Respiration in Plants

12 Chapter

1. Differentiate between

a. Respiration and Combustion

Ans: Differences between respiration and combustion are as follows:

Respiration	Combustion
It occurs inside living cells (cellular process).	It is a non-cellular process
Respiration is a biochemical process.	Combustion is a physio-chemical process.
Chemical bonds are broken down into steps, as a result, energy is released in stages.	All chemical steps occur simultaneously, as a result, energy is released in a single step.
A considerable amount of energy is stored in ATP molecules.	ATP is not formed.
Oxidation occurs at the end of the reaction (terminal oxidation) between reduced coenzymes and oxygen.	During combustion, the substrate is oxidized directly.
Several intermediates are formed. They are utilized in the synthesis of various organic compounds	No intermediates are produced in combustion.

Less than 50% of energy is liberated in the form of heat energy. Light is rarely produced.	Energy is liberated in the form of both light and heat energy.
Temperature is not allowed to rise.	Temperature becomes very high.
Several enzymes are needed, one for each step or reaction.	Burning is a non-enzymatic process.

b. Glycolysis and Krebs' cycle

Ans: Differences between glycolysis and Krebs' cycle are as follows:

Glycolysis	**Krebs' Cycle**
It occurs inside the cytoplasm.	Krebs' cycle operates inside mitochondria.
Glycolysis is the first step in respiration where glucose is broken down to pyruvate.	Krebs' cycle is the second step in respiration in which an active acetyl group is broken down completely.
This process is common in both aerobic and anaerobic respiration.	It only occurs during aerobic respiration.
It degrades a molecule of glucose into 2 molecules of pyruvate, an organic substance.	It degrades pyruvate completely into inorganic substances i.e., CO_2 and H_2O.
Glycolysis requires two ATP molecules for the initial phosphorylation of the substrate molecule.	It does not require ATP molecules.
One glucose molecule yields four ATP molecules in glycolysis through	Two acetyl residues in the Krebs cycle liberate two ATP or GTP molecules

substrate-level phosphorylation.	through substrate-level phosphorylation.
The net gain is 2 molecules of NADH and 2 molecules of ATP for every molecule of glucose broken down.	Krebs' cycle produces 6 molecules of NADH, and 2 molecules of $FADH_2$ for every two molecules of acetyl CoA oxidized by it. Two molecules of NADH are released during the conversion of two pyruvates to acetyl CoA.
The net gain of energy during glycolysis is equal to 8 ATP molecules.	In krebs' cycle, the net gain of energy is equal to 24 ATP molecules. Six molecules of ATP can be produced from 2 molecules of $NADH_2$ formed during the dehydrogenation of 2 pyruvates.
In glycolysis, no CO_2 is evolved.	CO_2 is evolved during Krebs' cycle.
Oxygen is not required for glycolysis.	Oxygen is used as a terminal oxidant during krebs' cycle.

c. Aerobic respiration and Fermentation

Ans: Differences between aerobic respiration and fermentation are as follows:

Aerobic Respiration	Fermentation
It uses oxygen for breaking the respiratory material into simpler substances.	Oxygen is not used in the breakdown of the respiratory substrate.
Respiratory material is completely oxidized.	Respiratory material is incompletely broken.
The end products are inorganic i.e.,	Small, reduced organic molecules (ethanol or lactic acid) are produced as

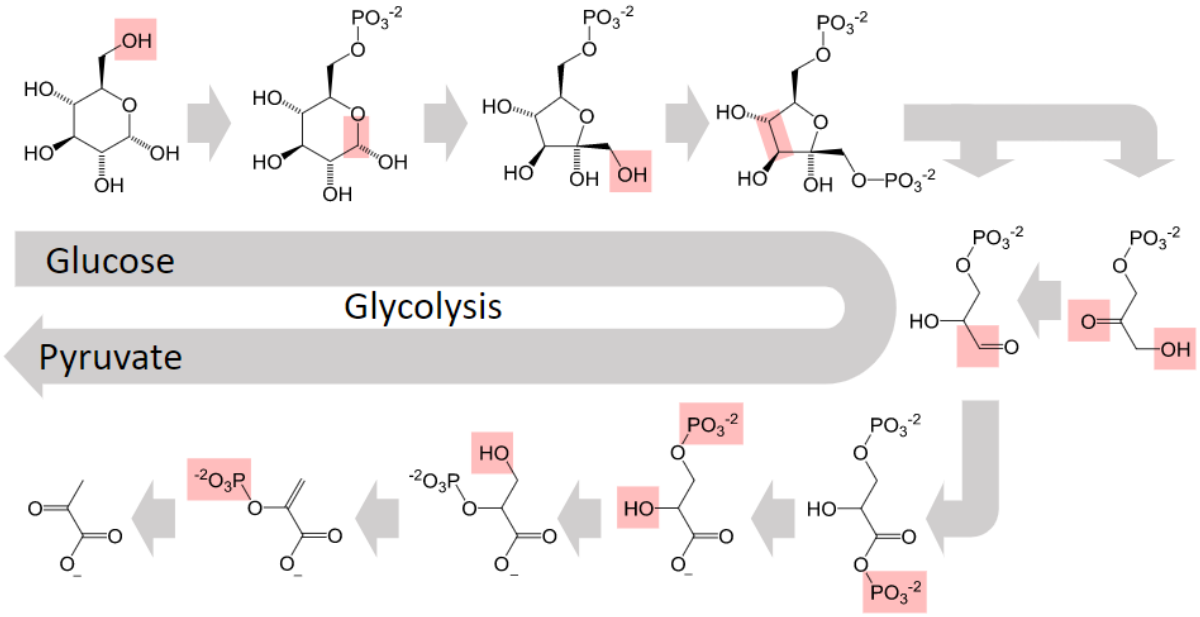
CO_2 and H_2O.	end products. Inorganic substances (CO_2) may or may not be produced.
Aerobic respiration is known for the normal mode of respiration in both plants and animals.	It occurs in yeast cells, bacteria and in the muscle cells of animals during vigorous exercise.
Aerobic respiration consists of three-step: - Glycolysis, Krebs' cycle and terminal oxidation.	Anaerobic respiration or fermentation consists of two steps: - Glycolysis and incomplete breakdown of pyruvic acid.
Every carbon atom in the food is oxidised, releasing a substantial amount of carbon dioxide.	Less quantity of carbon dioxide is evolved.
Water is formed.	Water is usually not formed.
686 kcal of energy is produced per gm mole of glucose.	39 – 59 kcal of energy is produced per gm mole of glucose.
It continues indefinitely.	It cannot be continued indefinitely (except in some microorganisms) due to the accumulation of poisonous compounds and the reduced availability of energy per gram mole of food broken.

2. What are respiratory substrates? Name the most common respiratory substrate.

Ans: Respiratory substrates are organic substances. They are oxidized during respiration to release energy within living cells. Carbohydrates, proteins, fats, and organic acids are common respiratory substrates. The most common respiratory substrates are glucose (carbohydrates). It is a type of hexose monosaccharide.

3. Give the schematic representation of glycolysis.

Ans: The schematic representation of glycolysis is:



4. What are the main steps in aerobic respiration? Where does it take place?

Ans: The main steps of aerobic respiration are as follows: - Glycolysis, link reaction, Krebs cycle and terminal oxidation.

i. Glycolysis (EMP Pathway): - The process of breakdown of glucose into pyruvic acid is known as glycolysis. Glucose is partially oxidized to form two molecules of pyruvate, two NADH, and two ATP. This is a common pathway for both aerobic and anaerobic modes of respiration. It takes place in the cytoplasm.

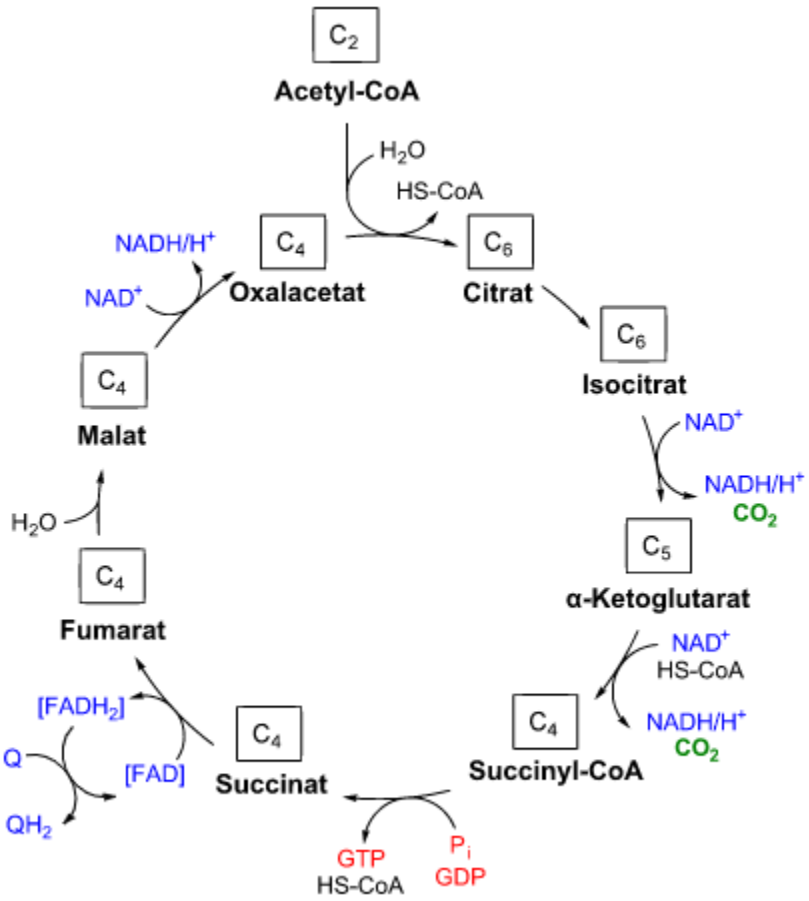
ii. Link Reaction (Gateway Reaction): - Pyruvic acid undergoes oxidative decarboxylation to form acetyl CoA and NADH. This reaction occurs within the matrix of mitochondria.

iii. Krebs' Cycle (TCA Cycle): - The Krebs' Cycle occurs within the matrix of mitochondria. The net gain of energy is equal to 24 ATP molecules along with other products.

iv. Terminal Oxidation: - Electron Transport System or oxidative phosphorylation takes place in the inner mitochondrial membrane.

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

Ans: The schematic representation of an overall view of krebs' cycle (Citric acid cycle):



6. Explain ETS.

Ans: The electron transport system (ETS) is also called Oxidative Phosphorylation. It is present in the inner mitochondrial membrane. It's a metabolic pathway that allows electrons to go from one carrier to the next. The passes of electrons from NADH and $FADH_2$ to oxygen (O_2) is facilitated by five multiprotein complexes in the ETS. The complexes are:

Complex I (NADH dehydrogenase), Complex II (Succinate dehydrogenase), Complex III (Cytochrome bc_1 Complex), Complex IV (Cytochrome c oxidase) and Cytochrome V (ATP Synthase). The steps involved in ETS are as follows:

1. Electrons from NADH produced in the inner mitochondrial matrix during the citric acid cycle are oxidized by NADH dehydrogenase (Complex I).

2. Post this, electrons are transferred to Ubiquinone which receives reducing equivalents via $FADH_2$ (Complex II).

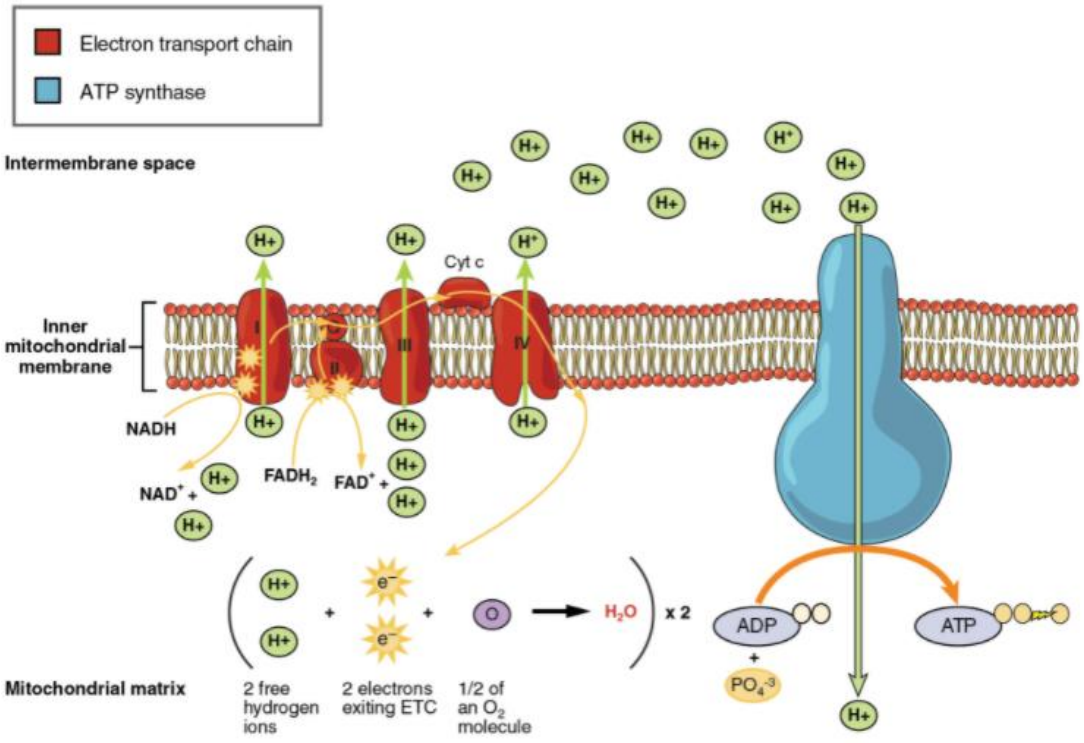
3. Ubiquinol (reduced ubiquinone) is then oxidized with the transfer of electrons to Cytochrome c via Cytochrome bc_1 Complex (Complex III).

4. Cytochrome c oxidase Complex (Complex IV) contains cytochromes a, a_3 and two Cu centres.

5. When electrons travel from one carrier to another in the electron transport chain via complex I to IV, they are connected to ATP Synthase (complex V).

6. Complex V consists of components like F_1 (peripheral membrane protein complex) and F_0 (integral membrane protein complex). At F_1 ATP is synthesized from ADP and Pi. Protons passing through channels formed by F_0 are coupled to the catalytic site of F_1.

7. One molecule of NADH (oxidized) provides 3 molecules of ATP. One molecule of $FADH_2$ produces 2 molecules of ATP.



7. Distinguish between the following:

a. Aerobic respiration and Anaerobic respiration

Ans: The differences between aerobic and anaerobic respiration are as follows:

Aerobic Respiration	Anaerobic respiration
It occurs in the presence of oxygen.	It occurs in the absence of oxygen.
It is a type of respiration in which food (generally carbohydrates) is completely oxidized to carbon dioxide and water with the release of chemical energy.	It is a type of respiration in which food (generally carbohydrates) is partially oxidized with the release of chemical energy.
Since the substrate is completely oxidized, the energy yield of this type of respiration is more than that of anaerobic respiration.	Since the substrate is oxidized partially, the energy yield of this type of respiration is lower than that of aerobic respiration.
Complete oxidation of one molecule of glucose leads to a net gain of 38 ATP molecules.	Partial oxidation of one molecule of glucose leads to a net gain of 2 ATP molecules.
The end product of aerobic respiration is CO_2 and H_2O (all higher organisms).	The end product of anaerobic respiration is lactic acid (animal cells), ethanol and CO_2 (lower organisms like bacteria and yeast).
Some reactions of aerobic respiration occur in the cytoplasm (glycolysis) and the mitochondria (Krebs' cycle and ETS).	All reactions of anaerobic respiration occur in the cytoplasm. There is no involvement of mitochondria in this process.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 686Kcal$	$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH + 59Kcal$

b. Glycolysis and Fermentation

Ans: The differences between glycolysis and fermentation are as follows:

Glycolysis	Fermentation
Glycolysis is a common pathway for both aerobic and anaerobic modes of respiration.	Fermentation is a type of anaerobic respiration which occurs in the absence of oxygen.
Glucose is split into two molecules of pyruvic acid during glycolysis.	During fermentation, pyruvic acid is converted to ethyl alcohol (yeast and some other microbes) or lactic acid (muscle cells of humans).
Glycolysis results in a net gain of 2 molecules of ATP.	No ATP is produced during fermentation.
It gives out two molecules of NADH per glucose molecule.	It generally utilizes NADH produced during glycolysis.

c. Glycolysis and Citric acid cycle

Ans: The differences between glycolysis and citric acid cycle are as follows:

Glycolysis	Citric Acid Cycle
Glycolysis is the first step of respiration.	The citric acid cycle (Krebs' cycle or TCA Cycle) is the second step of respiration.
This process happens in the cytoplasm.	This process occurs in the matrix of

	mitochondria.
It occurs both aerobically and anaerobically.	It occurs anaerobically.
Two ATPs are consumed during this process.	No consumption of ATP in the citric acid cycle.
The total gain of ATP is 8 (which includes NADH).	The net gain of ATP is 24.
Oxidative phosphorylation is not involved.	Oxidative phosphorylation is involved.
It is a linear pathway.	It is a circular pathway.
Carbon-di-oxide has not evolved.	Carbon-di-oxide is evolved.

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

Ans: Calculating the net gain of ATP for each glucose molecule oxidised is doable, but it could only be a theoretical exercise in practise. These calculations can only be made based on the following assumptions:

i. There is a sequential, orderly pathway is in function, with one substrate forming the next and glycolysis, TCA cycle, and ETS pathway occurring one after the other.
ii. The NADH produced during glycolysis is transferred to the mitochondria and undergoes oxidative phosphorylation. None of the intermediates in the pathway is used to make another compound.
iii. Only glucose is respired. No other alternative substrates enter the pathway at any of the intermediate stages.

These kinds of assumptions, however, are not valid in a living system. All pathways occur simultaneously and do not occur one after the other. Substrates enter the pathways and are withdrawn from them as needed. ATP is used as

and when it is required. Multiple factors influence enzymatic rates. As a result, aerobic respiration of one molecule of glucose can result in a net gain of 36 ATP molecules.

9. Discuss "The respiratory pathway is an amphibolic pathway".

Ans: The amphibolic pathway is the one that is used for both breakdown (catabolism) and build-up (anabolism) reactions. Respiratory pathways are mainly a catabolic process that serves to run the living system by providing energy. Several intermediates are produced by the respiratory pathway. Many of them serve as raw materials for the formation of both primary and secondary metabolites. acetyl CoA is essential not only for the Krebs cycle but also for the synthesis of fatty acids, aromatic compounds, steroids, terpenes and carotenoids. In amination, $\alpha-$ ketoglutarate forms glutamate (an important amino acid). In amination, OAA (Oxaloacetic acid) produces aspartate. Aspartate and glutamate are components of proteins. Other products include pyrimidines and alkaloids. Succinyl CoA is the precursor to cytochromes and chlorophyll.

When fatty acids are used as a substrate, they are broken down to acetyl CoA before entering the respiratory pathway. acetyl CoA is withdrawn from the respiratory pathway when the organism needs to synthesize fatty acids.

As a result, the respiratory pathway is involved in both the breakdown and synthesis of fatty acids.

Similarly, respiratory intermediates serve as a link during the breakdown and synthesis of proteins. Catabolism is the breaking down processes within a living organism, while anabolism is the synthesis of new ones. Since the respiratory system is engaged in both anabolism and catabolism in plants, it is better to think of it as an amphibolic instead of a catabolic pathway.

10. Define RQ. What is its value for fats?

Ans: The ratio of the volume of CO_2 evolved to the volume of O_2 consumed in respiration over a given period is known as a respiratory quotient (RQ) or respiratory ratio. Its value can be equal to one, zero, more than one or less than one.

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

When fat or protein is used as a respiratory substrate, the respiratory quotient (RQ) is less than one.

$$C_{57}H_{104}O_6 + 80O_2 \rightarrow 57CO_2 + 52H_2O$$

$$RQ = \frac{57CO_2}{80O_2}$$

$$= 0.71$$

The respiratory quotient (RQ) is about 0.7 for most of the common fats.

11. What is oxidative phosphorylation?

Ans: The process by which ATP is formed as a result of the transfer of electrons from NADH or $FADH_2$ to O_2 by a series of electron carriers is known as oxidative phosphorylation. This process, which occurs in mitochondria, is the primary source of ATP in aerobic organisms.

For example, when glucose is completely oxidized to CO_2 and H_2O, oxidative phosphorylation generates 26 of the 30 molecules of ATP.

12. What is the significance of the stepwise release of energy in respiration?

Ans: The following are the benefits of stepwise release of energy in respiration: -

i. There is a gradual release of chemical bond energy, which is easily trapped in the formation of ATP molecules.
ii. The temperature of the cell is not allowed to rise.
iii. Energy waste is reduced.
iv. A variety of intermediates can be used in the production of a variety of biochemicals.
v. Different substances can undergo respiratory catabolism via their metabolic intermediates.
vi. Each step of respiration is regulated by its enzyme. Specific compounds can either increase or decrease the activity of various enzymes. This aids in controlling the rate of respiration as well as the amount of energy released.