CHAPTER – 12

RESPIRATION IN PLANTS

EXERCISES

2 Mark Questions

Q1: What are respiratory substrates? Name the most common respiratory substrate.

Answer: Respiratory substrates are those organic substances which are oxidised during respiration to liberate energy inside the living cells. The common respiratory substrates are carbohydrates, proteins, fats and organic acids. The most common respiratory substrate is glucose. It is a hexose monosaccharide.

Q2: Define RQ. What is its value for fats?

Answer: Respiratory quotient (RQ) is the ratio of the volume of carbon dioxide produced to the volume of oxygen consumed in respiration over a period of time. Its value can be one, zero, more than 1 or less than one.

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

Volume of C02 evolved Volume of 02 consumed

RQ is less than one when the respiratory substrate is either fat or protein.

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

$RQ = 57CO_2/80O_2 = 0.71$

RQ is about 0.7 for most of the common fats.

Q3: How is the energy released and stored during oxidation of compounds in respiration?

Answer: The energy released is directly collected in ATP in the form of chemical bonds. ADP + IP + energy → ATP This bond is broken and utilized whenever required ATP → ADP + IP + energy

Q4: What is 'Energy Currency'. Name the substance in animals and plants that act as an energy currency.

Answer: Energy is required by every cell to function. Energy currency releases and stores energy as and when required in the cell. In both plants and animals, ATP is known as the energy currency.

Q5: In man and yeast, when does anaerobic respiration take place?

Answer: In man, it occurs when there is a lack of oxygen during cellular respiration, hence pyruvic acid is reduced to lactic acid by the lactate dehydrogenase. In yeasts also it occurs in the absence of oxygen.

4 Mark Questions

Q1: What are the main steps in aerobic respiration? Where does it take place?

Answer: Aerobic respiration is an enzymatically controlled release of energy in a stepwise catabolic process of complete oxidation of organic food into carbon dioxide and water with oxygen acting as terminal oxidant. It
occurs by two methods, common pathway and pentose phosphate pathway. Common pathway is known so because its first step, called glycolysis, is common to both aerobic and anaerobic modes of respiration. The common pathway of aerobic respiration consists of three steps – glycolysis, Krebs' cycle and terminal oxidation. Aerobic respiration takes place within mitochondria. The final product of glycolysis, pyruvate is transported from the cytoplasm into the mitochondria.

Q2: What is the significance of step-wise release of energy in respiration?

Answer: The utility of step-wise release of energy in respiration are given as follows :
(i) There is a step-wise release of chemical bond energy which is very easily trapped in forming ATP molecules.
(ii) Cellular temperature is not allowed to rise.
(iii) Wastage of energy is reduced.
(iv) There are several intermediates which can be used in production of a number of biochemicals.

(v) Through their metabolic intermediates different substances can undergo respiratory catabolism.
(vi) Each step of respiration is controlled by its own enzyme. The activity of different enzymes can be enhanced or inhibited by specific compounds.
This helps in controlling the rate of respiration and the amount of energy liberated by it.

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Q4:Give the schematic representation of an overall view of Krebs' cycle.
Answer:

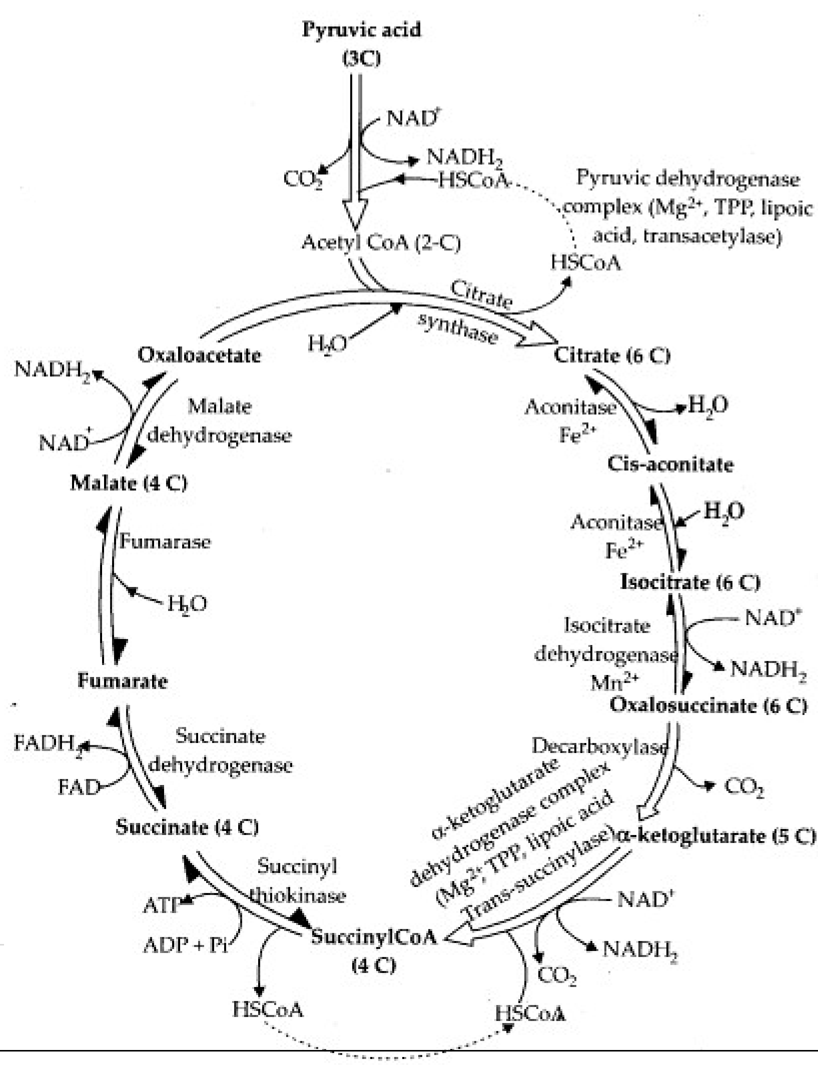

Fig.: Schematic representation of Krebs' cycle

7 Mark Questions

Q1:Differentiate between
(a) Respiration and Combustion
(b) Glycolysis and Krebs'cycle
(c) Aerobic respiration and Fermentation

Answer:

(a) Differences between respiration and combustion are as follows:

	Respiration	Combustion
(i)	It occurs inside living cells.	It is a noncellular process.
(ii)	Respiration is a biochemical process.	Combustion is a physio-chemical process.
(iii)	Energy is released in stages as chemical bonds are broken in steps.	Energy is released in a single step as all chemical steps occur simultaneously.
(iv)	Most of the energy is trapped in ATP molecules.	ATP is not formed.
(v)	Oxidation occurs at the end of reaction (terminal oxidation) between reduced coenzymes and oxygen.	The substrate is directly oxidised in combustion.
(vi)	A number of intermediates are formed. They are used in the synthesis of different organic compounds	No intermediates are produced in combustion.
(vii)	A number of enzymes are required, one for each step or reaction.	Burning is a non-enzymatic process.
(viii)	Less than 50% energy is liberated in the form of heat energy. Light is rarely produced.	Energy is libreated in the form of both light and heat energy.
(ix)	Temperature is not allowed to rise.	Temperature becomes very high.

(b) Differences between glycolysis and Krebs' cycle are as follows:

	Glycolysis	Krebs' cycle
(i)	It occurs inside the cytoplasm.	Krebs' cycle operates inside mitochondria.
(ii)	Glycolysis is the first step of respiration in which glucose is broken down to the level of pyruvate.	Krebs' cycle is the second step in respiration where an active acetyl group is broken down completely.
(iii)	The process is common to both aerobic and anaerobic modes of respiration.	It occurs only in aerobic respiration.
(iv)	It degrades a molecule of glucose into two molecules of an organic substance, pyruvate.	It degrades pyruvate completely into inorganic substances ($CO_2 + H_2O$).
(v)	Glycolysis consumes 2 ATP molecules for the initial phosphorylation of substrate molecule.	It does not consume ATP.
(vi)	In glycolysis, one glucose molecule liberates 4 ATP molecules through substrate level phosphorylation.	In Krebs' cycle, two acetyl residues liberate two ATP or GTP molecules through substrate level phosphorylation.
(vii)	Net gain is two molecules of NADH and two molecules of ATP for every molecule of glucose broken down.	Krebs' cycle produces six molecules of NADH, and 2 molecules of $FADH_2$ for every two molecules of acetyl CoA oxidised by it. Two molecules of NADH are liberated during conversion of two pyruvates to acetyl CoA.
(viii)	The net gain of energy is equal to 8 ATP.	The net gain of energy is equal to 24 molecules of ATP. Six molecules of ATP can be produced from $2NADH_2$ formed during dehydrogenation of two pyruvates.
(ix)	No carbon dioxide is evolved in glycolysis.	Carbon dioxide is evolved in Krebs' cycle.
(x)	Oxygen is not required for glycolysis.	Krebs' cycle uses oxygen as terminal oxidant.

(C)Differences between aerobic respiration and fermentation are as follows:

	Aerobic respiration	Fermentation
(i)	It uses oxygen for breaking the respiratory material into simpler substances.	Oxygen is not used in the breakdown of respiratory substrate.
(ii)	Respiratory material is completely oxidised.	Respiratory material is incompletely broken.
(iii)	The end products are inorganic.	At least one of the end products is organic. Inorganic substances may or may not be produced.
(iv)	Aerobic respiration is the normal mode of respiration of plants and animals.	It is the normal mode of respiration in some parasitic worms and microorganisms. In others, anaerobic respiration is a stop-gap arrangement.
(v)	Aerobic respiration consists of three steps –glycolysis, Krebs' cycle and terminal oxidation.	Anaerobic respiration or fermentation consists of two steps – glycolysis and incomplete breakdown of pyruvic acid.
(vi)	Every carbon atom of the food is oxidised and a large quantity of carbon dioxide is evolved.	Less quantity of carbon dioxide is evolved.
(vii)	Water is formed.	Water is usually not formed.
(viii)	686 kcal of energy are produced per gm mole of glucose.	Only 39-59 kcal of energy are formed per gm mole of glucose.
(ix)	It continues indefinitely.	It cannot continue indefinitely (except in some micro-organisms) because of the accumulation of poisonous compounds and less availability of energy per gm mole of food broken.

Q2:Give the schematic representation of glycolysis.

Answer:

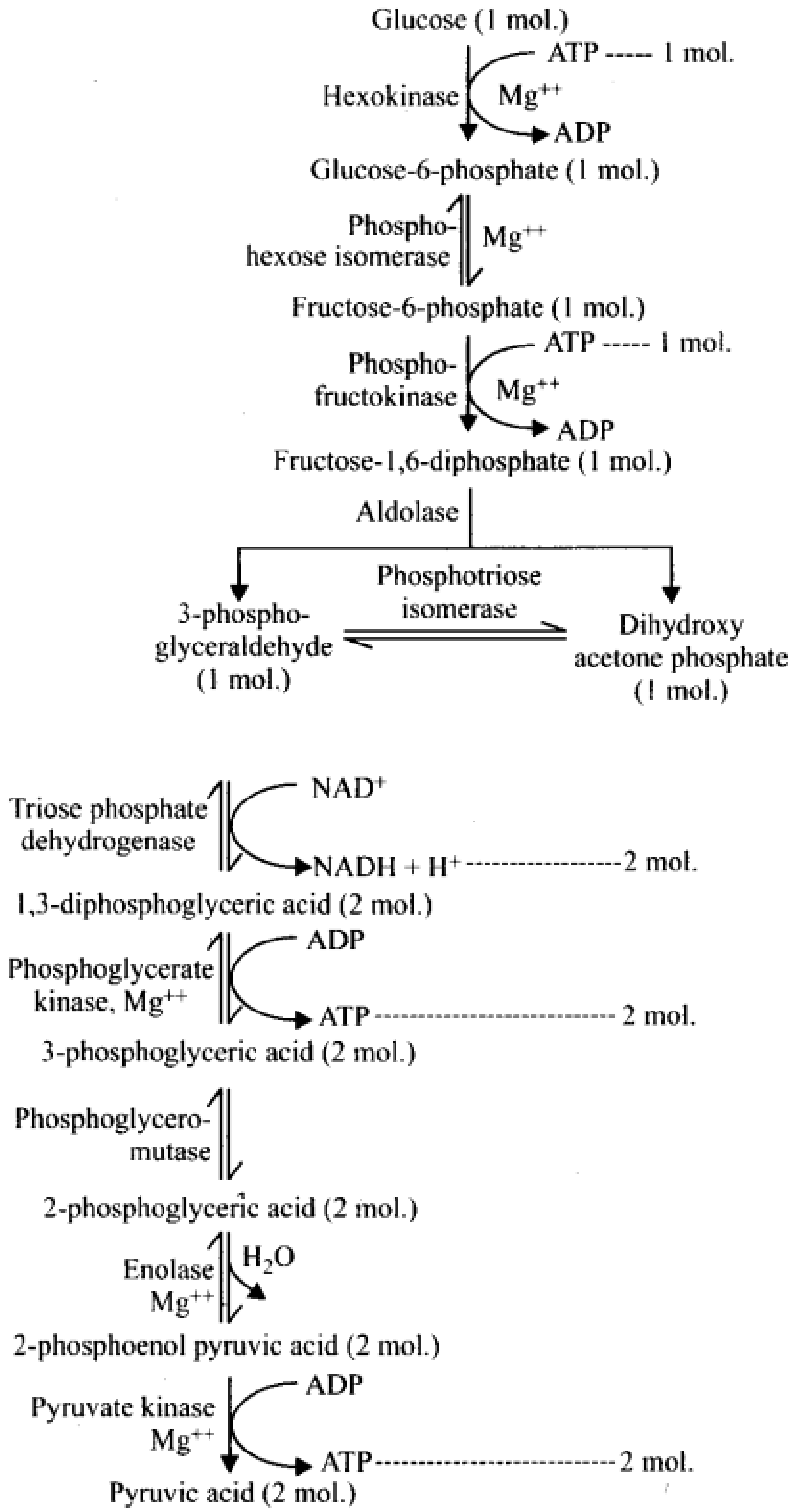

Fig.: Glycolysis or EMP-pathway.

Q3:Explain ETS.

Answer:An electron transport chain or system (ETS) is a series of coenzymes and cytochromes that take part in the passage of electrons from a chemical to its ultimate acceptor. Reduced coenzymes participate in electron transport chain. Electron transport takes place on cristae of mitochondria [oxysomes (F_0 -F_1 , particles) found on the inner surface of the membrane of mitochondria]. NADH formed in glycolysis and citric acid cycle are oxidised by NADH dehydrogenase (complex I) and the electrons are transferred to ubiquinone. Ubiquinone also receives reducing equivalents via FADH2 through the activity of succinate dehydrogenase (complex II). The reduced ubiquinone is then oxidised by transfer of electrons of cytochrome c via cytochrome Fc, complex (complex III). Cytochrome c acts as a mobile carrier between complex III and complex IV. Complex IV refers to cytochrome c oxidase complex containing cytochromes a and $a_3$and two copper centres. When the electrons are shunted over the carriers via complex I to IV in the electron transport chain, they are coupled to ATP synthetase (complex V) for the formation of ATP from ADP and Pi. Oxygen functions as the terminal acceptor of electrons and is reduced to water along with the hydrogen atoms. Reduced coenzymes (coenzyme I, II and FAD) do not combine directly with the molecular O_2. Only their hydrogen or electrons are transferred through various substances and finally reach O_2. The substances useful for the transfer of electron are called electron carriers. Only electrons are transferred through cytochromes (Cyt F_1 Cyt c,,C_2, a, a_3) and finally reach molecular O_2. Both cytochrome a and a3 form a system called cytochrome oxidase. Copper is also present in Cyt a_3 in addition to iron. The molecular oxygen that has accepted electrons now receives the protons that were liberated into the surrounding medium to give rise to a molecule of water. The liberated energy is utilised for the synthesis of ATP from ADP and Pi.

Q4:Distinguish between the following:
(a) Aerobic respiration and Anaerobic respiration.
(b) Glycolysis and Fermentation.
(c) Glycolysis and Citric acid cycle.

Answer:

(a) Differences between aerobic and anaerobic respiration are as follows:

Aerobic respiration	Anaerobic respiration
Aerobic respiration is a type of respiration in which foodstuffs (usually carbohydrates) are completely oxidised to carbon dioxide and water, with the release of chemical energy, in a process requiring atmospheric oxygen. The reaction can be summarized by the equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$	Anaerobic respiration is a type of respiration in which foodstuffs (usually carbohydrates) are partially oxidised, with the release of chemical energy, in a process not involving atmospheric oxygen. Since the substrate is never completely oxidised the energy yield of this type of respiration is lower than that of aerobic respiration. It occurs in some yeasts and bacteria and in muscle tissue when oxygen is absent.

(b) Differences between glycolysis and fermentation are as follows:

	Glycolysis	Fermentation
(i)	It is the first step of respiration which occurs without requirement of oxygen and is common to both aerobic and anaerobic modes of respiration.	It is anaerobic respiration or respiration which does not require oxygen.
(ii)	Glycolysis produces pyruvic acid.	Fermentation produces different products. The common ones are ethanol (and CO_2) and lactic acid.
(iii)	It produces two molecules of NADH per glucose molecule.	It generally utilises NADH produced during glycolysis.
(iv)	It forms 2 ATP molecules per glucose molecule.	It does not produce ATP.

Q5:Discuss “The respiratory pathway is an amphibolic pathway”.

Answer:Amphibolic pathway is the one which is used for both breakdown (catabolism) and build-up (anabolism) reactions. Respiratory pathway is mainly a catabolic process which serves to run the living system by providing energy. The pathway produces a number of intermediates. Many of them are raw materials for building up both primary and secondary metabolites. Acetyl CoA is helpful not only in Krebs’ cycle but is also raw material for synthesis of fatty acids, steroids, terpenes, aromatic compounds and carotenoids, a-ketoglutarate is organic acid which forms glutamate (an important amino acid) on amination. OAA (Oxaloacetic acid) on amination produces asparate. Both aspartate and glutamate are components of proteins. Pyrimidines and alkaloids are other products. Succinyl CoA forms cytochromes and chlorophyll.

Hence, fatty acids would be broken down to acetyl CoA before entering the respiratory pathway when it is used as a substrate. But when the organism needs to synthesise fatty acids, acetyl CoA would be withdrawn from the respiratory pathway for it. Hence, the respiratory pathway comes into the picture both during breakdown and synthesis of fatty acids. Similarly, during breakdown and synthesis of proteins too, respiratory intermediates form the link. Breaking down processes within the living organism is catabolism, and synthesis is anabolism. Because the respiratory pathway is involved in both anabolism and catabolism, it would hence be better to consider the respiratory pathway as an amphibolic pathway rather than as a catabolic one.

Q6:What is oxidative phosphorylation?

Answer:Oxidative phosphorylation is the synthesis of energy rich ATP molecules with the help of energy liberated during oxidation of reduced co-enzymes (NADH, $FADH_2$) produced in respiration. The enzyme required for this synthesis is called ATP synthase. It is considered to be the fifth complex of electron transport chain. ATP synthase is located in FT or head piece of F_0 -F_1 or elementary particles. The particles are present in the inner mitochondrial membrane. ATP synthase becomes active in ATP formation only where there is a proton gradient having higher concentration of H^+ or protons on the F_0 side as compared to F x side (chemiosmotic hypothesis of Peter Mitchell).
Increased proton concentration is produced in the outer chamber or outer surface of inner mitochondrial membrane by the pushing of proton with the help of energy liberated by passage of electrons from one carrier to another. Transport of the electrons from NADH over ETC helps in pushing three pairs of protons to the outer chamber while two pairs of protons are sent outwardly during electron flow from $FADH_{2.}$ The flow of protons through the F_0 channel induces F_1 particle to function as ATP-synthase. The energy of the proton gradient is used in attaching a phosphate radical to ADP by high energy bond. This produces ATP. Oxidation of one molecule of $NADH_2$ produces 3 ATP molecules while a similar oxidation of $FADH_2$ forms 2 ATP molecules.

Multiple Choice Questions

1. **Alpha-ketoglutarate dehydrogenase results in**
    a. Oxidation and Decarboxylation
    b. Reduction
    c. Oxidation
    d. None of the above

Answer: Oxidation and Decarboxylation

2. **__________ is a product of aerobic respiration**
    a. Malic acid
    b. Pyruvate
    c. Ethylene
    d. Lactose

Answer: Malic acid

3. **Energy gained during aerobic respiration is ________ times more than anaerobic respiration.**
    a. 8
    b. 12
    c. 19
    d. 32

Answer: 19

4. **Glycolysis is also known as _________**
    a. EMP pathway
    b. TCA pathway
    c. carbon sequestration
    d. None of the above

Answer: EMP pathway

5. **Protons accumulate on the __________ in mitochondria.**
    a. Inner membrane
    b. Intermembrane space
    c. Outer membrane
    d. None of the above

Answer: Intermembrane space

6. **Oxidative phosphorylation usually refers to________**
    a. Anaerobic production of ATP
    b. Citric acid cycle production of ATP
    c. Alcoholic fermentation
    d. None of the above

Answer: Citric acid cycle production of ATP

7. **The process of cell respiration is carried out by _______**
    a. Mitochondria
    b. Chloroplast
    c. Nucleus
    d. None of the above

Answer: Mitochondria

8. **An important product of the Krebs cycle is**
    a. Water
    b. Methane
    c. ATP
    d. None of the above

Answer: ATP

9. **Acetyl CoA forms a 6-C compound after combining with**
    a. Oxygen
    b. Pyruvic acid
    c. Citric acid
    d. Oxaloacetic acid

Answer: Oxaloacetic acid

SUMMARY

Plants unlike animals have no special systems for breathing or gaseous exchange. Stomata and lenticels allow gaseous exchange by diffusion. Almost all living cells in a plant have their surfaces exposed to air. The breaking of C-C bonds of complex organic molecules by oxidation cells leading to the release of a lot of energy is called cellular respiration. Glucose is the favoured substrate for respiration. Fats and proteins can also be broken down to yield energy. The initial stage of cellular respiration takes place in the cytoplasm. Each glucose molecule is broken through a series of enzyme catalysed reactions into two molecules of pyruvic acid. This process is called glycolysis. The fate of the pyruvate depends on the availability of oxygen and the organism. Under anaerobic conditions either lactic acid fermentation or alcohol fermentation occurs. Fermentation takes place under anaerobic conditions in many prokaryotes, unicellular eukaryotes and in germinating seeds. In eukaryotic organisms aerobic respiration occurs in the presence of oxygen. Pyruvic acid is transported into the mitochondria where it is converted into acetyl CoA with the release of CO2. Acetyl CoA then enters the tricarboxylic acid pathway or Krebs' cycle operating in the matrix of the mitochondria. NADH + H+ and FADH2 are generated in the Krebs' cycle. The energy in these molecules as well as that in the NADH + H+ synthesised during glycolysis are used to synthesise ATP. This is accomplished through a system of electron carriers called electron transport system (ETS) located on the inner membrane of the mitochondria. The electrons, as they move through the system, release enough energy that are trapped to synthesise ATP. This is called oxidative phosphorylation. In this process O2 is the ultimate acceptor of electrons and it gets reduced to water. The respiratory pathway is an amphibolic pathway as it involves both anabolism and catabolism. The respiratory quotient depends upon the type of respiratory substance used during respiration.