CHAPTER 14

Respiration in Plants

NCERT FOCUS

ANSWERS

Topic 1

1. 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.

2. 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.

3. 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 one or less than one.

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

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

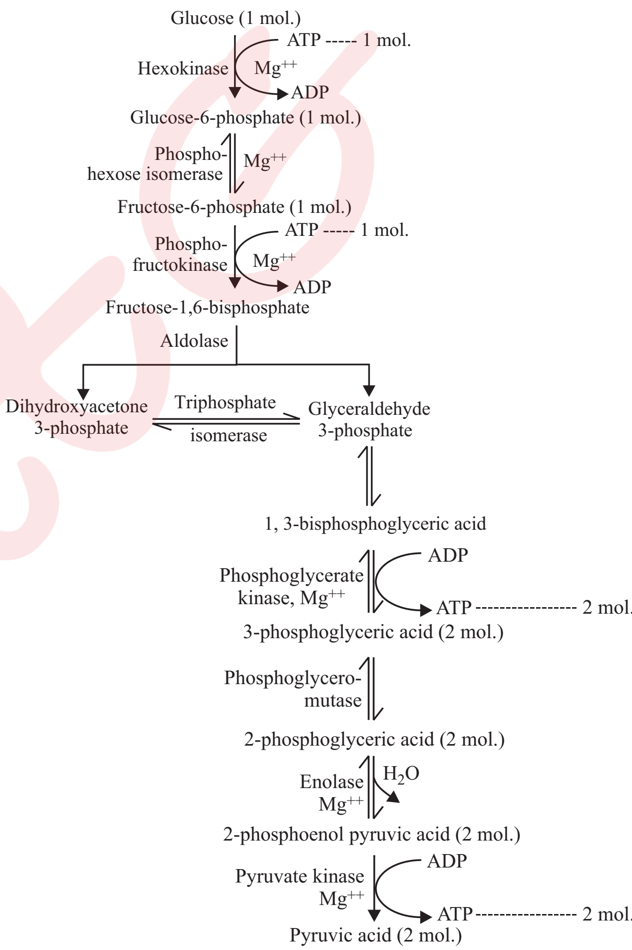
$C_{57}H_{104}O_6 + 80\ O_2 \rightarrow 57CO_2 + 52H_2O$

$RQ = 57CO_2/80\ O_2 = 0.71$

RQ is about 0.7 for most of the common fats.

Topic 2

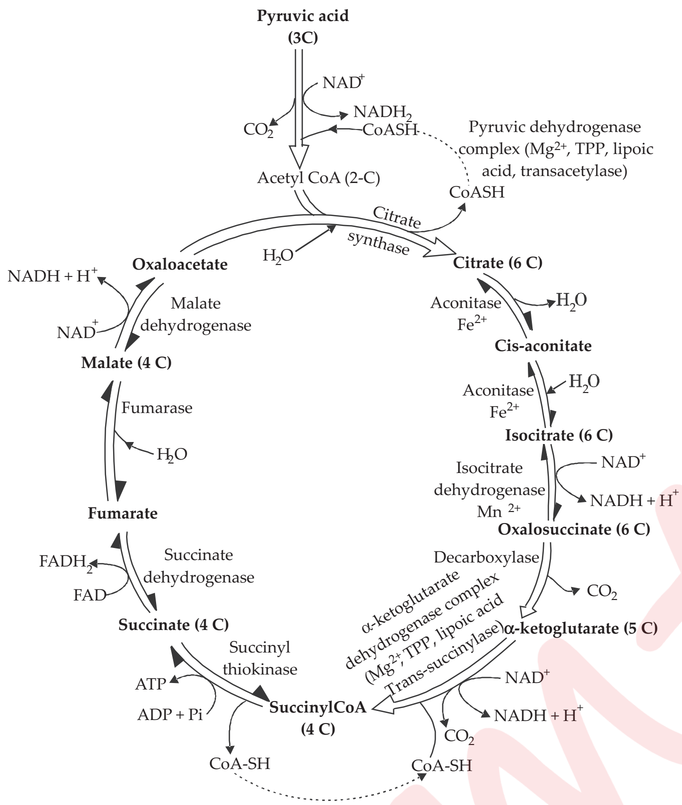
1. The schematic representation of glycolysis is given below:



2. 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. 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.

3. A schematic representation of Krebs' cycle is given below :



4. 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* $FADH_2$ through the activity of succinate dehydrogenase (complex II). The reduced ubiquinone is then oxidised by transfer of electrons of cytochrome *c via* cytochrome bc_1 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 synthase (complex V) for the formation of ATP from ADP and P_i. 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 *b*, Cyt c_1, c_2, *a*, a_3) and finally reach molecular O_2. Both cytochrome *a* and a_3 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 P_i.

5. It is possible to make calculations of the net gain of ATP for every glucose molecule oxidised; but in reality this can remain only a theoretical exercise. These calculations can be made only on certain assumptions that :

– There is a sequential, orderly pathway functioning, with one substrate forming the next and with glycolysis, TCA cycle and ETS pathway following one after another.

– The NADH synthesised in glycolysis is transferred into the mitochondria and undergoes oxidative phosphorylation.

– None of the intermediates in the pathway are utilised to synthesise any other compound.

– Only glucose is being respired – no other alternative substrates are entering in the pathway at any of the intermediary stages.

But these kind of assumptions are not really valid in a living system; all pathway work simultaneously and do not take place one after another; substrates enter the pathways and are withdrawn from it as and when necessary ; ATP is utilised as and when needed; enzymatic rates are controlled by multiple means. Hence, there can be a net gain of 36 or 38 ATP molecules during aerobic respiration of one molecule of glucose.

6. 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 F_1 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_1 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.

Topic 3

1. 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.

α-ketoglutarate is organic acid which forms glutamate (an important amino acid) on amination. OAA (Oxaloacetic acid) on amination produces aspartate. 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 or an anabolic one.

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

S. No.	Respiration	Combustion
(i)	It occurs inside living cells.	It is a non-cellular 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 liberated 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:

S.No.	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:

S.No.	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 microorganisms) because of the accumulation of poisonous compounds and less availability of energy per gm mole of food broken.

3. (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 summarised by the equation : $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + 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:

S.No.	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.

(c) *Refer to answer 2(b).*