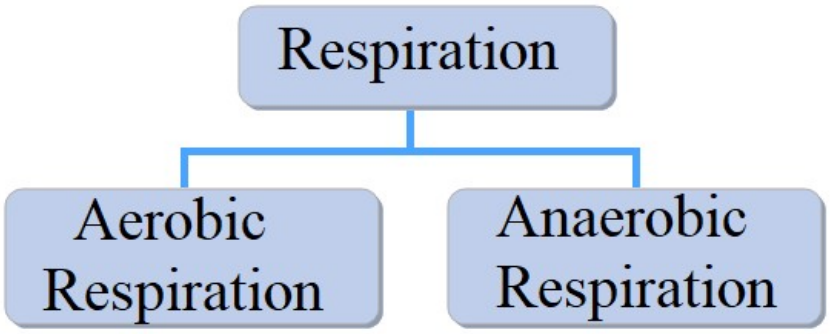
BIOLOGY

RESPIRATION IN PLANTS

Respiration

Respiration is an energy releasing, enzymatically controlled catabolic process which involves a step-wise oxidative breakdown of food substance inside living cells.



Aerobic Respiration: 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.

Anaerobic Respiration: Anaerobic respiration is the type of respiration through which cells can break down sugars to generate energy in the absence of oxygen. This is in contrast to the highly efficient process of aerobic respiration, which relies on oxygen to produce energy.

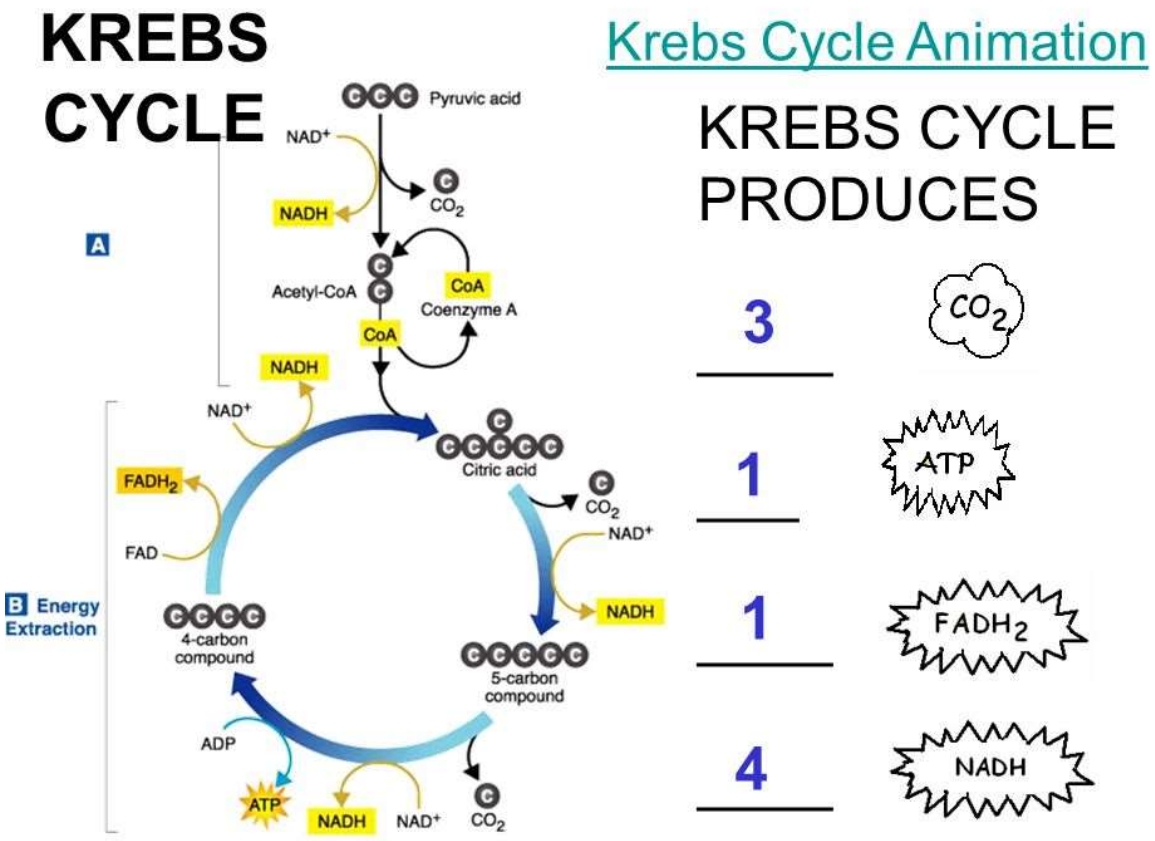
Aerobic Respiration

- Glycolysis
- Kreb's Cycle
- Terminal Oxidation

Glycolysis

- The scheme of glycolysis is given by Gustav Embden, Otto Meyerhof, and J. Parnas. It is also called as EMP pathway.
- Glycolysis is the partial oxidation of glucose or similar hexose sugar into two molecules of pyruvic acid through a series of enzyme mediated reaction releasing some ATP and NADH2. It occurs in cytoplasm.
- In plants glucose is derived from sucrose or from storage carbohydrates. Sucrose is converted into glucose and fructose by enzyme invertase.
- Glycolysis starts with phosphorylation of glucose in presence of enzyme hexokinase to form Glucose-6-phosphate. One molecules of ATP is used in this process.

- In next steps Glucose-6-phosphate is converted into fructose-6-phosphate, catalyzed by enzyme phosphohexose isomerase.
- Fructose-6-phosphate uses another molecule of ATP to form Fructose-1-6 biphosphate in presence of enzyme phosphofructokinase.



Tricarboxylic Acid Cycle/ Kreb's Cycle

- The Acetyl CoA enters a cyclic pathway called TCA cycle or Kreb's cycle.
- TCA cycle was discovered by Hans Krebs in 1940. This cycle is called TCA cycle because initial product is citric acid.
- Acetyl CoA combine with OAA (Oxaloacetic acid) and water to yield citric acid in presence of enzyme citrate synthase to release CoA.
- Citrate is then isomerized to isocitrate. It is followed by two successive steps of decarboxylation, leading to the formation of α-ketoglutaric acid and then succinyl-CoA.
- In the remaining steps, succinyl-CoA is oxidized to OAA allowing the cycle to continue.
- There are three points in the cycle where NAD + is reduced to $NADH_2$ and one point where FAD + is reduced to $FADH_2$.
- A molecule of glucose produces two molecules of $NADH_2$, 2ATP and two pyruvate while undergoing glycolysis. The two molecules of pyruvate are completely degraded in Krebs

cycle to form two molecules of ATP, $8NADH_2$ and $2FADH_2$.

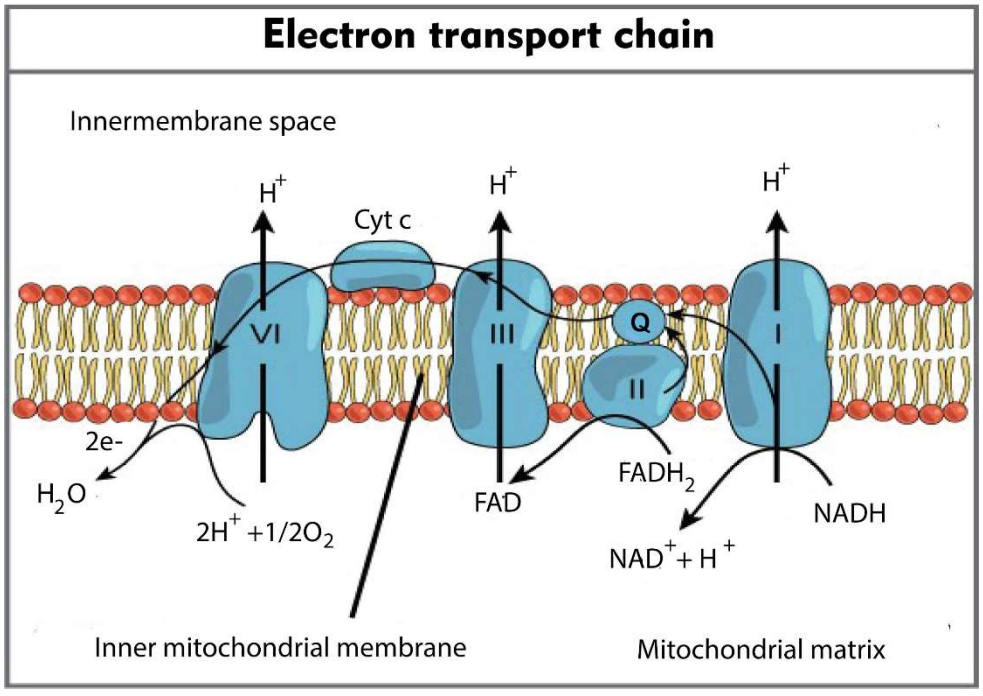
$$\text{Pyruvic} + 4NAD^+ + FAD^+ + 2H_2O + ADP + Pi \xrightarrow[\text{Matrix}]{\text{Mitochondrial}} 3CO_2 + 4NADH + 4H^+ + FADH_2 + ATP$$

Terminal Oxidation

Terminal Oxidation is the name of oxidation found in aerobic respiration that occurs towards end of catabolic process and involves the passage of both electrons and protons of reduced coenzyme to oxygen to produce water.

Electron Transport Chain

- The metabolic pathway through which the electron passes from one carrier to another inside the inner mitochondrial membrane is called ETC or mitochondrial respiratory chain.
- Electrons from NADH produced during citric acid cycle are oxidized by NADH dehydrogenase and electrons are transferred to ubiquinone located within the inner membrane. Ubiquinone also receives electrons from $FADH_2$ which is transferred to cytochrome c via cytochrome bc_1 complex.
- When the electrons pass from one carrier to another via electron transport chain, they produce ATP from ADP and inorganic phosphate. The number of ATP molecules synthesized depends upon electron donor.
- Oxidation of one molecule of NADH gives rise to 3 molecules of ATP, while oxidation of one molecule of FAD_2 produce two molecules of ATP.



Oxidative phosphorylation

It occurs in respiration process. Energy of oxidation-reduction is used for production of proton gradient required for phosphorylation.

Photophosphorylation

It occurs in photosynthesis. Light energy is utilized for production of proton gradient for phosphorylation.

Fermentation

- It accounts for incomplete oxidation of glucose.
- In fermentation, there is net gain of only two molecules of ATP.
- NADH is oxidized to NAD+ very slowly.

Aerobic Respiration

- It accounts for complete oxidation of glucose.
- In aerobic respiration, there is more net gain of ATP.
- NADH is oxidized to NAD+ very fast.

Amphibolic Pathway

- Glucose is the favored substrate for respiration. All carbohydrates are usually converted into glucose before used for respiration.
- Fats needs to be broken down into glycerol and fatty acid, which is further broken converted into Acetyl CoA and enter the respiratory pathway.
- Proteins are broken into amino acids and further enter Krebs cycle.
- Breaking down process within living organism is called catabolism and synthesis process is called anabolism process. So, respiration is an Amphibolic pathway.

CHAPTER : 14 RESPIRATION IN PLANTS

Respiration in Plants

Definition

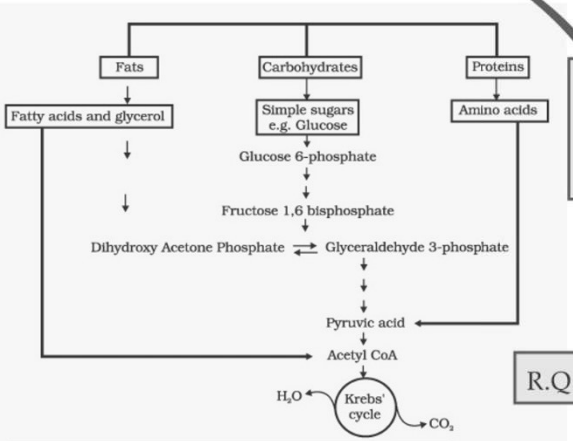
Respiration is an energy releasing enzymatically controlled catabolic process which involves a step–wise oxidative breakdown of food substances inside living cells.

Repiratory Quotient.

$$RQ = \frac{\text{Volume of } CO_2 \text{ Evolved}}{\text{Volume of } O_2 \text{ Consumed}}$$

R.Q. values = 1 (for carbohydrate...
R.Q.= 0.7...
R.Q. = 0.9....

R.Q formula



Amphibolic Pathway

Respiration is termed as amphibolic pathway as it involves both anabolism and catabolism.

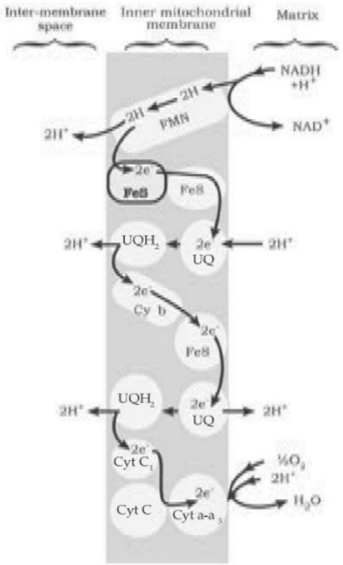
Aerobic respiration

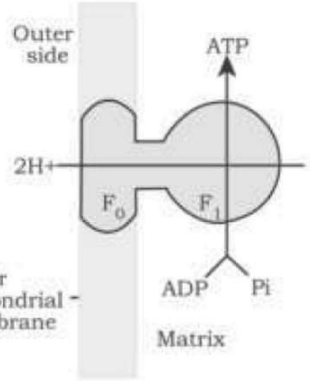
TCA Tricarboxylic Acid (Matrix of mitochondria)

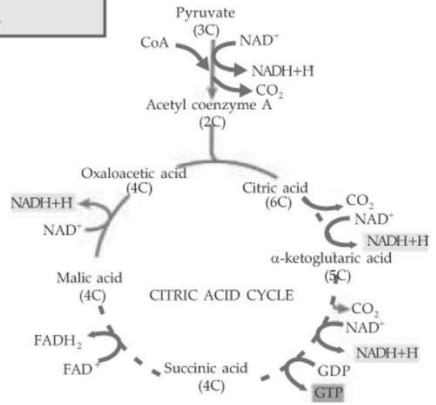
2nd of - Electron transport chain (Site: Inner mitochondrial membrane)

1st of - Oxidative Phosphorylation Site: F0- F1 particles in the inner mitochondrial membrane.

3rd of- TCA/ Tricarboxylic acid (Site: Matrix of mitochondria)



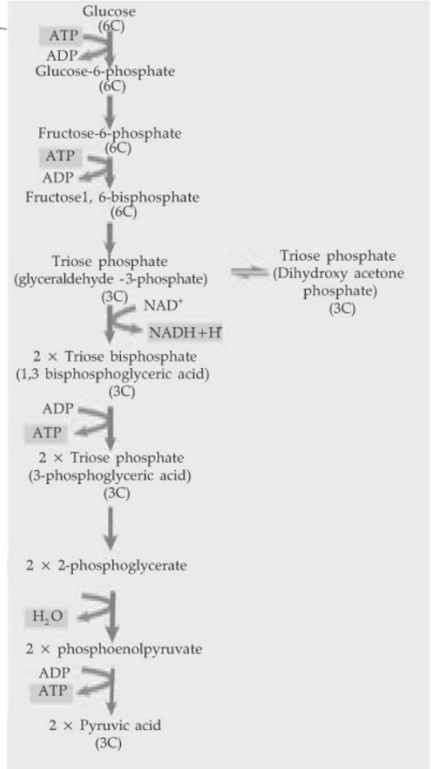




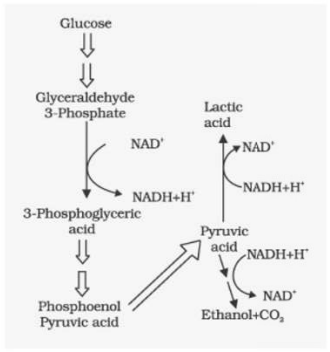
The Citric acid cycle

Glycolysis box

Glycolysis Or EMP pathway (Site: Cytoplasm)



Fermentation (Incomplete oxidation of pyruvic acid, under anaerobic condition)



Important Questions

➢ Multiple Choice Questions:

Question 1. Major fraction of CO_2 released during cellular respiration is transported in blood through the lungs in the form of

(a) Free CO_2

(b) HCO_3

(c) $H_2 CO_3$

(d) In combination with Hb CO_2

Question 2. Sudden deep inspiration is due to

(a) Increase in concentration of CO_2

(b) Increase in concentration of O_2

(c) Either increase in cone, of CO_2 or decrease in concentration of O_2

(d) Decrease in concertration of CO_2

Question 3. Fixing of CO_2 and liberation of oxygen in light is done with the help of

(a) chioroplast

(b) Mesophyll cells

(c) Mitocondria

(d) Chromatophores

Question 4. AH vegetation is only due to

(a) CO_2

(b) Water

(c) Oxygen

(d) Hydrogen

Question 5. Chioroplast DNA or ct DNA is

(a) Naked

(b) Circular

(c) Single stranded

(d) All of these

Question 6. During synthesis of a glucose molecule, ATP and NADPH consumed are respectively

(a) 15 and 12

(b) 12 and 8

(c) 30 and 20

(d) 18 and 12

Question 7. Photorespiration takes place in

(a) Lvsosomes

(b) Peroxisomes

(c) Ribosomes

(d) Mitochondria

Question 8. Chlorophyll 'a' is found in all

(a) Oxygen liberation photosvnthetic organisms

(b) Autotrophs

(c) Higher plants

(d) Algae

Question 9. The atmosphere contains CO_2 by volume

(a) 0.1%

(b) 0.5%

(c) 0.03%

(d) 0.3%

Question 10. Green plants convert solar energy into chemical energy of organic matter was proved by

(a) Van Mayer

(b) Lavoisier

(c) Joseph Priestly

(d) Semebier

Question 11. Wastage of energy is associated with

(a) Glycolysis

(b) Photosynthesis

(c) Krebs cycle

(d) Photorespiration

Question 12. If a photosvnthesising plant releases oxygen containing more amount of lsO, it is concluded that the plant has been supplied with

(a) ^{18}O from $^{18}CO_2$

(b) ^{18}O from $^{18}CO_2$

(c) ^{18}O from $H_2\ ^{18}O$

(d) None of these

Question 13. Carbon dioxide acceptor in C_3 plants is:

(a) RuBP

(b) RMP

(c) PGA

(d) PEP

Question 14. Photosynthetic process is completed in

(a) Chloroplasts

(b) Chlorophyll

(c) Chromatophores

(d) Mitochondria

Question 15. During synthesis of a glucose molecule, ATP and NADPH consumed are respectively

(a) 12 and 8

(b) 30 and 20

(c) 15 and 12

(d) 18 and 12

➢ Fill In the Blanks:

1. All the energy required for 'life' processes is obtained by oxidation of some macromolecules that we call ……
2. Green plants trap light energy and convert it into chemical energy that is stored in the bonds of carbohydrates like ……., …… and …….
3. Animals are …… i.e. they obtain food form plants directly (herbivores) or indirectly (carnivores).
4. The compounds that are oxidised during this process are known as …….
5. ……., …… and ……. respire at rates far lower than are characteristic for animals.
6. In stems, the '…….' cells are organised in thin layers in and beneath the bark.

➢ True or False:

1. Saprophytes like fungi are dependent on green plant.
2. Usually carbohydrates are oxidised to release energy, but proteins, fats and even organic acids can be used as respiratory substances in some plants, under certain conditions.
3. Only during photosynthesis are large volumes of gases exchanged and each leaf is well adapted to take care of its own needs during these periods.
4. In stems, the 'living' cells are organised in thin layers in and beneath the bark. They also have openings called lenticels.
5. The combustion reaction requires carbon.
6. Sucrose is converted into glucose and fructose by the enzyme invertase, and these two monosaccharides can readily enter the glycolytic pathway.

➢ Very Short Question:

1. Whether respiration is a catabolic or anabolic process?
2. Name the cell organelle where cellular respiration takes place.
3. Give the chemical equation for aerobic respiration.
4. Name the substance that is oxidized during respiration.
5. What is fermentation?
6. What is the main source of energy?
7. In what form the energy released by oxidation is stored in the body?
8. Name two respiratory, mediums for living beings.
9. What is cell respiration?
10. What holds the energy in the body?

➢ Short Questions:

1. What is respiration?
2. Define aerobic respiration.
3. Define the process of fermentation showing chemical equation.
4. On what factor the respiratory quotient depends?
5. What is a citric acid cycle?
6. What will be the value of RQ when organic acids are used as respiratory substrate?

$$2\ (COOH) + O_2 \longrightarrow 4\ CO_2 + 2H_2O + \text{Energy}$$

$$RQ = \frac{4\ CO_2}{1O_2} = 4$$

7. How many types of respiration occur in plants?
8. Describe the process of glycolysis and where it occurs.

➢ Long Questions:

1. Illustrate the mechanism of the electron transport system.
2. Describe the process and role of the citric acid cycle in living organisms.

Assertion Reason Question-

1. In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

   (a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.

   (b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

   (c) If Assertion is true but Reason is false.

   (d) If both Assertion and Reason are false.

   Assertion: Stomata are absent in submerged hydrophytes.

   Reason: Respiration occurs by means of air chambers in submerged plants. [AIIMS 1997]

2. In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

   (a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.

   (b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

   (c) If Assertion is true but Reason is false.

   (d) If both Assertion and Reason are false.

   Assertion: Glycolysis is the first step of respiration in which glucose completely breaks into CO_2 and H_2O.

   Reason: In this process, there is net gain of twenty four molecules of ATP. [AIIMS 2009]

✓ Answer Key-

➢ Multiple Choice Answers:

1. (c) H_2CO_3
2. (a) Increase in concentration of CO_2
3. (a) Chioroplast
4. (b) Water
5. (d) All of these
6. (d) 18 and 12

7. (b) Peroxisomes
8. (a) Oxygen liberation photosynthetic organisms
9. (c) 0.03 %
10. (a) Van Mayer
11. (d) Photorespiration
12. (c) ^{18}O from $H_2\,^{18}O$
13. (a) RuBP
14. (a) Chloroplasts.
15. (d) 18 and 12

➢ Fill In the Blanks:

1. Food
2. glucose, sucrose, starch
3. heterotrophic
4. respiratory substrates
5. Root, stems, leaves
6. living

➢ True or False:

1. False
2. True
3. True
4. True
5. False
6. True

➢ Very Short Answers:

1. Answer: Catabolic (destructive)
2. Answer: Mitochondria
3. Answer: $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + 686$ kcal.
4. Answer: Glucose
5. Answer: Respiration by microorganisms without the utilization of oxygen is called fermentation.

6. Answer: Carbohydrates, lipids, and proteins.
7. Answer: In the high-energy bonds of ATP molecules.
8. Answer: Air and water.
9. Answer: Enzymatic oxidation of food in body cells is known as cell respiration.
10. Answer: Molecules of food hold energy in their chemical bonds.

➢ Short Answer:

1. Answer: A process of physiochemical change by which environmental oxygen is taken in to oxidize the stored food or release CO2, water, and energy. The energy released is used for doing various life activities, whereas CO2 being is used by the plants for their growth and development.
2. Answer: The process of release of energy through intake of molecular oxygen and release of CO_2 is known as Aerobic respiration.
3. Answer: In this process, the carbohydrate is incompletely oxidized into some carbonic compounds such as ethyl alcohol, acetic acid, lactic acid, and CO_2. This process of oxygen being carried out in microbes is known as fermentation.

   $C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH$ + Energy (247 kJ).
4. Answer: The ratio of the volume of CO_2 evolved to the volume of O_2 consumed in respiration is called the respiratory quotient

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

   RQ (the respiratory quotient) depends upon the type of respiratory substrate used during respiration. This is different for different substrates.
5. Answer: This is also known as the Tricarboxylic acid cycle. When acetyl CO- A enters into a reaction to form citric acid and how pyruvate is broken down during metabolism is highlighted by the concept of cycles. This series of reactions is known as the citric acid cycle.
6. Answer: Organic acids contain more oxygen than carbohydrates; therefore the RQ is more than one. Less amount of oxygen is required for their oxidation.
7. Answer: Depending upon the availability of oxygen, respiration is of two types.
   - Aerobic respiration
   - Anaerobic respiration.

   Aerobic respiration: Complete oxidation of organic substances in presence of oxygen takes place.

   Anaerobic respiration: This type of respiration takes place in the complete absence of

oxygen.

8. Answer: Glycolysis is the first stage of breakdown of glucose and common in all organisms. In anaerobic organisms, it is only the process of respiration. In this process, glucose undergoes partial oxidation. This process occurs in the cytoplasm of the cell.

➢ Long Answer:

1. Answer: The glucose molecule is completely oxidized by the end of the citric acid cycle. But the energy is not released unless NADH and FADH are oxidized through the electron transport system. Here oxidation means the removal of electrons from it.

   The metabolic pathway through which the electron passes from one carrier to another is called the electron transport system (ETS) and it is operative in the inner mitochondrial membrane. Electrons from NADH produced in the mitochondrial matrix are oxidized by an NADH dehydrogenase (Complex I) and electrons are then transferred to ubiquinone.

   The ubiquinone located within the inner membrane also receives reducing equivalents via FADH, which is generated during the oxidation of succinate, through the activity of the enzyme, succinate dehydrogenase (complex II). The reduced ubiquinone is then oxidized with the transfer of electrons to the cytochrome complex (Complex III).

   Cytochrome is a small protein attached to the outer surface of the inner membrane and acts as a mobile carrier for the transfer of electrons between complex III and complex IV.

   (Complex IV) is cytochrome.

   When the electrons pass from one carrier to another via complex 1 to IV in the electron transfer chain, they are coupled to ATP synthase (Complex V) for the production of ATP from ADP and inorganic phosphate. Oxidation of one molecule of NADH gives rise to 3 molecules of ATP, while that of one molecule of FADH, produces 2 molecules of ATP.

   The electrons are earned by the cytochromes and recombine with their protons before the final stage when the hydrogen atom is accepted by oxygen to form water. Oxygen acts as the final hydrogen acceptor. The whole process by which oxygen allows the production of ATP by phosphorylation of ADP is called oxidative phosphorylation.

   Note: There are two routes by which hydrogen from the substrate molecule passes. In route 1.3 ATP molecules are formed for every pair of hydrogen atoms. In route 2, only 2ATP molecules are formed from one pair of hydrogen atoms.

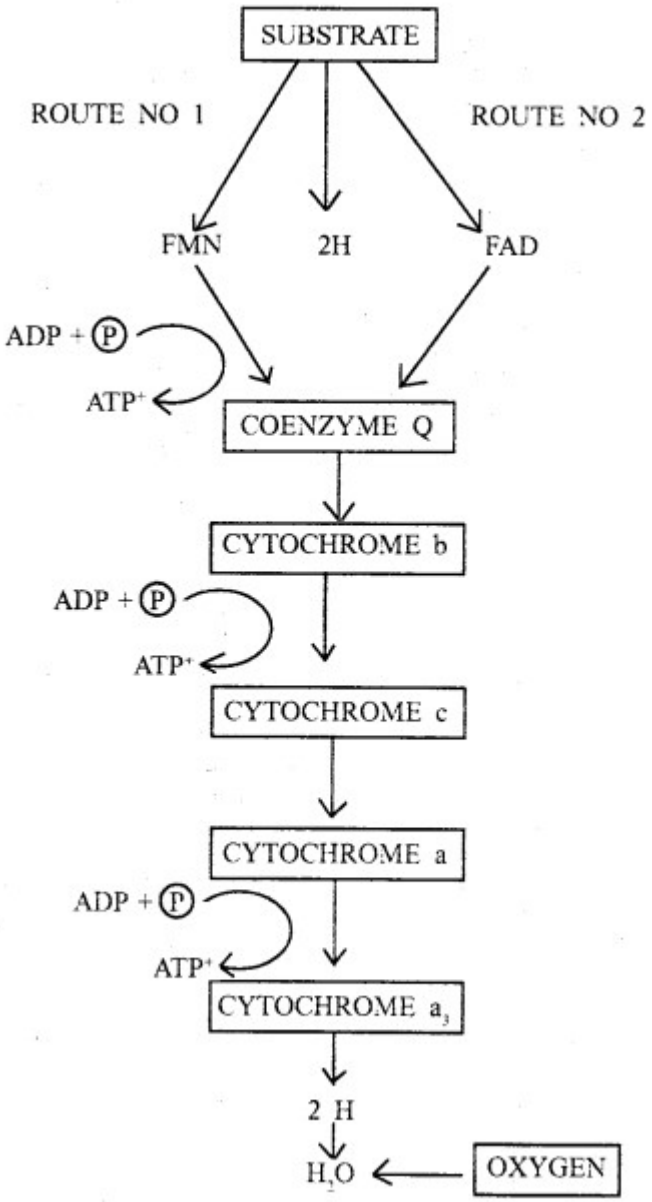
   Oxygen acts as the final hydrogen acceptor and forms water.

   NAD = nicotinamide adenine dinucleotide.

   MN = flavin mononucleotide,

   FAD = flavin adenine dinucleotide.

   ETC produces 32 ATP molecules per glucose molecule and is the major source of cell energy.

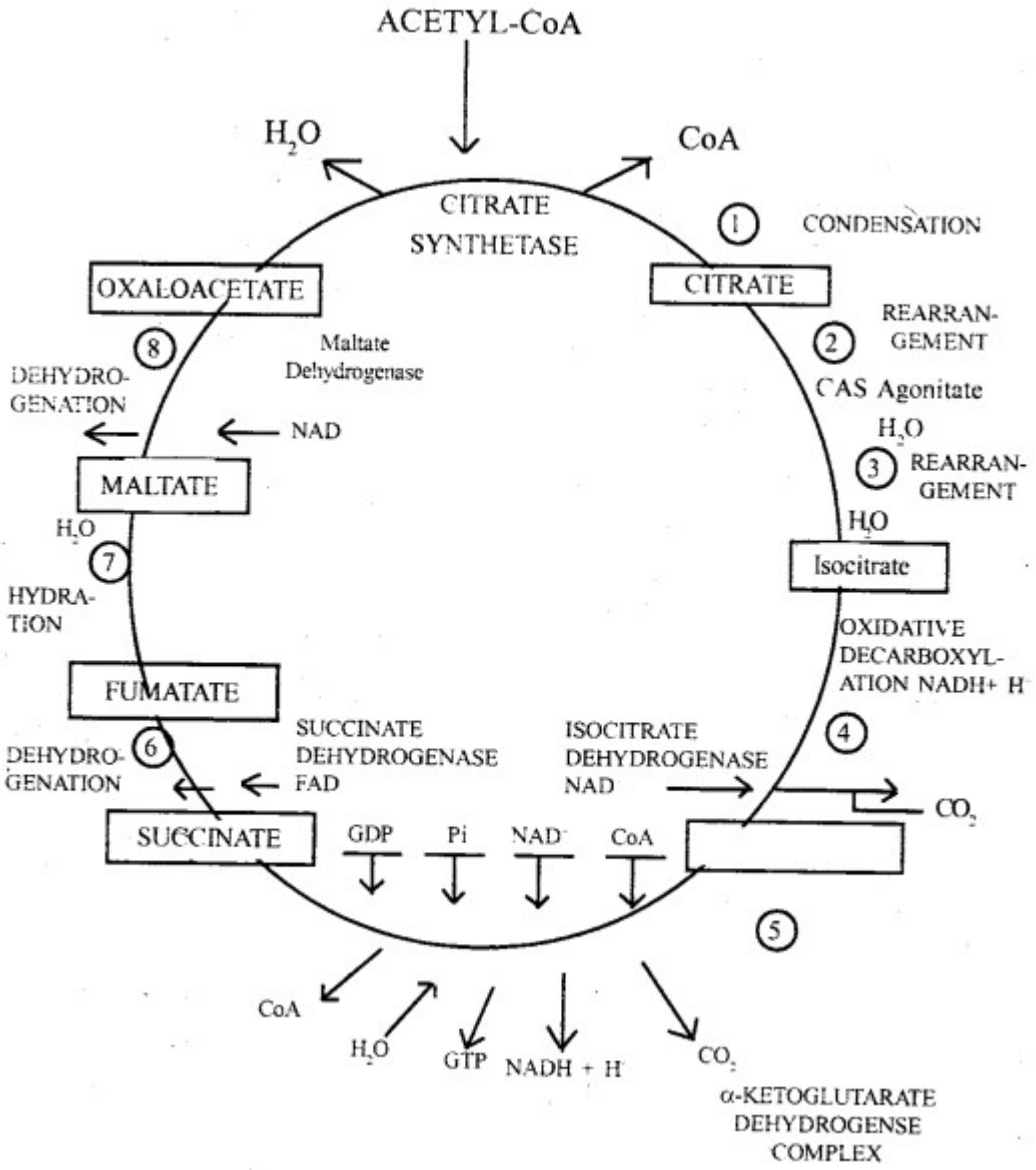


Electron Transport Chain.

2. Answer: In the process of respiration, the carbohydrates are converted into pyruvic acid through a series of enzymatic reactions. These reactions are known as glycolysis and take place in the cytosol. The pyruvic acid thus formed enters in mitochondria where O_2 and necessary enzymes are available; the pyruvic acid is finally converted into CO_2 and H_2O. This reaction series is known as Krebs Cycle or Citric acid cycle or Tricarboxylic acid (TCA) cycle.

   During this cycle, 3 molecules of NAD and one molecule of FAD (Flavin Adenine Dinucleotide) are reduced to produce NADH and FADH respectively. NADH and FADH, so produced during the citric acid cycle are linked with the electron transport system and produce ATP by oxidative phosphorylation, The summary equation for this phase of respiration may therefore be written as follows:

$$\text{Pyruvic acid} + 4\,NAD^+ + FAD + 2H_2O + ADP + Pi \xrightarrow[\text{Matrix}]{\text{Mitochondria}} 3CO_2 + 4NADH + 4H^+ + FADH_2 + ATP$$



Kreb's cycle. It follows glycolytic reactions shown in and pyruvate oxidation.

It involves two processes

i. removal of hydrogen and

ii. the breaking off of carbon dioxide units one by one.

Assertion Reason Answer-

1. (b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

   Explanation: Stomata are absent since gaseous exchange takes place through diffusion in submerged plants.

2. (d) If both Assertion and Reason are false.

Explanation: Glycolysis is the process of breakdown of glucose or similar hexose sugar into two molecules of pyruvic acid through a series of enzyme mediated reactions, releasing energy (ATP) and reducing power (NADH2). It is the first step of respiration, which occurs inside the cytoplasm and is independent of O2. In glycolysis, two molecules of ATP are consumed during double phosphorylation of glucose to form fructose 1, 6 diphosphate. Four molecules of ATP are produced in the conversion of 1, 3-diphosphoglycerate to 3-phosphoglycerate and phosphenol pyruvate to pyruvate whereas, two molecules of NADH2 are formed during oxidation of glyceraldehyde 3-phosphate to 1,3-diphosphoglycerate. Since, each NADH is equivalent to 3 ATP, so net gain in glycolysis is 8 ATP.