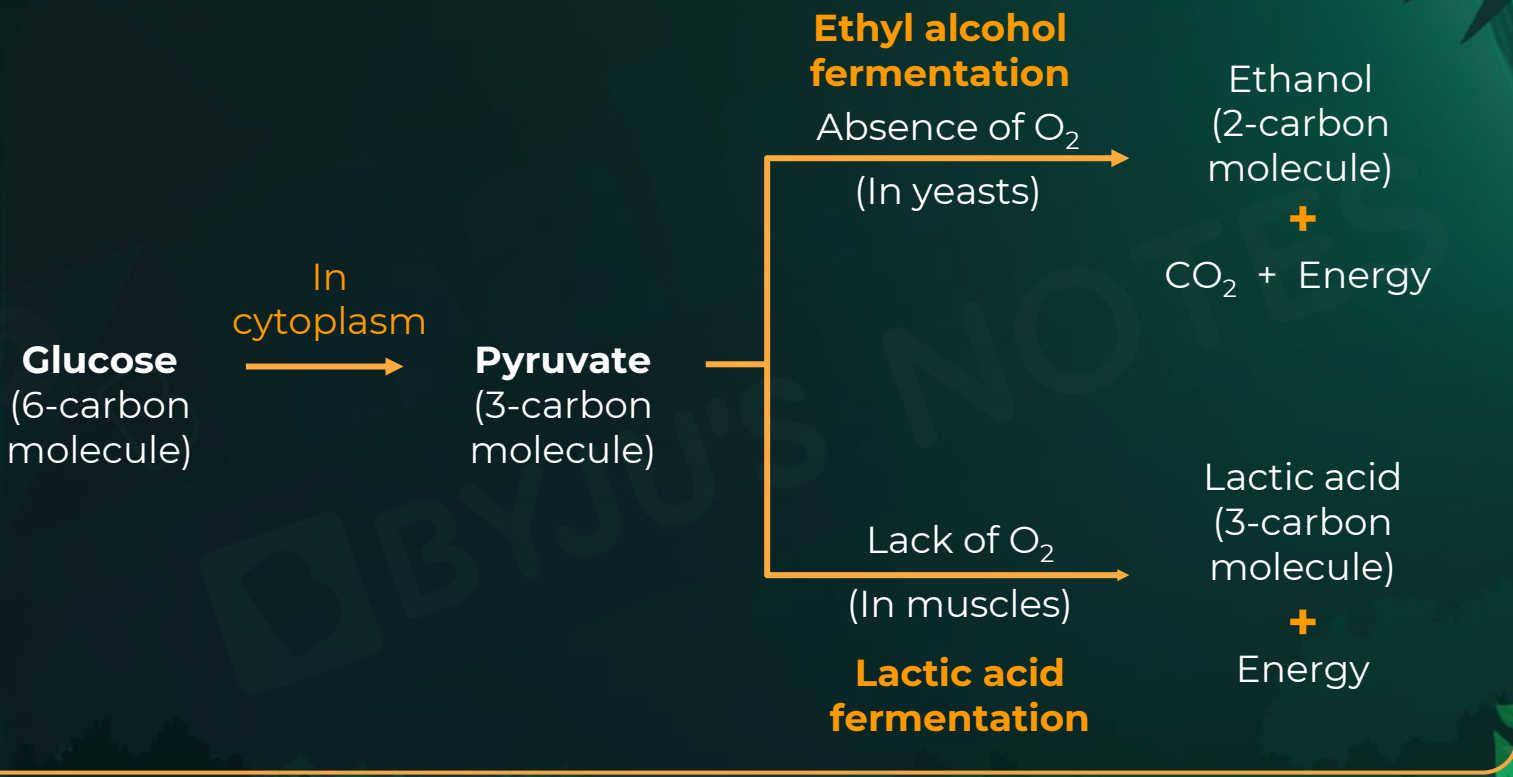
Investment/ Return	Step	No. of ATPs gained	No. of ATPs gained per glucose molecule
Investment	Glucose → Glucose-6-phosphate	-1	-1
Investment	Fructose-6-phosphate → Fructose-1,6 -bisphosphate	-1	-1
Return	1,3-Bisphosphoglycerate → 3-Phosphoglycerate	1	2
Return	Phosphoenolpyruvate → Pyruvate	1	2
Total			**2**

Anaerobic Respiration

- **Anaerobic respiration** is a type of cellular respiration that occurs in the absence of oxygen in cytoplasm.
- Fermentation is the process of release of energy in an enzymatically controlled stepwise partial degradation of organic food (glucose) in the absence of O_2.

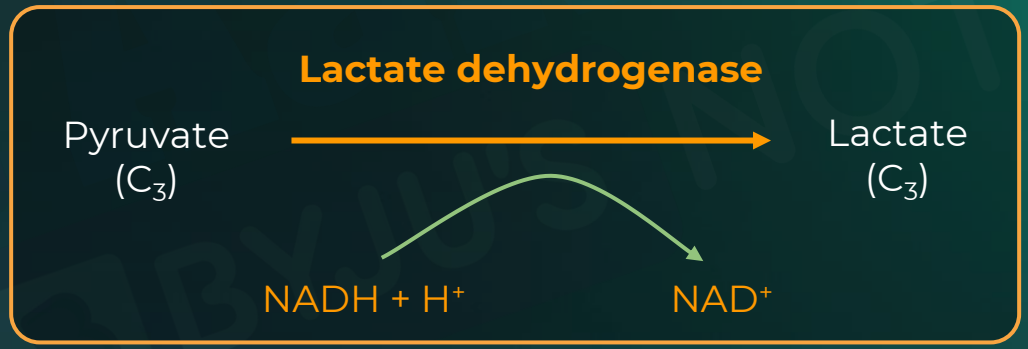


Anaerobic Respiration



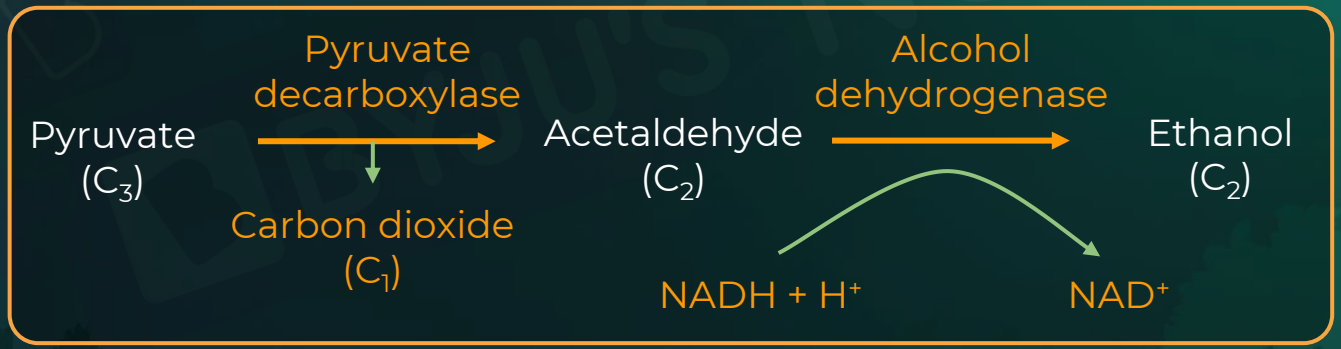
Lactic Acid Fermentation

- In lactic acid fermentation, incomplete oxidation of glucose takes place under anaerobic conditions by sets of reactions where **pyruvic acid is converted to lactic acid** without any release of CO_2.
- NADH gives electrons and hydrogens to pyruvic acid.

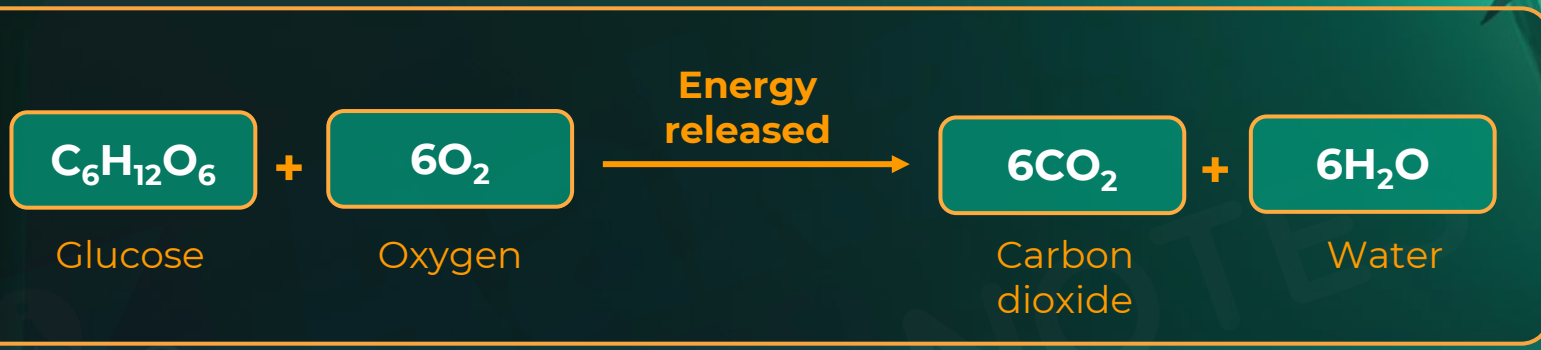


Alcoholic Fermentation

- **Pyruvate decarboxylase** catalyzes **release** of carbon dioxide from pyruvate and results in formation of **acetaldehyde and carbon dioxide**.
- **Alcohol dehydrogenase**, catalyzes **oxidation of NADH** to **NAD^+**, on the cost of **reduction of acetaldehyde** to **ethanol**.
- Yeasts poison themselves to death when the concentration of alcohol reaches about **13%**.

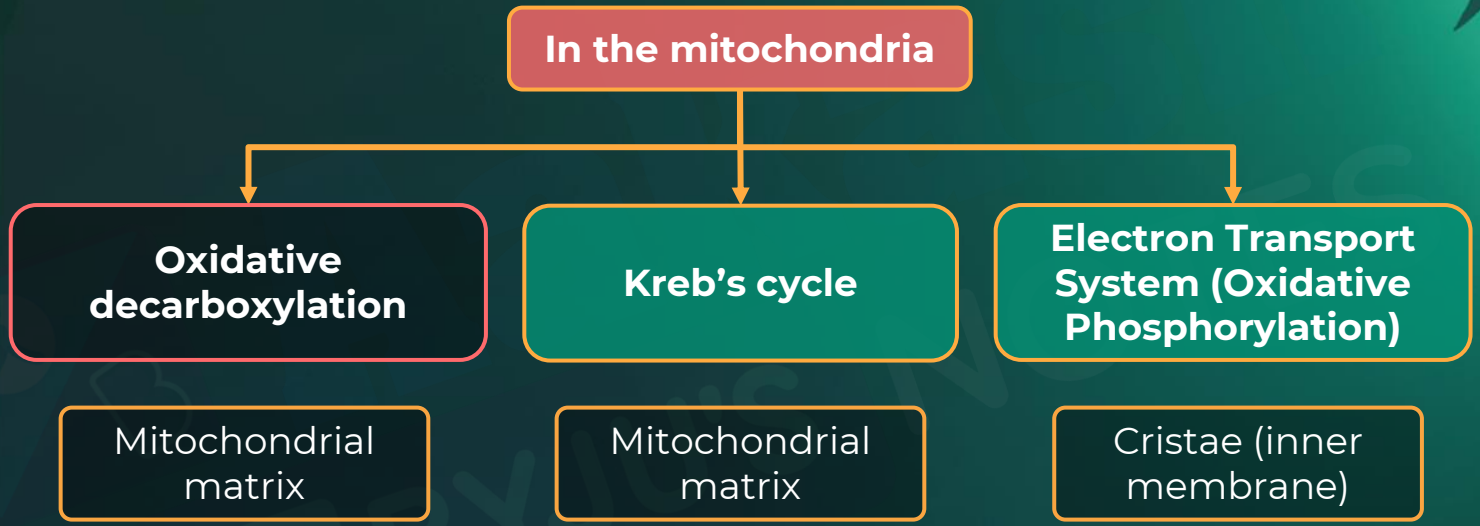


Aerobic Respiration



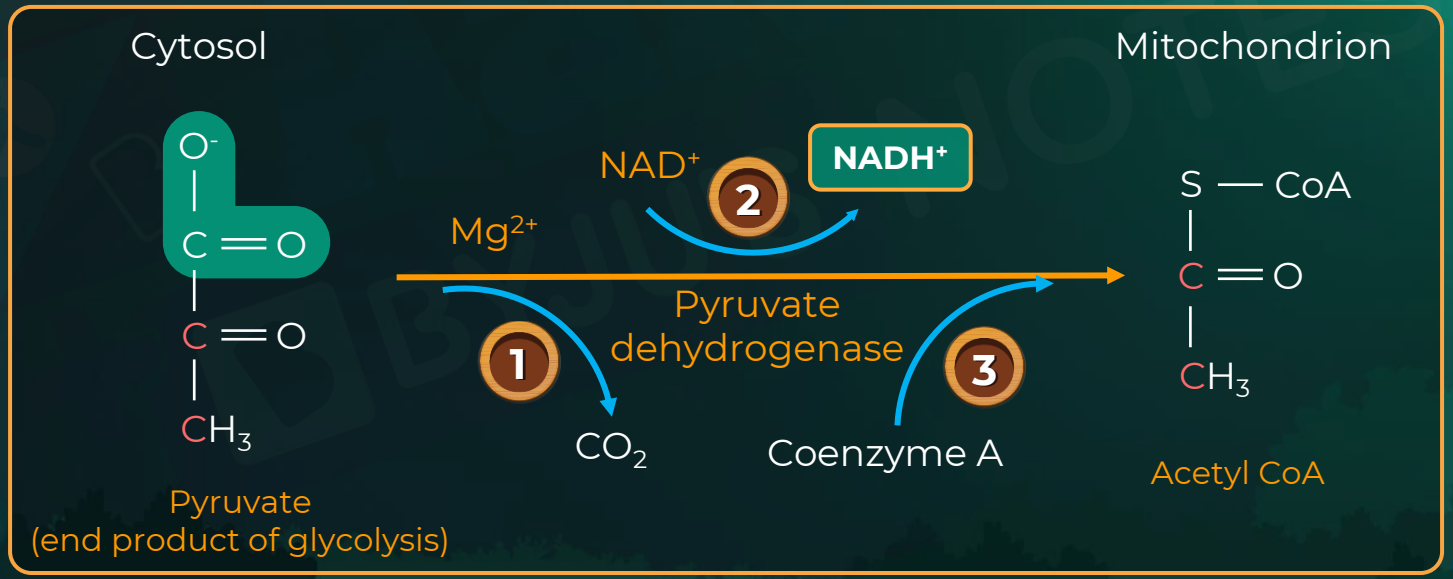
- Aerobic respiration leads to a complete oxidation of organic substances in the **presence of oxygen**, and releases CO_2, water and a large amount of energy present in the substrate.
- It is most common in higher organisms.

Aerobic Respiration



Oxidative Decarboxylation

- A carboxyl group from pyruvate is removed to form CO_2 – **Decarboxylation**.
- The 2-carbon molecule loses electrons ----> NAD^+ to NADH – **Oxidation**.
- 2 carbon acetyl groups formed react with coenzyme A to form **acetyl CoA**.

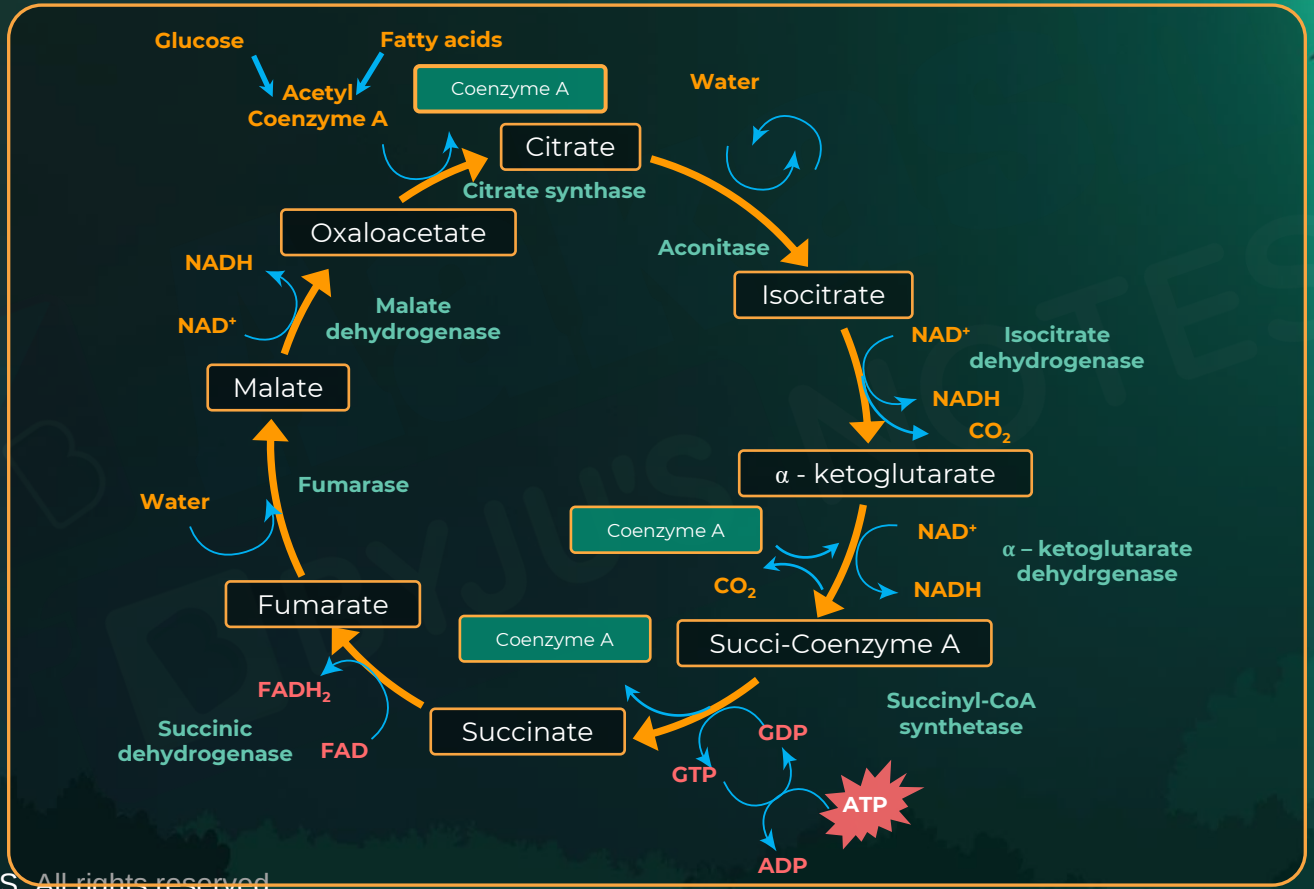


Krebs Cycle

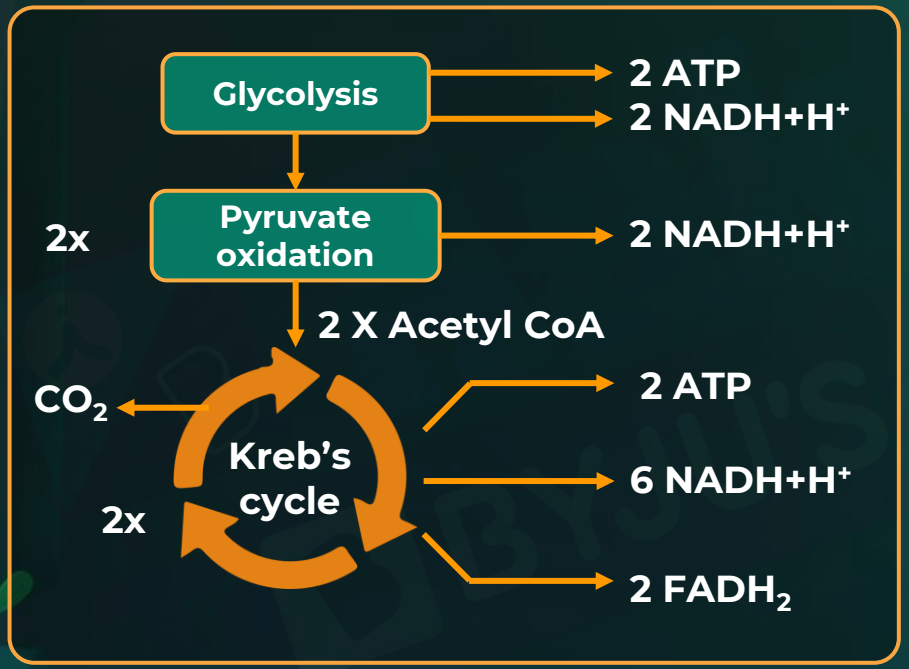
- The acetyl CoA then enters a cyclic pathway, Krebs' cycle.
- It is also known as **tricarboxylic acid cycle or citric acid cycle**.
- It was elucidated by **Hans Krebs**.
- Krebs' cycle starts with condensation of acetyl CoA with oxaloacetate in presence of a condensing enzyme citrate synthase to form a tricarboxylic, 6-carbon compound called **citric acid**.
- It is the **1st product of Krebs' cycle** and CoA is liberated.

$$\text{Pyruvic acid} + 4NAD^+ + FAD^+ + 2H_2O + ADP + Pi \xrightarrow{\text{Mitochondrial matrix}} 3CO_2 + 4NADH + 4H^+ + FADH_2 + ATP$$

Krebs Cycle



ATP Yield



Glucose is broken down to release CO_2 and

- **10 molecules of (NADH + H^+)**
- **2 molecules of $FADH_2$**
- **4 molecules of ATP** (2 in TCA cycle and 2 in glycolysis) are produced.

Role of NADH and $FADH_2$

- NADH and $FADH_2$ are:
  - **Co-factors**: They are non-protein chemical compounds or metallic ions that are required for the enzyme's activity as a catalyst.
  - **Electron carriers**: Both carry two electrons per molecule from the earlier respiration processes.
- The electrons from NADH and $FADH_2$ are donated to an electron acceptor.
- Transfer of electron occurs through a series of steps that are meant to create a lot of ATPs.

Electron Transport System

- The metabolic pathway through which the **electron passes from one carrier to another**, is called the electron transport system (ETS).
- **Location**: Inner membrane of the mitochondria.
- **Components**:
  - **Complex I, II, III, IV** - Help with electron transport
  - **Complex V** - Helps in synthesis of ATP

Complex I

- Complex I (NADH dehydrogenase) - It consists of 2 prosthetic groups
  - **FMN (Flavin mononucleotide)**
  - **FeS (iron-sulphur complex)**
- Here, **NADH gives up the two electrons** and gets oxidised to **NAD^+**.
- These electrons (one by one) are passed on to FMN.
- It moves from FMN to the iron sulphur cluster that gets reduced from ferric ion (Fe^{3+}) to ferrous ion (Fe^{2+}).
- **UQ** or **ubiquinone** is a **mobile electron carrier** closely associated with the complex I.
  - It carries 2 electrons (e^-), 2 protons (H^+) (taken from matrix) across to the next stage.

Complex II

- Complex II (Succinate dehydrogenase) consists of:
  - **FAD** (Flavin Adenine Dinucleotide)
  - **FeS cluster**
- **UQ the mobile electron carrier** is also present.
- **Succinate,** present in the matrix, transforms to **fumarate** in Krebs' cycle and donates **two electrons** to complex II.
- **FAD** takes up both the electrons and hydrogen from succinate to **become $FADH_2$**.
- These electrons then move to the iron sulphur cluster, **reducing Fe^{3+} to Fe^{2+}.** Now $FADH_2$ becomes FAD by losing the $2H^+$.
- **UQ picks up the two electrons and $2H^+$** from matrix to become **UQH_2**.

Complex III

- Complex III (cytochrome bc1 complex) consists of
  - **cytochrome b**
  - **(Fe-S) cluster**
  - **cytochrome c_1**
- UQH2 arriving from complex I and II interacts with complex III, resulting in pumping of **4 protons into the intermembrane space**.
- One by one, electrons move from **Cyt b → Fe-S → Cyt c_1**.
- Cyt c is reduced by accepting electrons from Cyt c_1.
- Cytochrome c is a small protein attached to the outer surface of the inner membrane.
- It acts as a mobile carrier for transfer of electrons between complex III and IV.

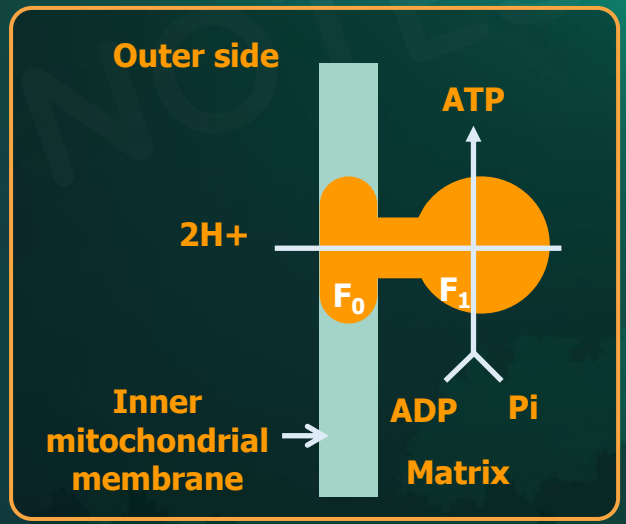
Complex IV

- Complex IV (cytochrome c oxidase complex) consists of
  - **cytochromes a and a_3**
  - **two copper centres**
- One by one, two electrons move from Cyt c of Complex IV

  ($Cu_A \rightarrow$ Cyta $\rightarrow$ $Cyta_3 \rightarrow Cu_B$)
- Further, two protons are pumped out into the intermembrane space.
- Also, two electrons are transferred to oxygen, which then binds with 2 H^+ to yield water.

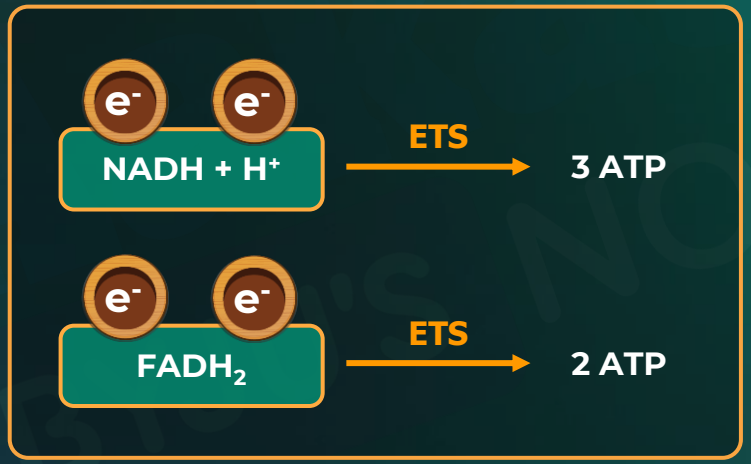
Complex V

- Complex V (ATP synthase) are coupled with complex I to IV when the electrons pass from one carrier to another.
- As the electrons are being transferred, the proteins pump hydrogen into the intermembrane space, creating an **electrochemical gradient**.
- This makes hydrogen pass through the ATP synthase.
- ATP synthase consists of two components:
  - **F_0**: integral membrane protein complex that **forms the channel for the passage of protons**.
  - **F_1**: peripheral membrane protein complex and a **site for the synthesis of ATP from ADP and inorganic phosphate**.



Complex V

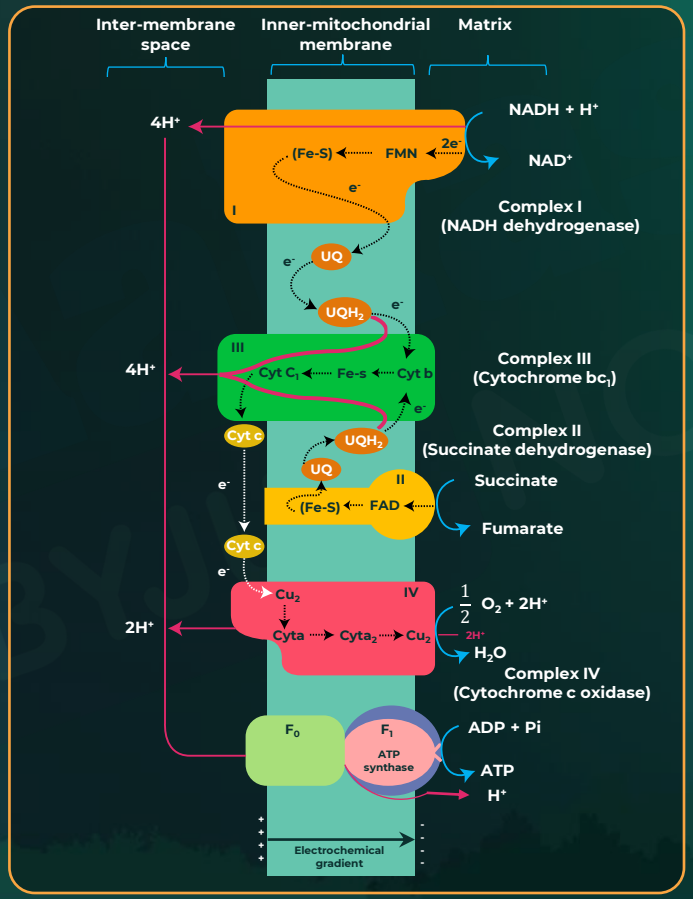
- For each ATP produced, $2H^+$ pass through F_0 from the intermembrane space to the matrix down the electrochemical proton gradient.



Electron Transport System

- The **role of oxygen is limited** to the terminal stage of the process.
- Yet, the presence of oxygen is vital, since it drives the whole process by removing hydrogen from the system.
- **Oxygen acts as the final hydrogen acceptor.**
- Unlike photophosphorylation, where it is the light energy that is utilised for the production of proton gradient required for phosphorylation, in respiration, the energy of oxidation-reduction is utilised for the same process.
- Hence, the process is called **oxidative phosphorylation**.

Electron Transport System



Respiratory Balance Sheet

Expectation	Reality
Net ATP yield = 38	Net ATP yield = 32
Pathway operates in the following sequence: Glycolysis - TCA – ETS.	All the pathways operate simultaneously.
None of the pathway intermediates are used to synthesise any other compound.	The entry and exit of molecules in cellular respiration can occur at any stage. They can be used to build other molecules.
Transfer of NADH requires no energy.	NADH produced during glycolysis needs to be transferred to mitochondria from cytoplasm, which requires 1 ATP/NADPH.
Glucose is the only substrate.	Other substrates might be used.

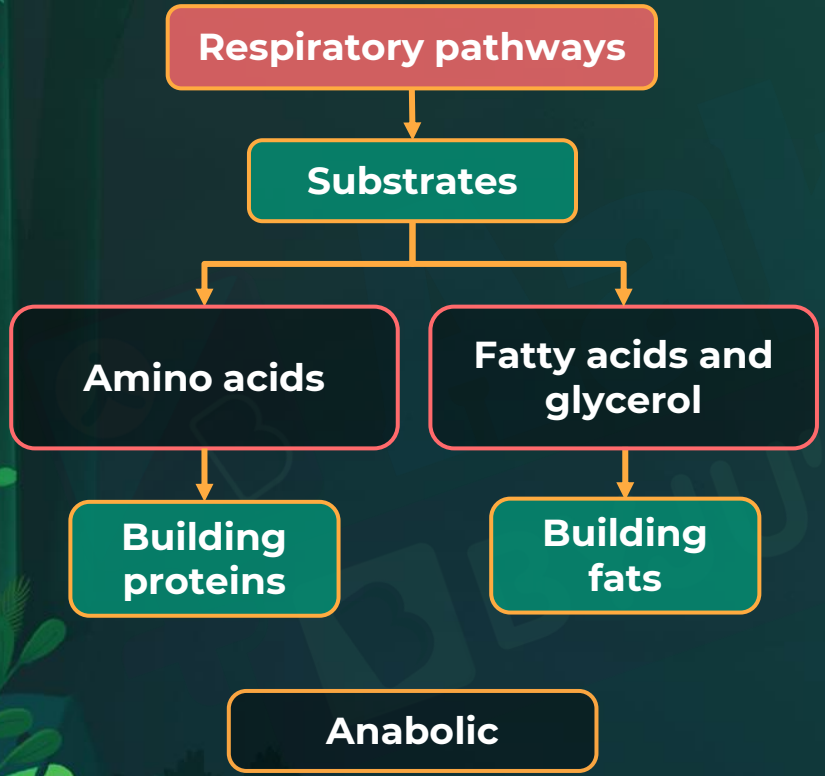
Respiratory Balance Sheet

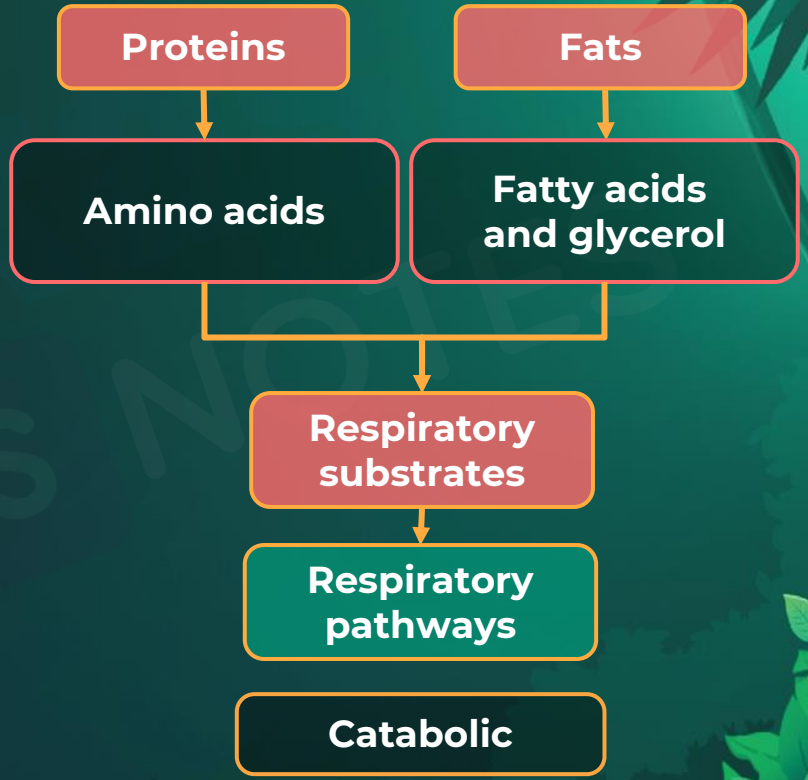
Anaerobic respiration	Aerobic respiration
Partial breakdown of glucose	Complete breakdown of glucose into carbon dioxide and water
Net gain of 2 ATP	Net gain of 30-36 ATP
NAD^+ from NADH is formed slowly	NAD^+ from NADH is formed very fast

Amphibolic Pathway

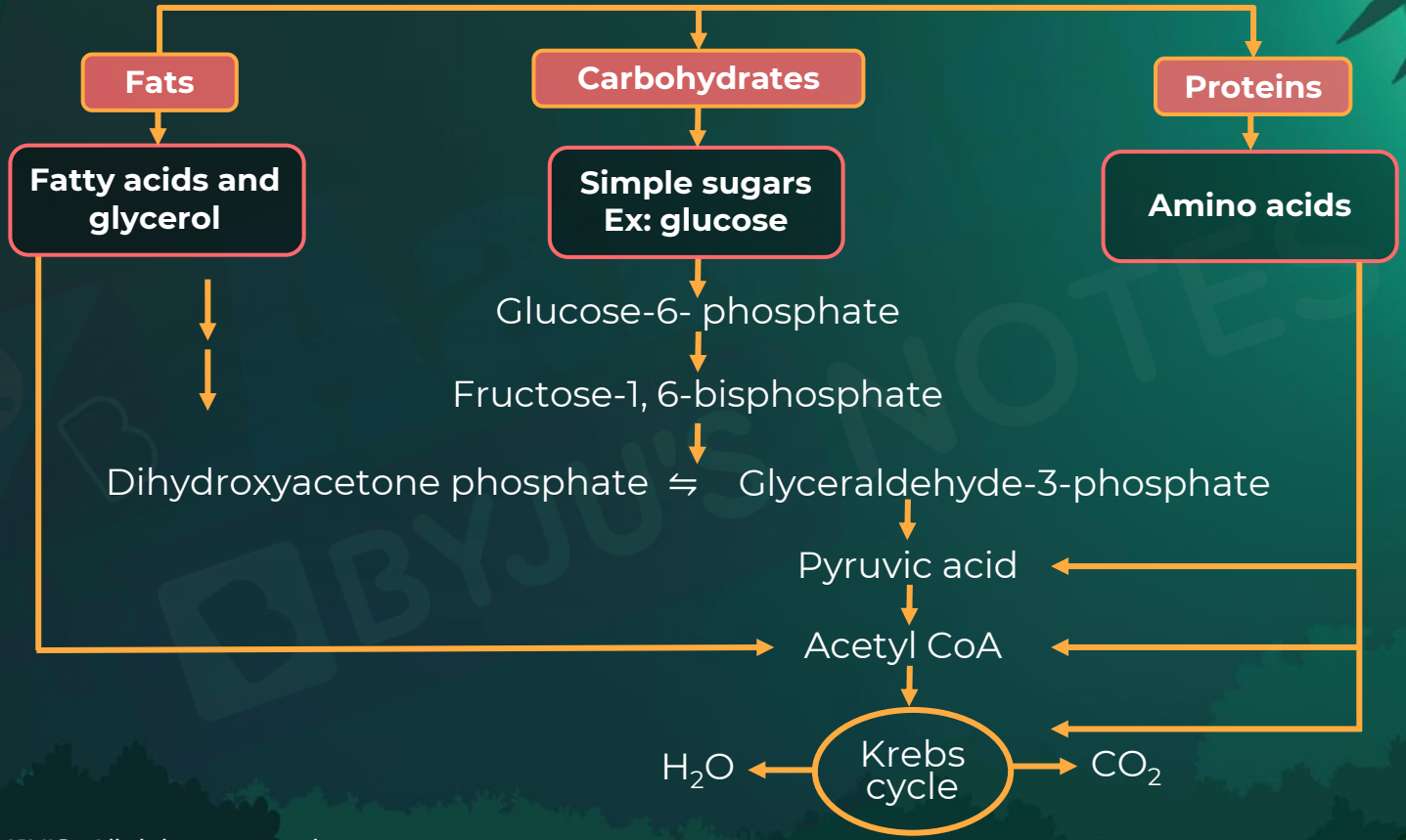
- When energy is required, proteins or fatty acids are broken down to form acetyl-CoA and dihydroxyacetone phosphate which are incorporated into the Krebs' cycle at their respective stages. This is **catabolism**.
- When the body requires fatty acids or proteins, respiratory pathway stops, and the same acetyl-CoA is utilised and fatty acids are manufactured. This process of synthesis is termed as **anabolism**.
- Hence the process is referred to as both catabolic and anabolic process respectively .
- Therefore, the respiratory pathway is considered to be an **amphibolic pathway.**

Amphibolic Pathway





Amphibolic Pathway



Respiratory Quotient

- Respiratory quotient is the ratio of the volume of the carbon dioxide evolved to the volume of oxygen required for any respiratory substrate.
- The **RQ ranges from 0 - 1**.
- The knowledge about the RQ **helps in identifying the respiratory substrate**.

$$\text{RQ} = \frac{\text{Volume of } CO_2 \text{ evolved}}{\text{Volume of } O_2 \text{ consumed}}$$

Respiratory Quotient

Respiratory quotient - Carbohydrates

$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6H_2O + ATP$$

$$RQ = \frac{6\ CO_2}{6\ O_2} = 1$$

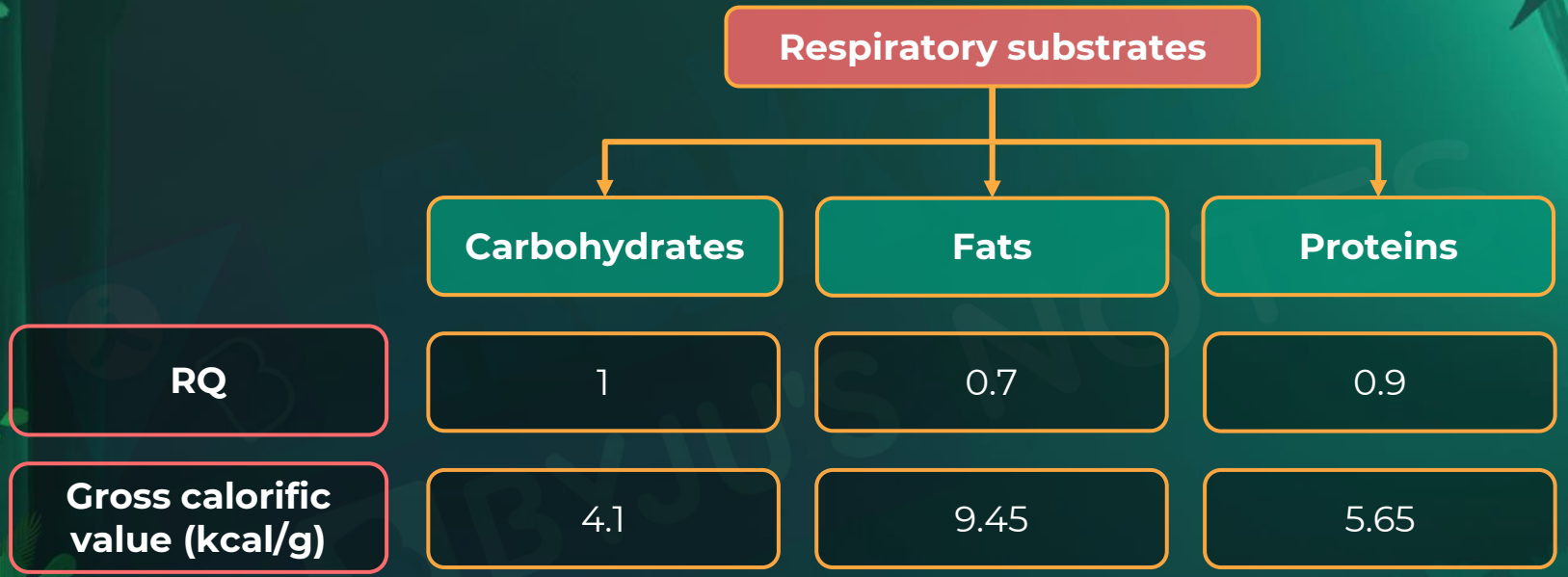
Respiratory quotient - Fats

$$2(C_{51}H_{98}O_6) + 145\ O_2 \longrightarrow 102\ CO_2 + 98\ H_2O + ATP$$

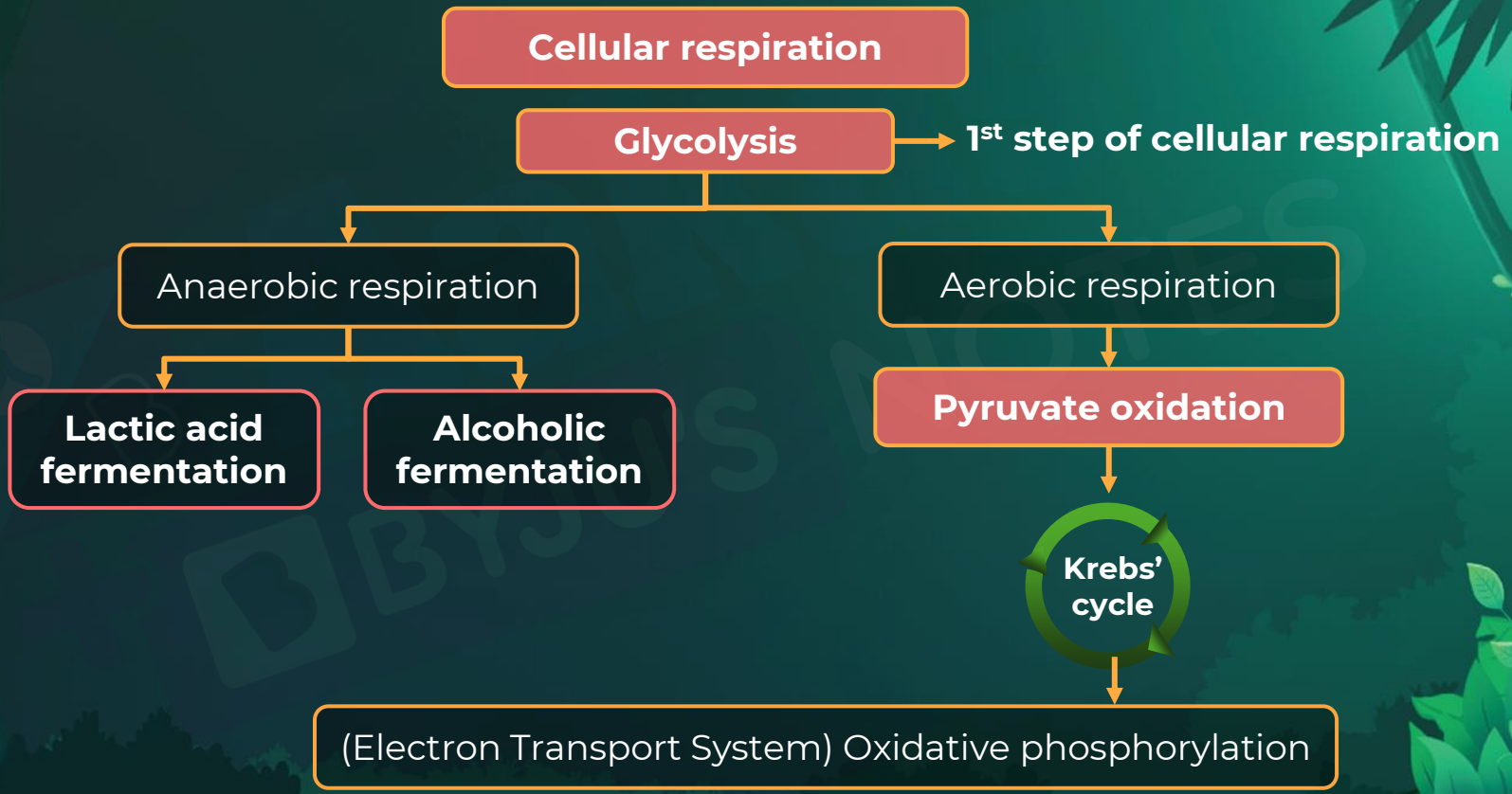
$$RQ = \frac{102\ CO_2}{145\ O_2} = 0.7$$

Respiratory quotient of proteins **is about 0.9**

Respiratory Quotient

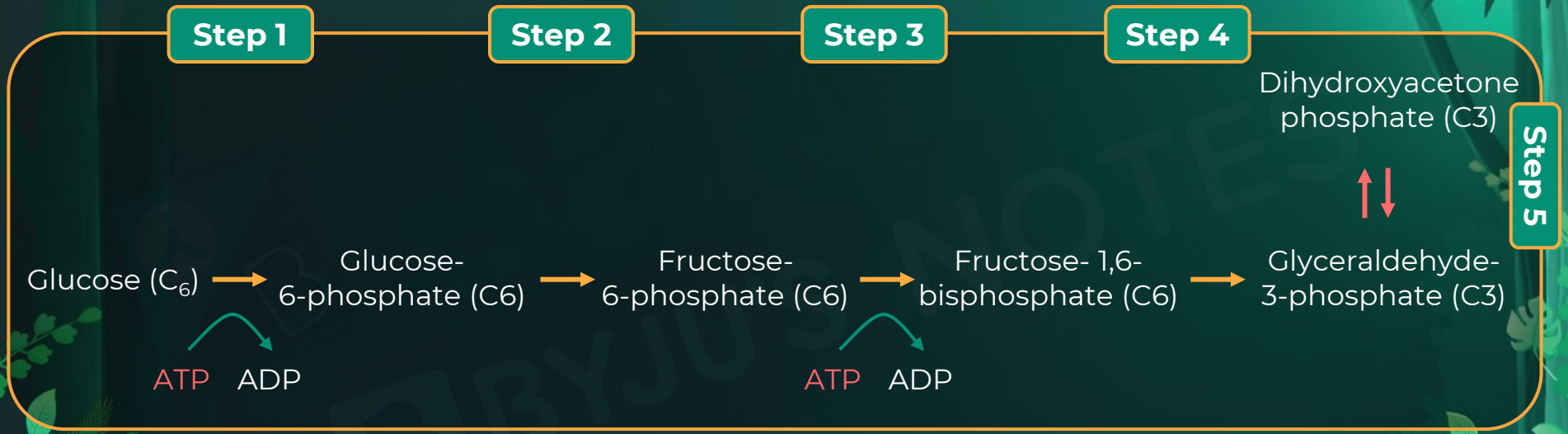


Summary



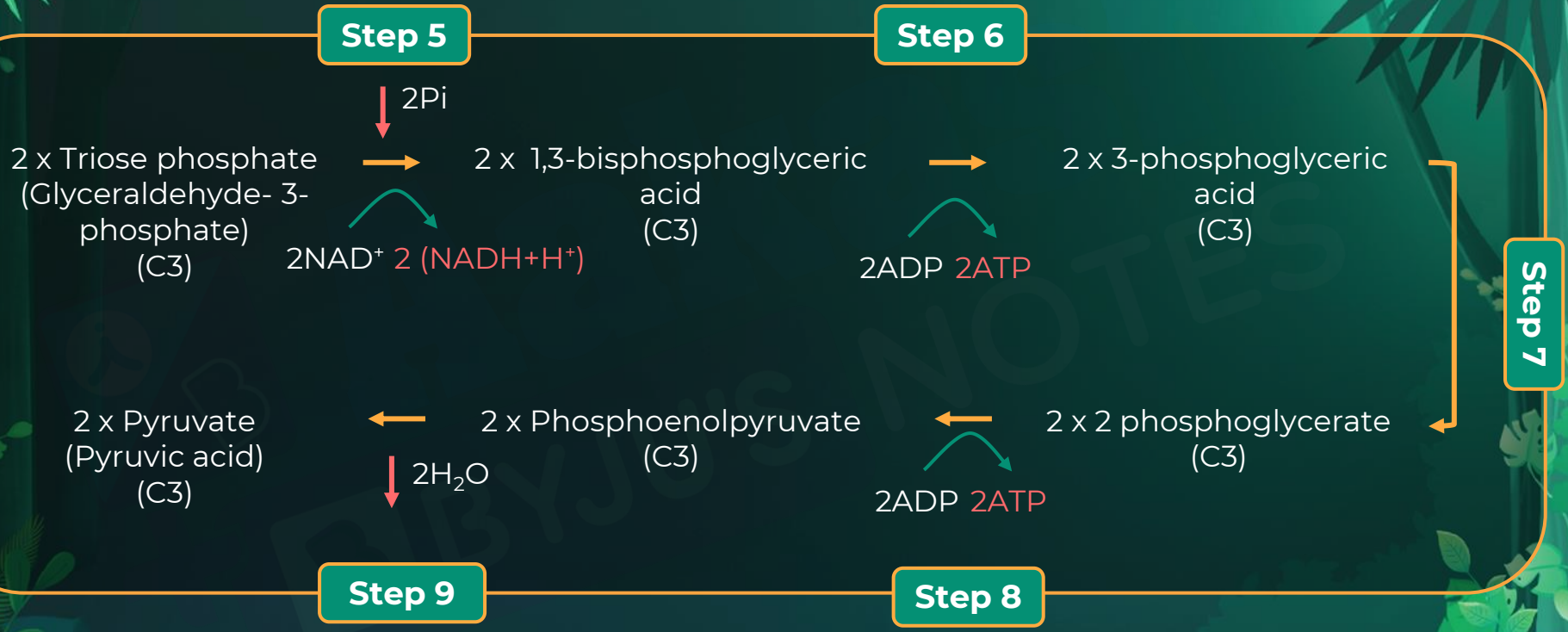
Summary

Glycolysis



Preparatory stage

Summary



Payoff stage

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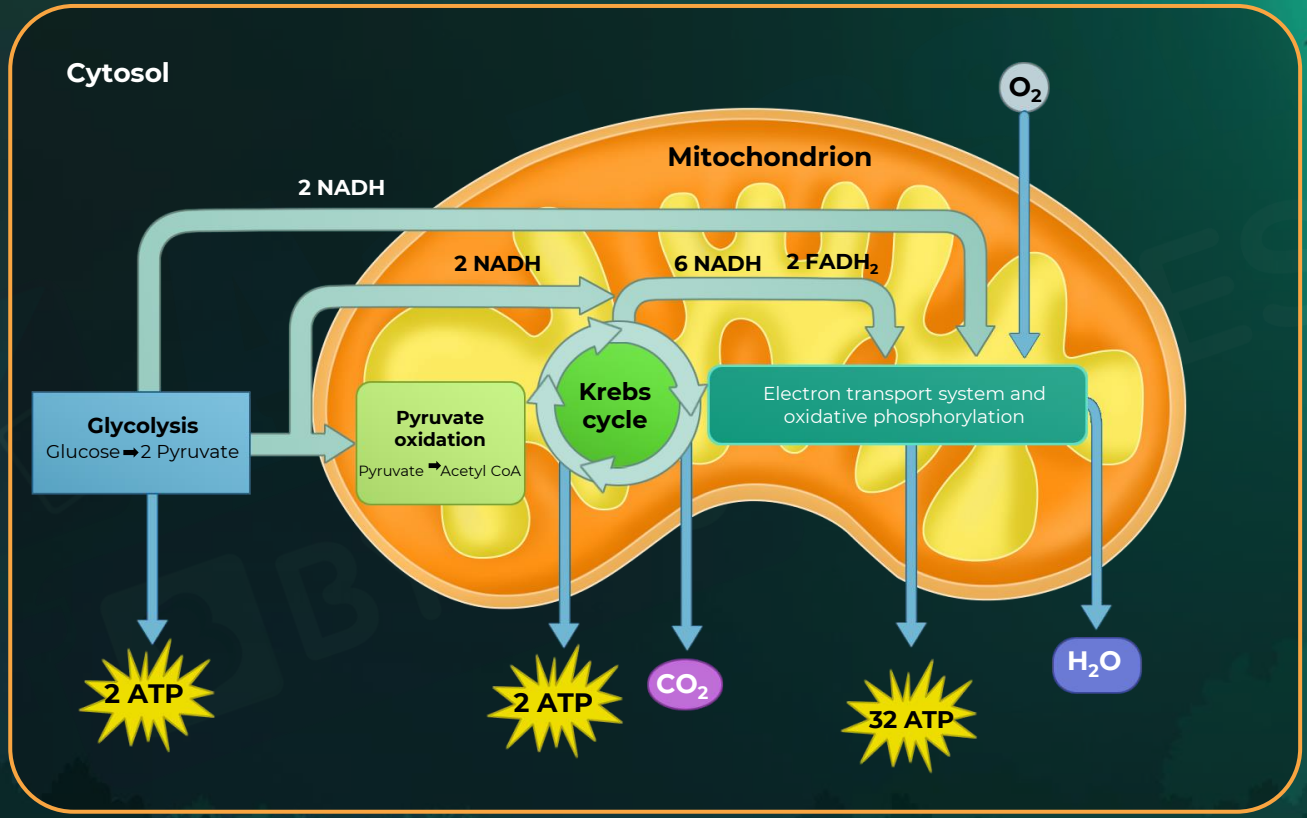

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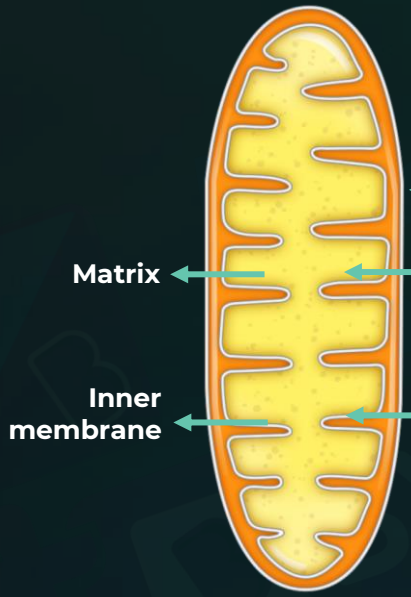


Mitochondrion

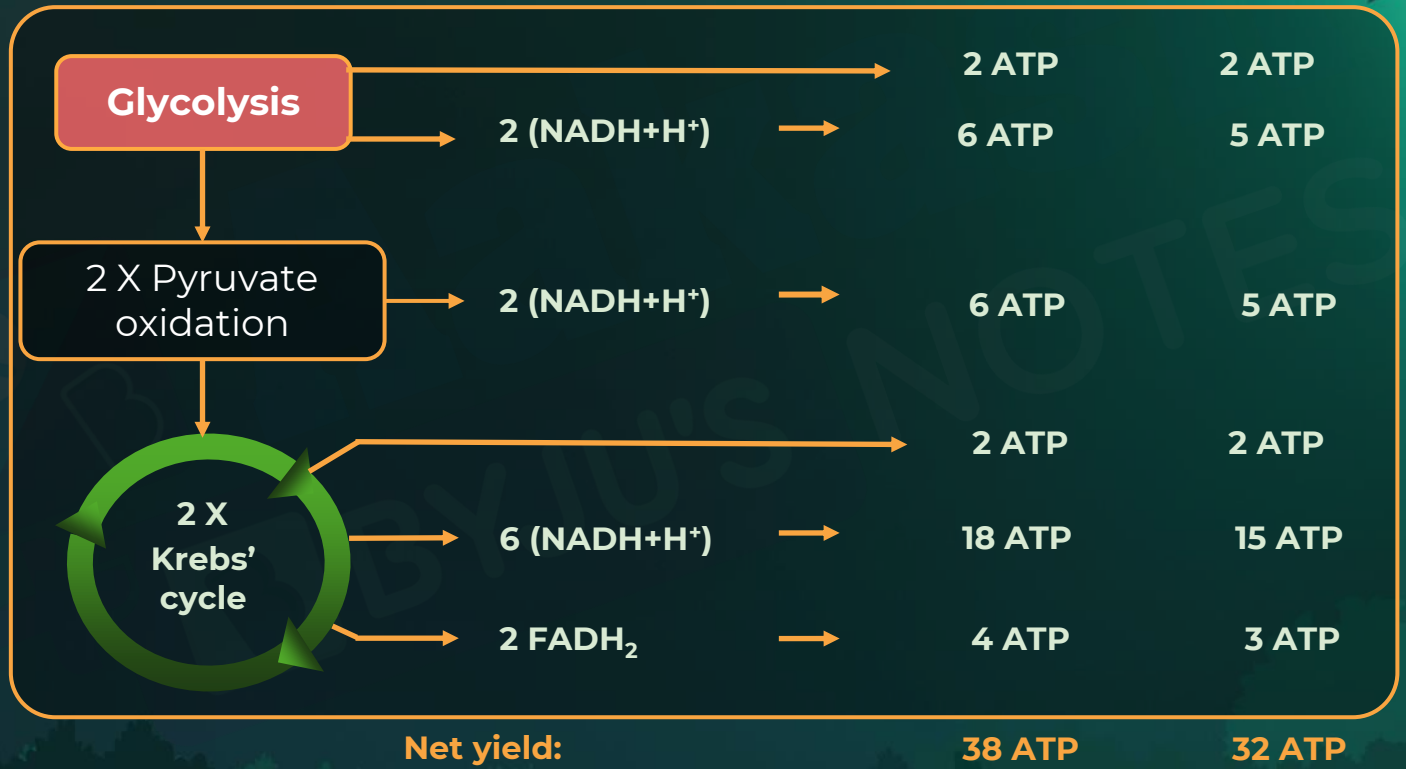
GLYCOLYSIS– In **cytoplasm** — Step #1

Mitochondria

Krebs' cycle takes place in the **matrix of the mitochondria** — Step #2

Electron transport chain takes place in the **inner membrane of the mitochondria** — Step #3

Summary



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