1st PUC Biology Chapter 14

RESPIRATION IN PLANTS

Question and Answer:

Question 1.
Differentiate between
(a) Respiration and Combustion
(b) Glycolysis and Krebs' cycle
(c) Aerobic respiration and Fermentation
Answer:

(a) Respiration vs Combustion

Feature	Respiration	Combustion
Definition	A biological process in which organic molecules (like glucose) are broken down enzymatically to release energy.	A chemical process where a substance reacts rapidly with oxygen to release energy as heat and light.
Control	Enzyme-catalysed, regulated by cellular machinery.	Not enzyme-catalysed, uncontrolled reaction.
Rate of Reaction	Slow and stepwise to capture energy in ATP.	Fast and explosive.
Energy Released	Partly stored in ATP for cellular activities; some released as heat.	Almost all energy released as heat and light.
Products	CO_2, H_2O, and ATP (in aerobic respiration)	CO_2, H_2O, and heat/light (in complete combustion)

Occurrence	Occurs in all living cells.	Occurs in non-living and living systems (if exposed to fire).

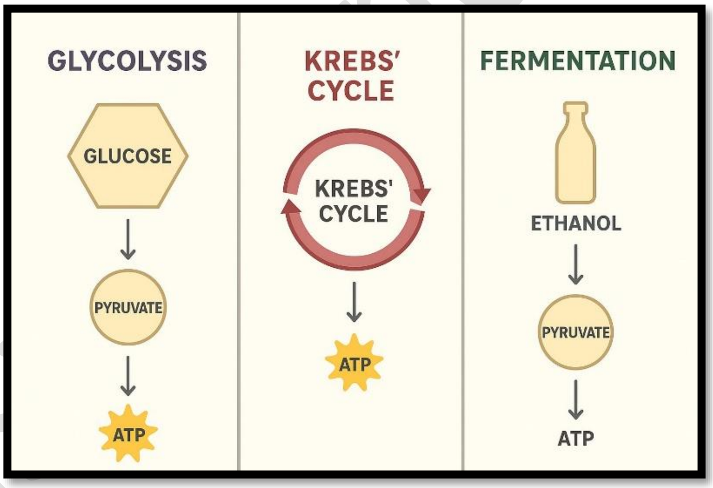
(b) Glycolysis vs Krebs' Cycle (TCA Cycle)

Feature	Glycolysis	Krebs' Cycle
Location	Cytoplasm of the cell	Mitochondrial matrix
Oxygen Requirement	Can occur in presence or absence of oxygen (anaerobic)	Requires oxygen indirectly (aerobic respiration)
Substrate	Glucose (6C)	Acetyl-CoA (2C)
End Product	2 Pyruvate, 2 ATP (net), 2 NADH	3 CO_2, 1 ATP (GTP), 4 NADH, 1 $FADH_2$ per acetyl-CoA
Energy Yield	Small amount of ATP (net 2)	Higher energy yield; contributes electrons to ETS for more ATP
Function	Initial breakdown of glucose	Complete oxidation of pyruvate-derived acetyl-CoA

(c) Aerobic Respiration vs Fermentation

Feature	Aerobic Respiration	Fermentation
Oxygen Requirement	Requires oxygen	Occurs without oxygen (anaerobic)
Location	Cytoplasm (glycolysis) +	Cytoplasm only

	Mitochondria (Krebs & ETS)	
End Products	CO_2 + H_2O + ATP	Lactic acid (animals) or Ethanol + CO_2 (yeast)
ATP Yield	High (~36–38 ATP per glucose)	Low (2 ATP per glucose)
Electron Acceptor	Oxygen (final electron acceptor)	Organic molecule (pyruvate or acetaldehyde)
Energy Efficiency	Efficient, maximum energy extraction	Inefficient, only partial energy extracted



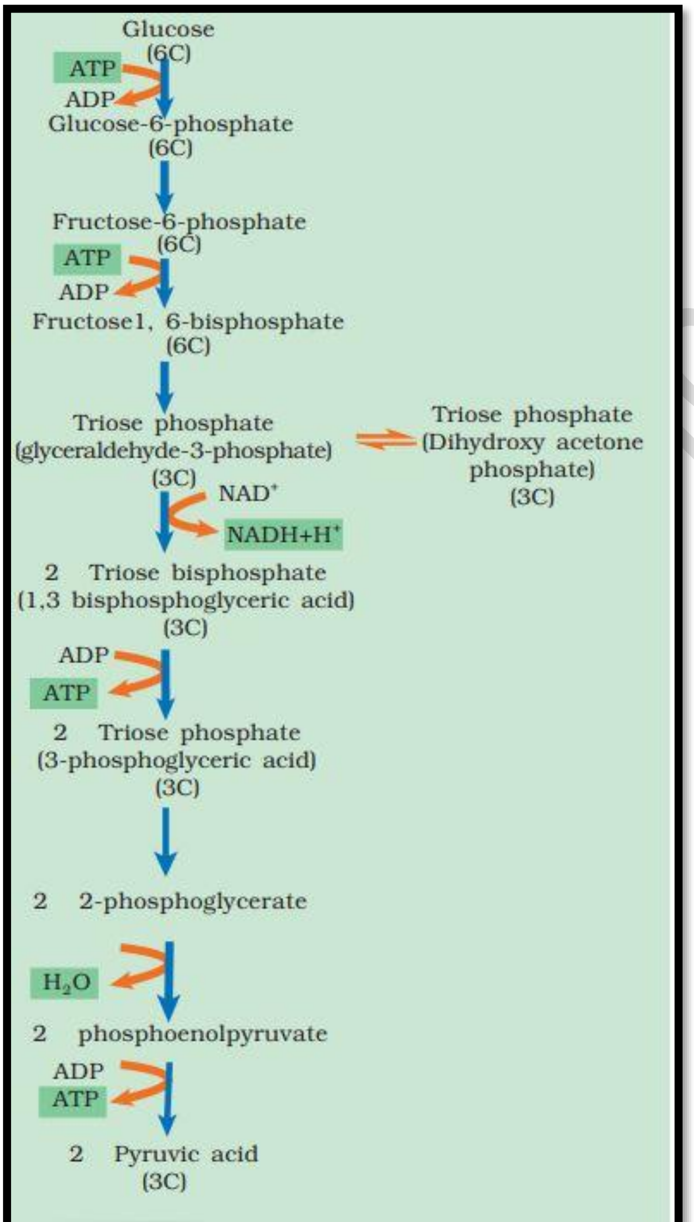
Question 2.
What are respiratory substrates? Name the most common respiratory substrate.
Answer:
Respiratory substrates are the compounds that are oxidized during respiration to release energy in the form of ATP. They provide the necessary fuel for cellular activities.

- The most common respiratory substrate is **carbohydrates**, especially **glucose**.
- Other compounds like **proteins, fats, and organic acids** can also serve as respiratory substrates in some plants under certain conditions.

Question 3.

Give the schematic representation of glycolysis?

Answer:

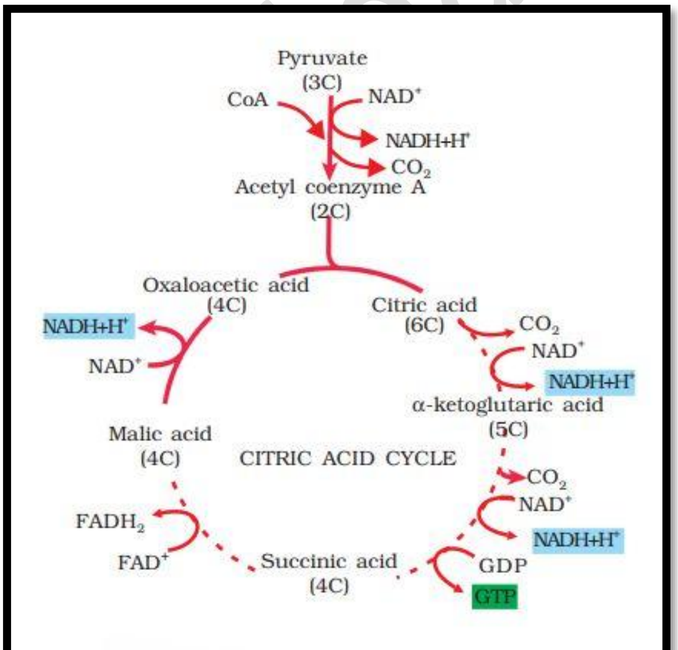


Steps of glycolysis

Question 4.
What are the main steps in aerobic respiration? Where does it take place?
Answer:
The major steps of aerobic respiration and their sites of occurrence are as follows:

Step	**Site of Occurrence**
Glycolysis	Cytoplasm
Krebs cycle	Matrix of mitochondria
Electron transport system (ETS)	Inner mitochondrial membrane
Oxidative phosphorylation	F_0–F_1 particles of inner mitochondrial membrane

Question 5.
Give the schematic representation of an overall view of Krebs' cycle.
Answer:



The Citric acid cycle

Question 6.
Explain ETS.
Answer:

Electron Transport System (ETS):

- ETS occurs in the electron transport particles (ETP) on the inner surface of the inner mitochondrial membrane.
- It is a metabolic pathway in which electrons are passed from one carrier to another, ultimately producing ATP.

Process:

1. **Electron Transfer:**

- Electrons from **NADH** (produced in the mitochondrial matrix during the Krebs cycle) are oxidized by **NADH dehydrogenase (Complex I)**.
- Electrons are then transferred to **ubiquinone (coenzyme Q)**.
- **$FADH_2$** (from succinate oxidation by **succinate dehydrogenase, Complex II**) also transfers electrons to ubiquinone.
- Reduced ubiquinone (**ubiquinol**) passes electrons to **cytochrome bc_1 complex (Complex III)**.
- **Cytochrome c** acts as a mobile carrier between Complex III and **Complex IV (cytochrome c oxidase complex)**, which contains cytochromes a and a_3 and two copper centers.

2. **ATP Formation (Oxidative Phosphorylation):**

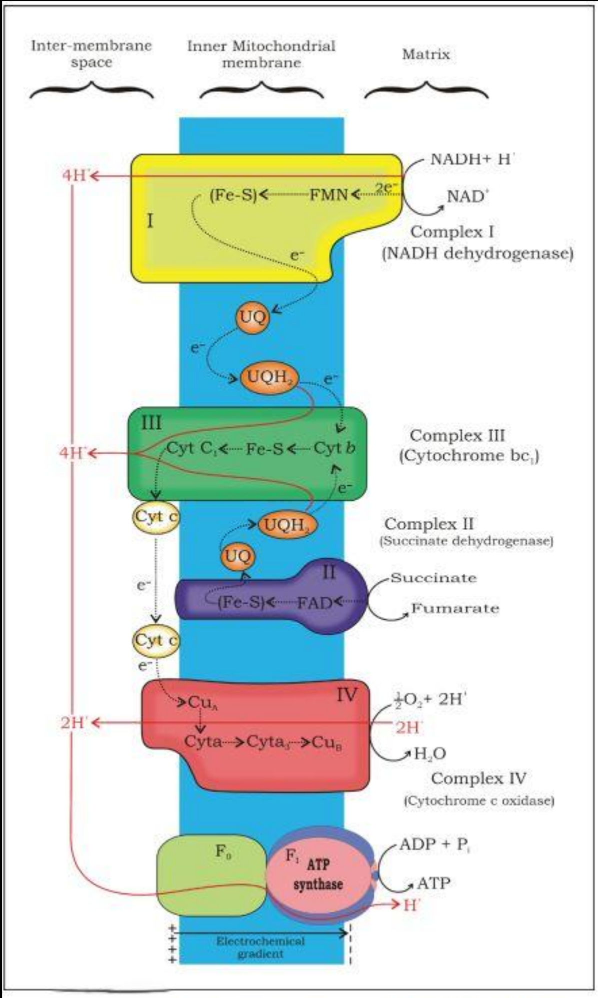
- Electron transfer through Complexes I–IV pumps protons (H^+) from the matrix to the intermembrane space, creating a **proton gradient**.
- Protons flow back into the matrix via **ATP synthase (Complex V)**, which consists of:
  - **F_1:** Peripheral headpiece with ATP synthesis site

        - **F_0:** Integral membrane channel for protons
    - The energy of the proton gradient drives the formation of ATP from ADP and inorganic phosphate (iP).
3. **Role of Oxygen:**
    - Oxygen is the **terminal electron acceptor**, combining with electrons and hydrogen to form water, keeping the system moving.

Energy Yield:

- Oxidation of 1 NADH → **3 ATP**
- Oxidation of 1 $FADH_2$ → **2 ATP**

Summary:
ETS couples the transfer of electrons to **ATP production via oxidative phosphorylation**, making it the major source of energy in aerobic respiration.



Electron Transport System (ETS)

Question 7.

Distinguish between the following:

(a) Aerobic respiration and Anaerobic respiration
(b) Glycolysis and Fermentation
(c) Glycolysis and Citric acid Cycle

Answer:

(a) Aerobic respiration and Anaerobic respiration

Feature	**Aerobic Respiration**	**Anaerobic Respiration**

Oxygen requirement	Takes place in the presence of oxygen	Occurs in the absence of oxygen
End products	CO_2 and H_2O	Ethanol and CO_2 (in yeast) or lactic acid (in muscles)
ATP yield	High (36–38 ATP per glucose)	Low (2 ATP per glucose)
Site of occurrence	Cytoplasm and mitochondria	Cytoplasm only
Completeness of oxidation	Glucose completely oxidized	Glucose partially oxidized

(b) Glycolysis and Fermentation

Feature	**Glycolysis**	**Fermentation**
Definition	Breakdown of glucose (6C) to two molecules of pyruvate (3C)	Conversion of pyruvate into alcohol or lactic acid
Oxygen requirement	Can occur with or without oxygen	Always occurs without oxygen
Site of occurrence	Cytoplasm	Cytoplasm
End products	2 Pyruvate, 2 ATP, 2 NADH	Ethanol + CO_2 or lactic acid + NAD^+
Role in respiration	Common step in both aerobic and anaerobic respiration	Alternative pathway after glycolysis under anaerobic conditions

(c) Glycolysis and Citric Acid Cycle (Krebs Cycle)

Feature	Glycolysis	Citric Acid Cycle (Krebs Cycle)
Site of occurrence	Cytoplasm	Mitochondrial matrix
Starting molecule	Glucose (6C)	Acetyl-CoA (2C)
End products	2 Pyruvate, 2 ATP, 2 NADH	CO_2, NADH, $FADH_2$, and ATP
Oxygen requirement	Does not require oxygen directly	Requires oxygen indirectly (aerobic process)
Type of process	Anaerobic process	Aerobic process
ATP yield	2 ATP (net gain)	1 ATP per cycle (2 per glucose)

Question 8.
What are the assumptions made during the calculation of net gain of ATP?
Answer:

The calculation of net gain of ATP for every glucose molecule oxidised is based on the following assumptions:

1. There is a **sequential and orderly pathway** functioning, where one substrate forms the next, and **glycolysis, TCA cycle, and ETS** operate one after another without any deviation.

2. The **NADH synthesized during glycolysis** in the cytoplasm is **transported into the mitochondria** and undergoes **oxidative phosphorylation** to produce ATP.
3. The **respiratory pathway operates efficiently**, with no intermediate compounds being used for other biosynthetic purposes.
4. **Complete oxidation of one molecule of glucose** takes place under aerobic conditions.

Note:
In actual conditions, the net gain of ATP may be **slightly less than the theoretical 38 ATP**, due to energy loss during transport of NADH into mitochondria and other cellular activities.

Question 9.
Discuss "The respiratory pathway is an amphibolic pathway."
Answer:

Glucose is the most favoured substrate for respiration, and all other carbohydrates are usually first converted into glucose before being used in respiration.

Respiration involves both the **breakdown (catabolism)** and the **synthesis (anabolism)** of substrates; hence, it performs dual functions.

- **Catabolic role:**
  During respiration, glucose is broken down to release energy. This degradative process is called **catabolism**.
- **Anabolic role:**
  Many intermediates of the respiratory pathway are withdrawn and used for the **synthesis of new compounds**. For example, **acetyl-CoA** can be used to synthesize fatty acids when required. This constructive process is called **anabolism**.

Thus, since the respiratory pathway involves both **catabolic and anabolic activities**, it is known as an **amphibolic pathway**.

Question 10.
Define RQ. What is its value for fats?
Answer:

Respiratory Quotient (RQ):
Respiratory Quotient or Respiratory Ratio is defined as the **ratio of the volume of carbon dioxide (CO_2) liberated to the volume of oxygen (O_2) consumed** during respiration.

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

The value of the respiratory quotient depends on the type of respiratory substrate used:

- For **carbohydrates**, the RQ is **1**.
- For **fats**, the RQ is **less than 1** because fats require **more oxygen** for complete oxidation than the amount of CO_2 produced.

Hence, the **RQ value for fats is approximately 0.7**.

Question 11.
What is oxidative phosphorylation?
Answer:

Oxidative phosphorylation is a metabolic pathway in which ATP is synthesized using the energy released during the oxidation of nutrients.

- Electrons are transferred from electron donors (NADH and $FADH_2$) to electron acceptors such as oxygen through a series of redox reactions in the electron transport chain (Complexes I–IV) located in the inner mitochondrial membrane.

- The energy released during electron transfer is used to pump protons (H^+) across the membrane, creating a proton gradient.
- Protons flow back into the matrix via ATP synthase (Complex V), driving the production of ATP from ADP and inorganic phosphate (Pi).
- ATP yield: Oxidation of 1 NADH → 3 ATP; oxidation of 1 $FADH_2$ → 2 ATP.
- Oxygen acts as the final electron acceptor, combining with electrons and protons to form water.

Unlike **photophosphorylation**, where light energy generates the proton gradient, in oxidative phosphorylation, it is the **energy from oxidation-reduction reactions** that drives ATP synthesis, hence the name.

Site: Inner mitochondrial membrane

Question 12.
What is the significance of step-wise release of energy in respiration?

Answer:
Respiration is the process by which energy is released from **food molecules** (respiratory substrates) such as carbohydrates, fats, and proteins through **oxidation**.

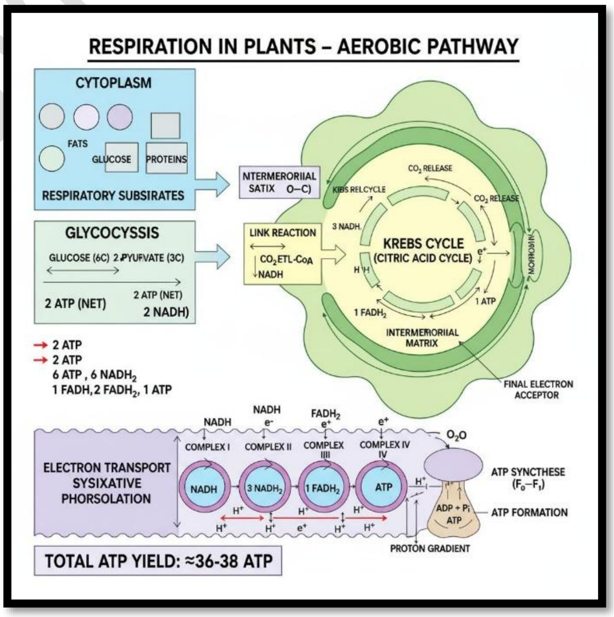
Significance of step-wise energy release:

1. **Controlled energy release:**
    - Energy in food is **not released all at once**; it is released gradually in a series of **enzyme-controlled steps**.
2. **Efficient ATP production:**

- The energy released in small steps is **trapped in the form of ATP**, which acts as the **energy currency of the cell**.

3. **Safety for the cell:**
   - Sudden release of all energy at once would be **wasted as heat** and could **damage cellular components**.
4. **Support for biosynthesis:**
   - Carbon skeletons and intermediates produced during respiration can be used as **precursors for the synthesis of other molecules** in the cell.
5. **Energy availability on demand:**
   - ATP can be **broken down wherever and whenever energy is needed** for various cellular processes, making energy use **efficient and controlled**.

Conclusion:
Step-wise release of energy ensures **safe, efficient, and regulated energy production**, while simultaneously providing intermediates for biosynthesis.



Additional Questions and Answers

Question 1.
What are respiratory substrates? Name the most common one.
Answer:
Respiratory substrates are **organic compounds that are oxidized to release energy** during respiration.

- Most common respiratory substrate: **Glucose**
- Other substrates: Fats, proteins, and organic acids.

Question 2.
Give the schematic representation of glycolysis.
Answer:
Glycolysis (in cytoplasm):

Glucose (6C) → Glucose-6-phosphate → Fructose-6-phosphate → Fructose-1,6-bisphosphate → Glyceraldehyde-3-phosphate → 2 Pyruvate (3C each)

- Net ATP: 2
- NADH formed: 2

Question 3.
Differentiate between:

Answer:
(a) Respiration and Combustion

Feature	Respiration	Combustion
Control	Enzyme-controlled	Uncontrolled
Energy release	Gradual, trapped as ATP	Sudden, lost as heat
By-products	$CO_2 + H_2O$	$CO_2 + H_2O$

(b) Aerobic respiration and Fermentation

Feature	Aerobic	Fermentation
Oxygen	Required	Not required
ATP yield	36–38	2
End products	CO_2 + H_2O	Alcohol + CO_2 / Lactic acid

Question 4.
Name the end products of:
Answer:

- **Aerobic respiration:** CO_2 and H_2O
- **Anaerobic respiration in yeast:** Ethanol + CO_2
- **Anaerobic respiration in muscles:** Lactic acid

Question 5.
Why is oxygen called the final electron acceptor?
Answer:
In aerobic respiration, electrons are transferred through the electron transport chain to **oxygen**, which combines with protons to form water. Without oxygen, electrons cannot flow, and ATP production stops.

Question 6.
What is the net ATP yield from one glucose molecule?
Answer:

- **Glycolysis:** 2 ATP
- **Krebs cycle:** 2 ATP
- **Electron Transport Chain (oxidative phosphorylation):** 34 ATP
  Total: 36–38 ATP per glucose molecule

Question 7.
Explain the term "oxidative phosphorylation."
Answer:
ATP synthesis that occurs when energy released from **electron**

transfer in the ETS is used to phosphorylate ADP to ATP. Oxygen acts as the **final electron acceptor**.

Question 8.
What is the Respiratory Quotient (RQ)? Give its value for carbohydrates, fats, and proteins.
Answer:

Substrate	RQ value
Carbohydrates	1
Fats	0.7
Proteins	0.8

Question 9.
Why is respiration called an amphibolic pathway?
Answer:
Because it serves both **catabolic** (breakdown of substrates for energy) and **anabolic** (providing intermediates for biosynthesis) functions.

Question 10.
Where do the following processes occur?
Answer:

Process	Site of Occurrence
Glycolysis	Cytoplasm
Link reaction	Mitochondrial matrix
Krebs cycle	Mitochondrial matrix
Electron transport system	Inner mitochondrial membrane
Oxidative phosphorylation	F_0–F_1 particles of inner mitochondrial membrane