Chapter 13: Respiration & Energy Transfer

EXERCISE [PAGES 159 - 160]

Exercise | Q 1. (A) | Page 159
Choose the correct option.
The reactions of the TCA cycle occur in _____.

1. ribosomes
2. grana
3. **mitochondria**
4. endoplasmic reticulum

SOLUTION

The reactions of the TCA cycle occur in **mitochondria.**

Exercise | Q 1. (B) | Page 159
Choose the correct option.
In eukaryotes the complete oxidation of a molecule of glucose results in the net gain of _____.

1. 2 molecules of ATP
2. 36 molecules of ATP
3. 4 molecules of ATP
4. **38 molecules of ATP**

SOLUTION

In eukaryotes the complete oxidation of a molecule of glucose results in the net gain of **38 molecules of ATP.**

Exercise | Q 1. (C) | Page 159
Choose the correct option.
The intermediate between glycolysis and TCA cycle is _____.

1. 2 molecule of ATP
2. 36 molecule of ATP
3. 4 molecule of ATP
4. **38 molecule of ATP**

SOLUTION

The intermediate between glycolysis and TCA cycle is **38 molecule of ATP.**

Exercise | Q 1. (D) | Page 159
Choose the correct option.
Which step of Kreb's cycle operates substrate-level phosphorylation?

1. α-ketoglutarate → succinyl CoA
2. **Succinyl CoA → succinate**
3. Succinate → fumarate
4. Fumarate → malate

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SOLUTION

Succinyl CoA → succinate

Exercise | Q 2. (A) | Page 159
Fill in the blank with a suitable word.
Acetyl CoA is formed from _____ and co-enzyme A.

SOLUTION

Acetyl CoA is formed from **pyruvic acid** and co-enzyme A.

Exercise | Q 2. (B) | Page 159
Fill in the blank with a suitable word.
In the prokaryotes _____ molecules of ATP are formed per molecule of glucose oxidised.

SOLUTION

In the prokaryotes **2/38** molecules of ATP are formed per molecule of glucose oxidised.

Exercise | Q 2. (C) | Page 159
Fill in the blank with a suitable word.
Glycolysis takes place in _____.

SOLUTION

Glycolysis takes place in **cytoplasm**.

Exercise | Q 2. (D) | Page 159
Fill in the blank with a suitable word.
F_1- F_0 particles participate in the synthesis of _____.

SOLUTION

F_1- F_0 particles participate in the synthesis of **ATP**.

Exercise | Q 2. (E) | Page 159
Fill in the blank with a suitable word.
During glycolysis _____ molecules of $NADH+H^+$ are formed.

SOLUTION

During glycolysis **2** molecules of $NADH+H^+$ are formed.

Exercise | Q 3. (A) | Page 159
Answer the following question.
When and where does anaerobic respiration occur in man and yeast?

SOLUTION

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1. In absence of oxygen, anaerobic respiration takes place in the skeletal muscles of man during vigorous exercise.
2. Anaerobic respiration occurs in the cytoplasm of the yeast cell.

Exercise | Q 3. (B) | Page 159

Answer the following question.
Why is less energy produced during anaerobic respiration than in aerobic respiration?

SOLUTION

Anaerobic respiration produces less energy because:

1. Incomplete breakdown of the respiratory substrate takes place.
2. Some of the products of anaerobic respiration can be oxidized further to release energy which shows that anaerobic respiration does not liberate the whole energy contained in the respiratory substrate.
3. $NADH_2$ does not produce ATP, as electron transport is absent.
4. Only 2 ATP molecules are generated from one molecule of glucose during anaerobic respiration.

Exercise | Q 3. (C) | Page 159

Answer the following question.
Where is the respiration electron transport system located in a cell?

SOLUTION

Not available.

Exercise | Q 3. (D) | Page 159

Answer the following question.
Which compound is the terminal electron acceptor in aerobic respiration?

SOLUTION

Molecular oxygen is the terminal electron acceptor in aerobic respiration.

Exercise | Q 3. (E) | Page 159

Answer the following question.
What is RQ?

SOLUTION

1. Respiratory quotient (R.Q.) or respiratory ratio is the ratio of volume of CO_2 released to the volume of O_2 consumed in respiration.

$$2.\ \text{R.Q.} = \frac{\text{Volume of } CO_2 \text{ released}}{\text{Volume of } O_2 \text{ consumed}}$$

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Exercise | Q 3. (E) | Page 159

Answer the following question.
What is its value for fats of R.Q.?

SOLUTION

The RQ value for Fats is 0.7.

Exercise | Q 3. (F) | Page 159
Answer the following question.
What are respiratory substrates?

SOLUTION

Respiratory substrates are the molecules that are oxidized during respiration to release energy which can be used for ATP synthesis

Exercise | Q 3. (G) (i) | Page 159
Answer the following question.
Write explanatory notes on Glycolysis.

SOLUTION

Glycolysis is a process where glucose is broken down into two molecules of pyruvic acid, hence called glycolysis (glucose-breaking). It is common to both aerobic and anaerobic respiration. It occurs in the cytoplasm of the cell. It involves ten steps. Glycolysis consists of two major phases:

Preparatory phase (1-5 steps):

1. In this phase, glucose is phosphorylated twice by using two ATP molecules and a molecule of fructose 1,6-bisphosphate is formed.
2. It is then cleaved into two molecules of glyceraldehyde-3-phosphate and dihydroxy acetone phosphate. These two molecules are 3-carbon carbohydrates (trioses) and are isomers of each other.
3. Dihydroxy acetone phosphate is isomerized to the second molecule of glyceraldehyde-3-phosphate.
4. Therefore, two molecules of glyceraldehyde-3- phosphate is formed.
5. Preparatory phase of glycolysis ends.

Payoff phase:

1. In this phase, both molecules of glyceraldehyde-3-phosphate are converted to two molecules of 1,3- bisphoglycerate by oxidation and phosphorylation. Here, the phosphorylation is brought about by inorganic phosphate instead of ATP.
2. Both molecules of 1, 3-bisphosphoglycerate are converted into two molecules of pyruvic acid through a series of reactions accompanied with the release of energy. This released energy is used to produce ATP (4 molecules) by substrate-level phosphorylation.

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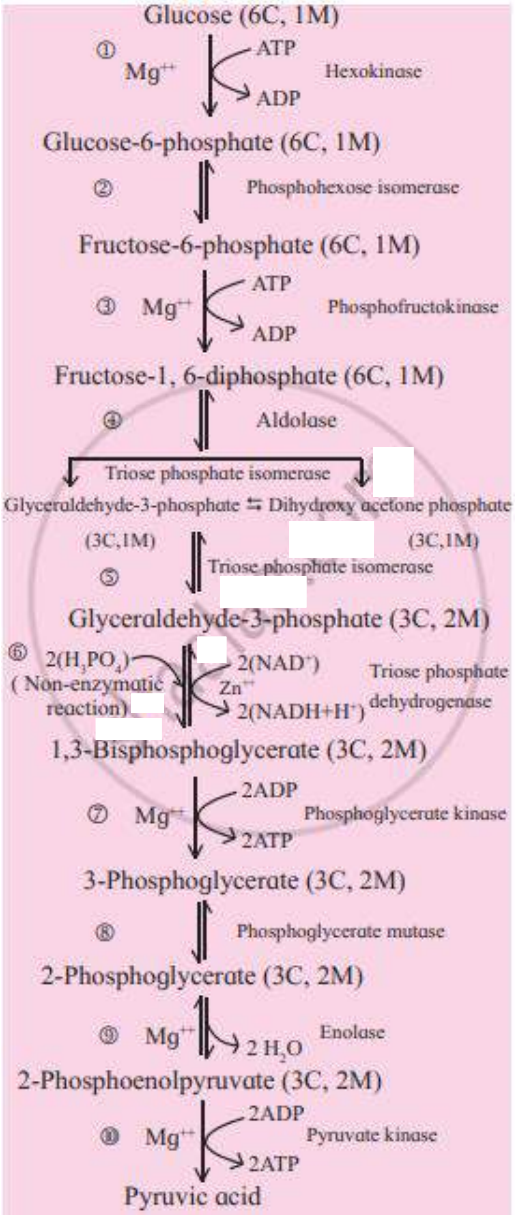

Exercise | Q 3. (G) (ii) | Page 159

Answer the following question.
Write explanatory notes on Fermentation by yeast.

SOLUTION

Alcoholic fermentation is a type of anaerobic respiration where the pyruvate is decarboxylated to acetaldehyde. The acetaldehyde is then reduced by $NADH+H^+$ to ethanol and Carbon dioxide. Since ethanol is produced during the process, it is termed alcoholic fermentation. It is represented as follows:

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Alcoholic fermentation-

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Glycolysis}} \underset{\text{Pyruvic acid}}{2\,CH_3COCOOH} \longrightarrow CO_2 \uparrow + \underset{\text{Acetaldehyde}}{2\,CH_3CHO} + 2\,NADH + H^+ \longrightarrow \underset{\text{Ethanol}}{2\,C_2H_5OH}$$

Exercise | Q 3. (G) (iii) | Page 159

Answer the following question.
Write explanatory notes on Electron transport chain.

SOLUTION

1. $NADH_2$ and $FADH_2$ produced during glycolysis, connecting link reaction and Krebs cycle are oxidized with the help of various electron carriers and enzymes.
2. These carriers and enzymes are arranged on the inner mitochondrial membrane in the form of various complexes as complex I, II, III, VI, and V.
3. $NADH+H^+$ is oxidized by NADH dehydrogenase (complex I) and it's electrons are transferred to ubiquinone (coenzyme Q-CoQ) present on the inner membrane of mitochondria. Reduced ubiquinone is called as ubiquinol.
4. $FADH_2$ is oxidized by complex II (Succinate dehydrogenase) and these electrons are also transferred to CoQ.
5. During oxidation of $NADH+H^+$ and $FADH_2$, electrons and protons are released but only electrons are carried forward whereas protons are released into the outer chamber of mitochondria (intermembrane space).
6. Ubiquinol is oxidized by complex-III (Cytochrome bc1 complex) and it's electrons are transferred to cytochrome C. Cytochrome C is a small, iron-containing protein, loosely associated with the inner membrane. It acts as a mobile electron carrier, transferring the electrons between complex III and IV.
7. Cytochrome C is oxidized by complex IV or cytochrome C oxidase consisting of cytochrome a and a_3. Electrons are transferred by this complex to the molecular oxygen. This is terminal oxidation.
8. Reduced molecular oxygen reacts with protons to form a water molecule called as metabolic water.
9. Protons necessary for this are channelled from the outer chamber of mitochondria into inner chamber by F_0 part of oxysome (complex V) present in the inner mitochondrial membrane. This proton channelling by F_0 is coupled to the catalytic site of F_1 which catalyzes the synthesis of ATP from ADP and

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inorganic phosphate. This is oxidative phosphorylation. As the transfer of protons is accompanied by a synthesis of ATP, this process is named 'Chemiosmosis' by Peter Mitchell.

Significance of ETS:

1. Major amount of energy is generated through ETS or terminal oxidation in the form of ATP molecules.
2. Per glucose molecule 38 ATP molecules are formed, out of which 34 ATP molecules are produced through ETS.
3. Oxidized coenzymes such as NAD and FAD are regenerated from their reduced forms ($NADH+H^+$ and $FADH_2$) for recycling.
4. In this process, energy is released in a controlled and stepwise manner to prevent any damage to the cell.
5. ETS produces water molecules.

Exercise | Q 3. (H) | Page 159
Answer the following question.

How are glycolysis, TCA cycle, and electron transport chain-linked? Explain.

SOLUTION

Glycolysis, TCA cycle and electron transport chain are linked in the following manner:

1. The coenzymes are initially present in the form of NAD^+ and FAD^+ which latter get reduced to $NADH+H^+$ and $FADH+H^+$ by accepting the hydrogen from the organic substrate during glycolysis, link reaction, and Krebs cycle.
2. During glycolysis, glucose is oxidized to two molecules of pyruvic acid with a net gain of 2 molecules of $NADH+H^+$.
3. This pyruvic acid undergoes a link reaction to form two molecules of acetyl CoA and two molecules of $NADH+H^+$.
4. Acetyl CoA, thus formed enters into the Krebs cycle and it gets completely oxidized to CO_2 and H_2O; with a net gain of 6 $NADH+H^+$ and 2 $FADH+H^+$ are formed.
5. During ETS, reduced coenzymes are reoxidized to NAD^+ and FAD^+ with a net gain of 34 ATPs.
6. The ATPs thus formed are used during glycolysis.
7. The oxidized NAD^+ and FAD^+ will again accept the hydrogen from the organic substrate. Thus, reduced coenzymes are converted back to their oxidized forms by dehydrogenation to keep the process going.

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Exercise | Q 3. (I) | Page 159

Answer the following question.

How would you demonstrate that yeast can respire both aerobically and anaerobically?

SOLUTION

Respiration in yeast can be demonstrated with the help of an experiment.

Anaerobic respiration in yeast:

1. A pinch of dry baker's yeast suspended in water containing 10ml of 10% glucose in a test tube (test tube A).
2. The surface of the liquid is covered with oil to prevent the entry of air and the test tube is closed tightly with a rubber stopper to prevent leakage.
3. One end of a short-bent glass tube is inserted through it to reach the air inside the tube.
4. Other end of the glass tube is connected by a polyethylene or rubber tubing to another bent glass tube fitted into a stopper.
5. The open end of the glass tube (delivery tube) is dipped into lime water containing in a test tube (Tube B).
6. Stoppers of both the tubes are fitted tightly to prevent leakage of gases. The first test tube is placed in warm water (37° C-38° C) in a beaker.
7. Lime water gradually turns milky, indicating the evolution of carbon dioxide from the yeast preparation.
8. The level of the lime water in the delivery tube does not rise, showing that there is no decline in the volume of gas in test tube A and consequently no utilization of oxygen by yeast.
9. Preparation is stored for a day or two.
10. When we open the stopper of tube A we will notice a smell of alcohol indicating the formation of ethanol.
11. From this activity it may be inferred that yeast respires anaerobically to ferment glucose to ethanol and carbon dioxide.

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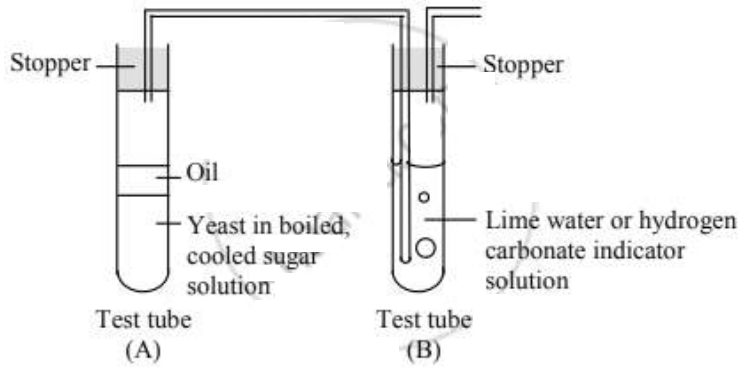

Aerobic respiration in yeast:

The experiment explained in above can be carried out for demonstrating aerobic respiration in yeast.

1. If the level of the lime water in the test tube B rises, indicating intake of oxygen, hence the level of volume of gas rises.
2. The preparation tube is stored for a day or two, if no smell of alcohol is noticed it indicates that the yeast respires aerobically.

Exercise | Q 3. (J) | Page 159

Answer the following question.

What is the advantage of step-wise energy release in respiration?

SOLUTION

In ETS energy is released in stepwise manner to prevent damage of cells.

1. A stepwise release of the chemical bond energy facilitates the utilization of a relatively higher proportion of that energy in ATP synthesis.
2. Activities of enzymes for the different steps may be enhanced or inhibited by specific compounds. This provides a means of controlling the rate of the pathway and the energy output according to needs of the cell.
3. The same pathway may be utilized for forming intermediates used in the synthesis of other biomolecules like amino acids.

Exercise | Q 3. (K) | Page 159

Answer the following question.

Explain ETS.

SOLUTION

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1. $NADH_2$ and $FADH_2$ produced during glycolysis, connecting link reaction and Krebs cycle are oxidized with the help of various electron carriers and enzymes.

2. These carriers and enzymes are arranged on the inner mitochondrial membrane in the form of various complexes as complex I, II, III, VI and V.

3. $NADH+H^+$ is oxidized by NADH dehydrogenase (complex I) and it's electrons are transferred to ubiquinone (coenzyme Q-CoQ) present on the inner membrane of mitochondria. Reduced ubiquinone is called as ubiqunol.

4. $FADH_2$ is oxidized by complex II (Succinate dehydrogenase) and these electrons are also transferred to CoQ.

5. During oxidation of $NADH+H^+$ and $FADH_2$, electrons and protons are released but only electrons are carried forward whereas protons are released into the outer chamber of mitochondria (intermembrane space).

6. Ubiquinol is oxidized by complex-III (Cytochrome bc1 complex) and it's electrons are transferred to cytochrome C. Cytochrome C is a small, iron-containing protein, loosely associated with the inner membrane. It acts as a mobile electron carrier, transferring the electrons between complex III and IV.

7. Cytochrome C is oxidized by complex IV or cytochrome C oxidase consisting of cytochrome a and a_3. Electrons are transferred by this complex to the molecular oxygen. This is terminal oxidation.

8. Reduced molecular oxygen reacts with protons to form a water molecule called as metabolic water.

9. Protons necessary for this are channelled from the outer chamber of mitochondria into the inner chamber by F_0 part of oxysome (complex V) present in the inner mitochondrial membrane.

   This proton channelling by F_0 is coupled to the catalytic site of F_1 which catalyses the synthesis of ATP from ADP and inorganic phosphate. This is oxidative phosphorylation. As the transfer of protons is accompanied with a synthesis of ATP, this process is named as 'Chemiosmosis' by Peter Mitchell.

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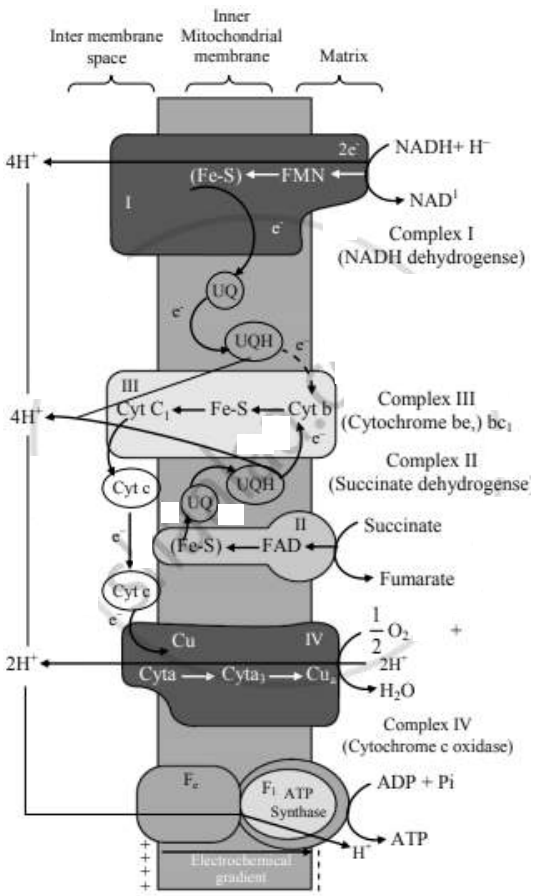

Exercise | Q 3. (L) | Page 159

Answer the following question.
Discuss "The respiratory pathway is an amphibolic pathway".

SOLUTION

1. Respiration is considered as a catabolic process; however, it is not entirely correct in case of Krebs cycle.
2. Many reactions of Krebs cycle involve oxidation of acetyl CoA to release energy and CO_2.
3. However, the breakdown of respiratory substrates provides intermediates like α-ketoglutarate, oxaloacetate is used as precursors for the synthesis of fatty acids, glutamic acid and aspartic acid respectively.
4. Thus, as the same respiratory process acts as catabolic as well as an anabolic pathway for synthesis of various intermediate metabolic products, it is called an amphibolic pathway.

Exercise | Q 3. (M) | Page 159

Answer the following question.
Discuss "The respiratory pathway is an amphibolic pathway".

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SOLUTION

1. Respiration is considered as a catabolic process; however, it is not entirely correct in case of Krebs cycle.
2. Many reactions of Krebs cycle involve oxidation of acetyl CoA to release energy and CO_2.
3. However, the breakdown of respiratory substrates provides intermediates like α-ketoglutarate, oxaloacetate is used as precursors for the synthesis of fatty acids, glutamic acid and aspartic acid respectively.
4. Thus, as the same respiratory process acts as catabolic as well as an anabolic pathway for synthesis of various intermediate metabolic products, it is called an amphibolic pathway.

Exercise | Q 3. (N) | Page 159

Answer the following question.
Which of the following step of aerobic respiration would be omitted when fatty acids are used as respiratory substrate?

1. **Glycolysis**
2. Krebs cycle
3. Electron transfer chain reaction
4. Terminal oxidation

SOLUTION

Glycolysis

Exercise | Q 4. (A) | Page 160
Compare Photosynthesis and Respiration.

SOLUTION

No.	Photosynthesis	Respiration
1.	It takes place in the cells containing chloroplasts.	It takes place in all living cells of higher organisms.
2.	It occurs in chloroplast.	It occurs in cytoplasm and mitochondria.
3.	It is an energy trapping process.	It is an energy-releasing process.
4.	It is an anabolic process.	It is a catabolic process.
5.	This process requires CO_2 and H_2O.	This process requires sugar and O_2.
6.	Light is necessary for photosynthesis.	Light is not necessary for aerobic respiration.
7.	End products are carbohydrates and oxygen	End products can be CO_2 and H_2O or ethanol or lactic acid and energy.

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Exercise | Q 4. (B) | Page 160

Compare Aerobic respiration and Anaerobic respiration.

SOLUTION

No.	Aerobic respiration	Anaerobic respiration
1.	It takes place in higher organisms.	It takes place in lower organisms.
2.	It takes place in cytoplasm and mitochondria.	It takes place in cytoplasm.
3.	It involves the participation of free molecular oxygen.	It does not involve participation of free molecular oxygen.
4.	Oxidation of food is complete.	Oxidation of food is incomplete.
5.	It produces CO_2 and H_2O.	It produces CO_2 and C_2H_5OH.
6.	It releases more energy, i.e. 38 ATP.	It releases less energy, i.e. 2 ATP.
7.	Overall equation: $C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + Energy$	Overall equation: $C_6H_{12}O_6 \longrightarrow 2\,C_2H_5OH + 2\,CO_2 + Energy$

Exercise | Q 5. (A) | Page 160

Differentiate between Respiration ans combustion.

SOLUTION

	Respiration	Combustion
1.	It is a biochemical and stepwise process.	It is physiochemical and spontaneous process.
2.	It occurs inside the cells.	It is a non-cellular process.
3.	Energy is released in steps.	Large amount of energy is released at a time.
4.	No light is produced in respiration.	Light may be produced in combustion.
5.	It is controlled by enzymes.	It is not controlled by enzymes.
6.	A number of intermediates are produced.	No intermediates are produced.

Exercise | Q 5. (B) | Page 160

Differentiate between Glycolysis and Krebs cycle.

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SOLUTION

	Glycolysis/EMP pathway	Krebs cycle/TCA cycle/ Citric acid cycle
1.	Glycolysis is common in both aerobic and anaerobic respiration.	Krebs cycle occurs only in aerobic respiration.
2.	It takes place in the cytoplasm.	It takes place in the mitochondria.
3.	CO_2 is not released.	CO_2 is released.
4.	Total amount of energy produced = 8 ATP	Total amount of energy produced = 24 ATP.
5.	It is linear pathway.	It is cyclic pathway.
6.	Pyruvic acid is the end product.	CO_2 and H_2O are the end products.

Exercise | Q 5. (C) | Page 160

Differentiate between Aerobic respiration and fermentation.

SOLUTION

	Aerobic respiration	Fermentation
1.	It takes place in higher organisms.	It takes place in both higher and lower organisms.
2.	It takes place in cytoplasm and mitochondria.	It takes place in cytoplasm.
3.	It involves the participation of free molecular oxygen.	It does not involve participation of free molecular oxygen.
4.	It involves many steps – glycolysis, link reaction, Krebs cycle and ETS.	It involves only glycolysis, decarboxylation and reduction. (alcoholic fermentation)
5.	Oxidation of food is complete.	Oxidation of food is incomplete.
6.	It produces CO_2 and H_2O.	It produces either ethanol or lactic acid and CO_2 depending upon the type of fermentation.
7.	It releases more energy, i.e. 38 ATP.	It releases less energy, i.e. 2 ATP.

Exercise | Q 6 | Page 160

Identify the cycle given below. Correct it and fill in the blanks and write discription of it in your own words.

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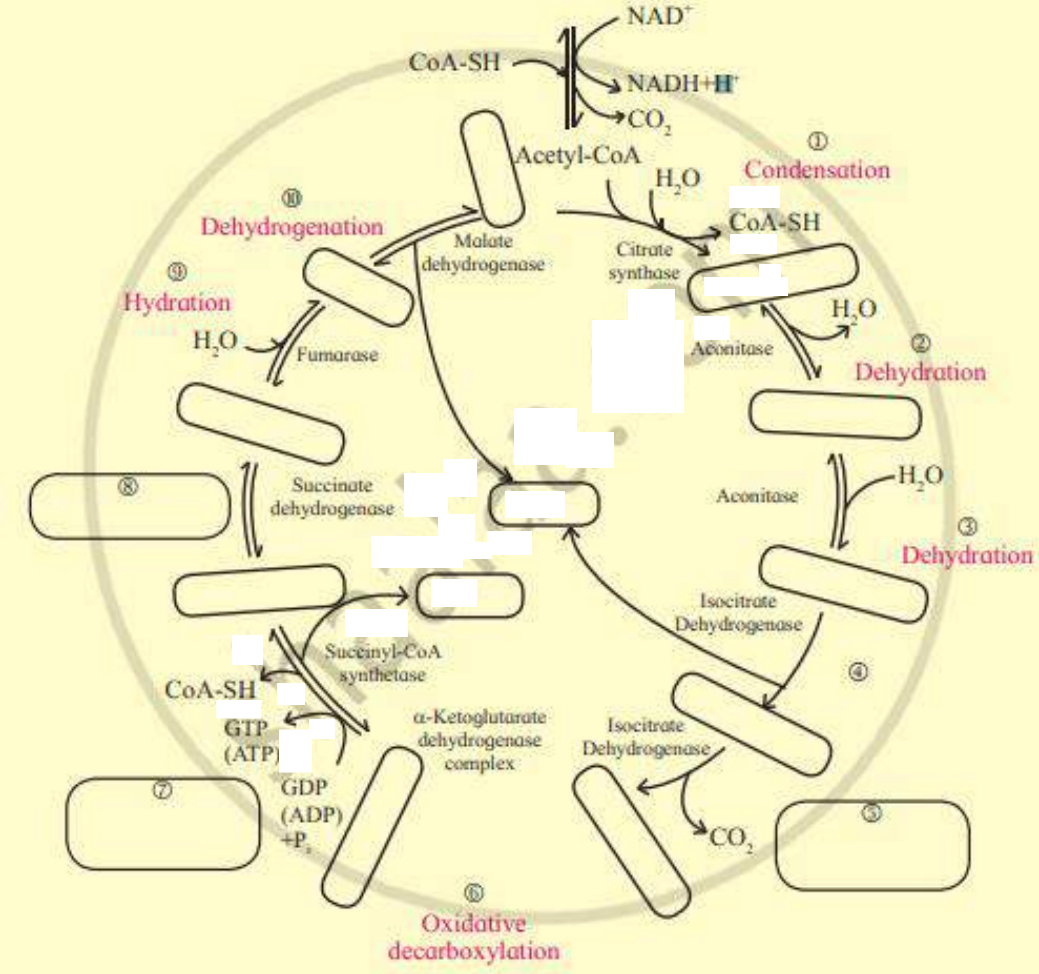

SOLUTION

Krebs Cycle-

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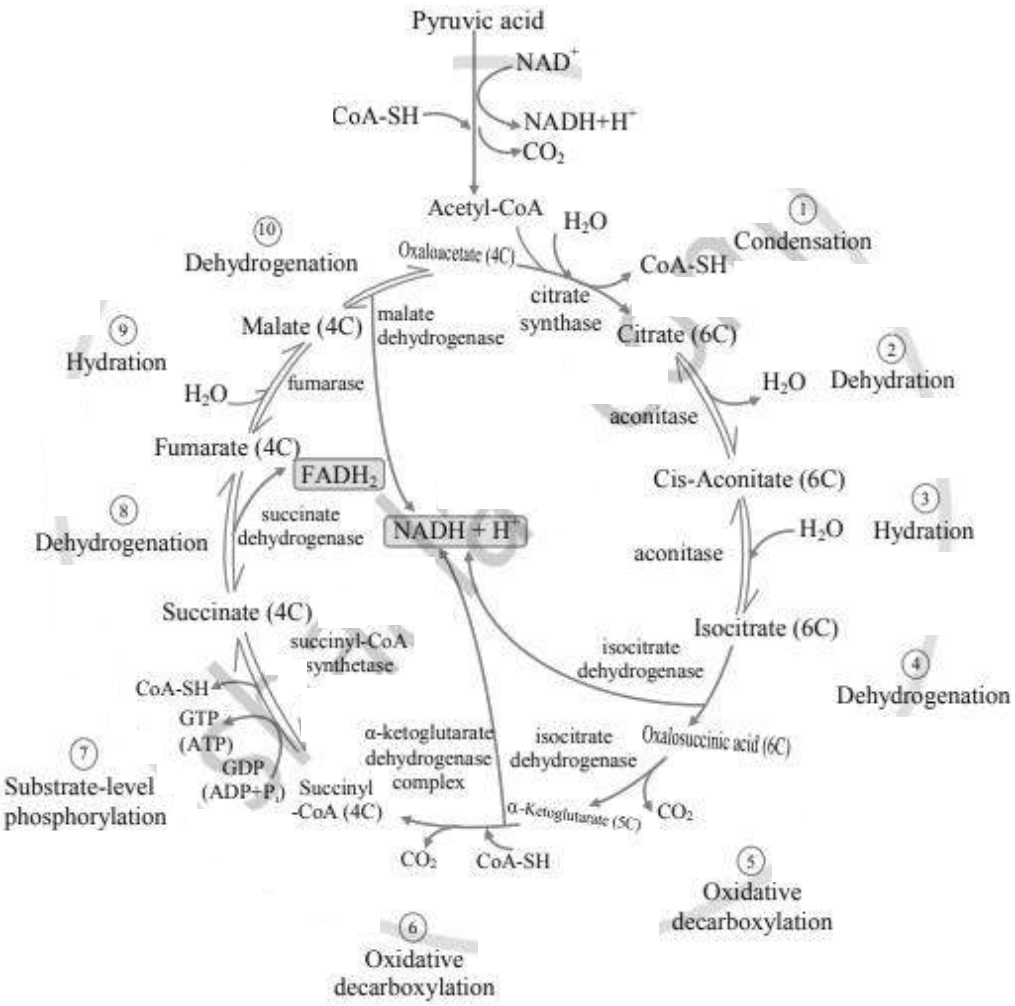

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