13. Respiration and Energy Transfer

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1. Choose correct option

A. The reactions of the TCA cycle occur in

a. ribosomes

b. grana

c. mitochondria

d. endoplasmic reticulum

B. In eukaryotes the complete oxidation of a molecule of glucose results in the net gain of

a. 2 molecules of ATP

b. 36 molecules of ATP

c. 4 molecules of ATP

d. 38 molecules of ATP

C. The intermediate between glycolysis and TCA cycle is:

a. acetylation of pyruvate

b. reduction of pyruvate

c. electron transport system

d. substrate level phosphorylation

D. Which step of Krebs cycle operates substrate-level phosphorylation?

a. α-ketoglutarate → succinyl CoA.

b. Succinyl CoA → Succinate
c. Succinate → fumarate

d. Fumarate → malate succinate fumarate

2. Fill in the blanks with suitable words

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

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

C. Glycolysis takes place in **cytoplasm** .

D. F1 – F0 particles participate in the synthesis of **ATP** .

E. During glycolysis **two** molecules of NADH+H+ are formed.

3. Answer the following questions.

A.When respiration occur in man and yeast ? and where does anaerobic

Ans. (1) In man, anaerobic respiration occurs in cytoplasm of skeletal muscles, during vigorous exercise.

(2) After accumulates and it leads to muscle fatigue.
vigorous exercise, lactic acid

(3) In yeast, anaerobic respiration takes place in cytoplasm in absence of oxygen.

B. Why is less energy produced during anaerobic respiration than anaerobic respiration ?

Ans. (1) In aerobic respiration, complete oxidation of glucose takes place and 686 kcal of energy is released from each molecule of glucose.

(2) The energy released is used to synthesize 38 ATP molecules.

(3) In anaerobic respiration, there is incomplete oxidation of glucose and only 50 kcal
of energy is released from each molecule of glucose.

(4) The energy released is used to synthesize only 2 ATP molecules.

(5) Hence, anaerobic respiration is less efficient than aerobic respiration.

C. Where is the respiration electron transport system located in a cell?

Ans. Electron carriers and enzymes of electron transfer system are arranged on inner membrane of mitochondria, as complex I, II, III, IV and V.

D. Which compound is terminal electron acceptor in aerobic respiration?

Ans. Oxygen is terminal electron acceptor in aerobic respiration.

E. What is R.Q.? What is its value for fats?

Ans. R.Q. is the ratio of volume of CO_2 release to the volume of O_2 consumed in respiration. The volume of R.Q. for fat is 0.7.

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

Ans. (1) The complex organic substances which are used for the release of energy during the process of respiration are called respiratory substrates. e.g. carbohydrates, fats and proteins.

(2) Glucose is the most common respiratory substrate as it is easily available and acceptable to all living organisms.

G. Write explanatory note on:
i. Glycolysis:

Ans. (1) Glycolysis is the first common step for both aerobic and anaerobic respiration.

(2) During glycolysis one molecule of glucose is broken down into two molecules of pyruvic acid, 2 NADH+H+ and 2 molecules of ATP.

(3) Pyruvic acid undergoes oxidative decarboxylation to form acetyl CoA which is a connecting link between glycolysis and Krebs cycle.

(4) Thus, during the process of glycolysis, 8 ATP molecules (2 ATP by substrate level phosphorylation and 6 ATP formed by oxidation of 2 NADH+H+ molecules through ETS) are generated.

ii. Fermentation by yeast:

Ans. (1) The process of fermentation carried out by yeast, in which ethyl alcohol is the end product is called alcoholic fermentation.

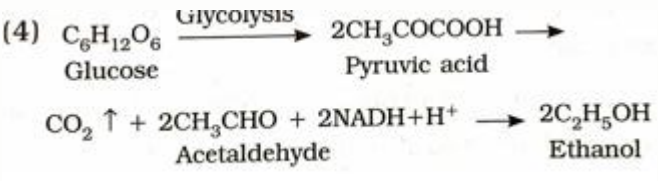
(2) It is completed in three steps:

(a) Glycolysis: In this step glucose is incompletely oxidized to form two molecules of pyruvic acid, 2 ATP and 2 $NADH_2$.

(b) Decarboxylation : Pyruvic acid molecules undergo decarboxylation to form

acetaldehyde and CO_2 is liberated. acid

(c) Reduction : Acetaldehyde is reduced to ethyl alcohol by using NADH+H+.



iii. Electron Transport chain

Ans:

(1) Electron carriers and enzymes of ETS are arranged on Inner mitochondrial membrane as complex I, II, III, VI and V.

(2) NADH dehydrogenase (complex I) is involved in oxidation of NADH+H+ and its electrons are transferred to ubiquinone (Coenzyme Q. COQ).

(3) CoQ is located on inner membrane of mitochondria.

(4) Reduced ubiquinone is called as ubiquinol.

(5) Complex II (Succinate dehydrogenase)
carries out oxidation of $FADH_2$ and these electrons are also transferred to CoQ.

(6) During oxidation of NADH+H+ and $FADH_2$ electrons and protons are released.

(7) Electrons released during oxidation of NADH+H+ and $FADH_2$ are transferred to electron carriers.

(8) Complex I, III, IV are involved in transport (Cytochrome be complex)
carries out oxidation of ubiquinol and its electrons are transferred to cytochrome C. (Cytochrome be complex)

(10) Cytochrome C is a small, iron-containing protein, loosely associated with inner membrane.

(11) It acts as a mobile electron carrier, which transfers electrons between complex III and IV.

(12) Complex IV or cytochrome C oxidase, carries out oxidation of cytochrome C.

(13) Complex IV consists of cytochrome a and a3.

(14) Electrons are transferred by complex IV to the molecular oxygen. This is terminal oxidation.

(15) Reduced molecular oxygen reacts with protons to form water molecule called as metabolic water.

(16) Protons required for this are transported from outer chamber of mitochondria into inner chamber by F0 part of oxysome (complex V) present in inner mitochondrial membrane.

(17) This proton channeling by F0 is coupled to catalytic site of F1 which catalyses the synthesis of ATP from ADP and inorganic phosphate. This is oxidative phosphorylation.

(18) This transfer of protons which is accompanied with synthesis of ATP, is named as 'Chemiosmosis' by Peter Mitchell.

(19) Oxidation of one NADH+H+ results in synthesis of 3 ATP molecules where as oxidation of one $FADH_2$ results in synthesis of 2 ATP molecules.

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

Ans. (1) Glycolysis involves breakdown of a glucose (6-C) molecule into two molecules of pyruvic acid (3C).

(2) It leads to synthesis of two molecules of ATP. two molecules of $NADH_2$ and two molecules of pyruvic acid per glucose molecule.

(3) Pyruvic Acid oxidative undergoes decarboxylation to form acetyl (2C), which combines with CoA to form acetyl coenzyme A.
The reaction is catalyzed by a multienzyme complex called pyruvate dehydrogenase.

(4) Hydrogen liberated during the reaction is accepted by NAD to form $NADH_2$.

(5) Acetyl CoA participates in Krebs cycle.
Hence, it is the connecting link between glycolysis and Krebs cycle. (TCA cycle)

(6) Two Krebs cycle produce $6NADH_2$, $2FADH_2$, and 2ATPs by substrate level phosphorylation.

(7) The electron transfer system (ETS) or terminal oxidation generates major amount of energy in the form of ATP molecules.

(8) 34 ATP (10 $NADH_2$ X 3ATP = 30 ATP and 2$FADH_2$ X 2ATP = 4ATP) molecules out of total 38 ATP molecules are produced through ETS.

(9) It regenerates oxidized coenzymes such as NAD+ and FAD+ from their reduced forms (NADH+H+ and $FADH_2$) for recycling.

(10) It also provides water molecules necessary for Krebs cycle.

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

Ans. (1) A pinch of dry bakers yeast suspended in water or a few ml of yeast suspension is added to about 10 ml of 10 % glucose solution in a test tube A.

(2) The surface of the liquid is carefully covered with oil to prevent contact with air.

(3) The test tube is closed tightly with rubber stopper.

(4) One end of a short bent glass tube is inserted through it to reach the air inside the tube.

(5) Other end of the glass tube is connected by a rubber tubing to another bent glass tube fitted into a stopper.

(6) The open end of the glass tube (delivery tube) is inserted into lime water containing in a test tube tube B.

(7) Stoppers of both the tubes are fitted tightly to prevent leakage of gases.

(8) First test tube is placed in warm water (37°C-38°C) in a beaker.

(9) Lime water gradually turns milky. This indicates the evolution of carbon dioxide from the yeast preparation.

(10) Level of the lime water in the delivery tube does not rise, which shows that there is no decline in volume of gas in test tube A and consequently no utilization of oxygen by yeast.

(11) Preparation is stored for a day or two.

(12) On opening the stopper of tube A, a smell of alcohol is noticed. This indicates the formation of ethanol.

(13) This activity demonstrates that yeast respires anaerobically to ferment

glucose to ethanol and carbon dioxide.

(14) Same experiment can be performed without covering glucose solution with oil to demonstrate aerobic respiration of yeast. Increase in the level of lime water in the delivery tube, indicates utilization of oxygen by yeast. Ethanol is not produced during aerobic respiration.

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

Ans: (1) A stepwise release of chemical bond energy facilitates the use of a relatively higher proportion of that energy in ATP synthesis.

(2) Activities of enzymes involved in various steps may be enhanced or inhibited by specific compounds. Thus, stepwise oxidation provides a means of controlling the rate of the pathway and the energy output according to the requirements of the cell.

(3) The same pathway may be utilized for the synthesis of intermediates, which are used in the synthesis of other biomolecules such as amino acids.

K. Explain ETS.

Ans: (1) Electron carriers and enzymes of ETS are arranged on Inner mitochondrial membrane as complex I, II, III, VI and V.

(2) NADH dehydrogenase (complex I) is involved in oxidation of NADH+H+ and its electrons are transferred to ubiquinone (Coenzyme Q CoQ).

(3) Cog is located On inner membrane of mitochondria.

(4) Reduced ubiquinone is called as ubiquinol.

(5) Complex II (Succinate dehydrogenase) carries out oxidation of FADH, and these electrons are also transferred to CoQ. II (Succinate dehydrogenase)

(6) During oxidation of NADH+H+ and $FADH_2$, electrons and protons are released.

(7) Electrons released during oxidation of NADH+H+ and $FADH_2$ are transferred to electron carriers.

(8) Complex I, III, IV are involved in transport of protons from matrix to intermembrane space i.e. outer chamber.

(9) Complex-III (Cytochrome bc1, complex) carries out oxidation of ubiquinol and its electrons are transferred to cytochrome C. (Cytochrome be complex)

(10) Cytochrome C is a small, iron-containing protein, loosely associated with inner membrane.

(11) It acts as a mobile electron carrier, which transfers electrons between complex III and IV.

(12) Complex IV or cytochrome C Oxidase, carries out oxidation of cytochrome C.

(13) Complex IV consists of cytochrome a and a3.

(14) Electrons are transferred by complex IV to the molecular oxygen. This is terminal oxidation.

(15) Reduced molecular oxygen reacts with protons to form water molecule called as metabolic water.

(16) Protons required for this are transported from outer chamber of mitochondria into inner chamber by F0 part of oxysome (complex V) present in inner mitochondrial membrane.

(17) This proton channeling by F0 is coupled to catalytic site of F1 which catalyses the synthesis of ATP from ADP and inorganic phosphate. This is oxidative phosphorylation.

(18) This transfer of protons which is accompanied with synthesis of ATP, is named as *Chemiosmosis' by Peter Mitchell.

(19) Oxidation of one NADH+H+ results in synthesis of 3 ATP molecules where as oxidation of one $FADH_2$ results in synthesis of 2 ATP molecules.

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

Ans. (1) Various reactions in Krebs cycle result in step-wise oxidation of acetyl part of acetyl CoA. This releases energy and CO_2.

(2) However as per requirement, acetyl CoA and other intermediates like a-ketoglutarate, oxaloacetate are used as precursors to synthesize fatty acids, glutamic acid and aspartic acid respectively.

(3) Thus it involves both catabolic and anabolic reactions.

(4) Hence, Krebs cycle is considered as an amphibolic pathway.

M. Why is Krebs cycle reffered as amphibolic pathway?

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N. Which of the following steps of aerobic respiration would be omitted when fatty acids are used as respiratory substrates ?(a) Glycolysis, (b) Krebs cycle, (c) Electron transport chain reaction, (d) Terminal oxidation. substrates ?

Ans. (1) When fatty acids are used as respiratory substrates, glycolysis step would be omitted. Fats are broken down to fatty acids and glycerol.

(2) Fatty acids are converted in Acetyl CoA, which then enters the respiratory pathway, in Krebs cycle.

4. Compare

A. Photosynthesis and Respiration

Photosynthesis	Respiration
1. Photosynthesis is energy trapping process.	1. Respiration is energy releasing process.
2. End products are glucose and O_2	2. End products of aerobic respiration are CO_2 and H2O. End products of anaerobic respiration include lactic acid or ethanol and CO_2.
3. Raw materials required for photosynthesis are CO_2 and H2O.	3. Raw materials required for respiration are glucose and O_2.
4. Photosynthesis takes place only in green cells.	4. Respiration takes place in all living cells.
5. It takes place only in chloroplasts.	5. It takes place in mitochondria and cytoplasm.
6. It involves synthesis of complex organic molecules hence, it is an anabolic process.	6. It involves break down of complex organic molecules into simple inorganic substances hence, it is catabolic process. Krebs cycle is an amphibolic pathway.
7. Photosynthesis is light dependent.	7. It is light independent.

8. Due to synthesis of organic compounds during photosynthesis, dry weight of the plant increases.	8. Due to breakdown of organic compounds during respiration, the dry weight of the plant decreases.

B. Aerobic respiration and Anaerobic respiration/Fermentation

Aerobic respiration	Anaerobic respiration/Fermentation
1. It takes place in all eukaryotic cells.	1. It takes place in most of the prokaryotic cells.
2. It requires molecular O_2.	2. does not require molecular O_2.
3. Oxidation of respiratory substrate is complete.	3. Oxidation of respiratory substrate is incomplete.
4. Large amount of energy is released per glucose molecule.	4. Small amount of energy is released per glucose molecule.
5. CO_2 and water are the end products.	5. The end products are CO_2 and ethyl alcohol or lactic acid.
6. It takes place in cytoplasm and mitochondria.	6. It takes place only in cytoplasm.
7. During aerobic respiration 38 ATP molecules are generated.	7. During anaerobic respiration only 2 ATP molecules are generated.
8. The reaction is represented as : $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$.	8. The reaction is represented as: $C_6H_{12}O_6 \xrightarrow{\text{Glycolysis}} \underset{\text{Pyruvic acid}}{2CH_3COCOOH} \longrightarrow$ (Glucose) $CO_2\uparrow + \underset{\text{Acetaldehyde}}{2CH_3CHO} + 2NADH+H^+ \longrightarrow \underset{\text{Ethanol}}{2C_2H_5OH}$ Lactic acid fermentation : $C_6H_{12}O_6 \xrightarrow{\text{Glycolysis}} \underset{\text{Pyruvic acid}}{2CH_3COCOOH} + 2NADH+H^+ \longrightarrow 2CH_3CHOHCOOH + 2NAD^+$ (Glucose, Lactic acid)

5. Differentiate between

A. Respiration and combustion :

Ans.

Respiration	Combustion
1. It occurs in living cells.	1. It is non-cellular.
2. Energy is released in stepwise manner.	2. Energy is released at once.
3. Enzymes are required for respiration.	3. Enzymes are not required for combustion.

4. Intermediates are formed.	4. Intermediates are not formed.
5. It occurs in the presence of water.	5. It does not require water.
6. It occurs at body temperature.	6. It needs external heat.
7. ATPs are formed.	7. ATPs are not formed.
8. It is a slow process.	8. It is a fast process.
9. Oxidation is complete in aerobic respiration and products are CO_2, water and energy.	9. Incomplete combustion results in unburnt carbon particles and CO.

B. Glycolysis and Krebs cycle :

Ans.

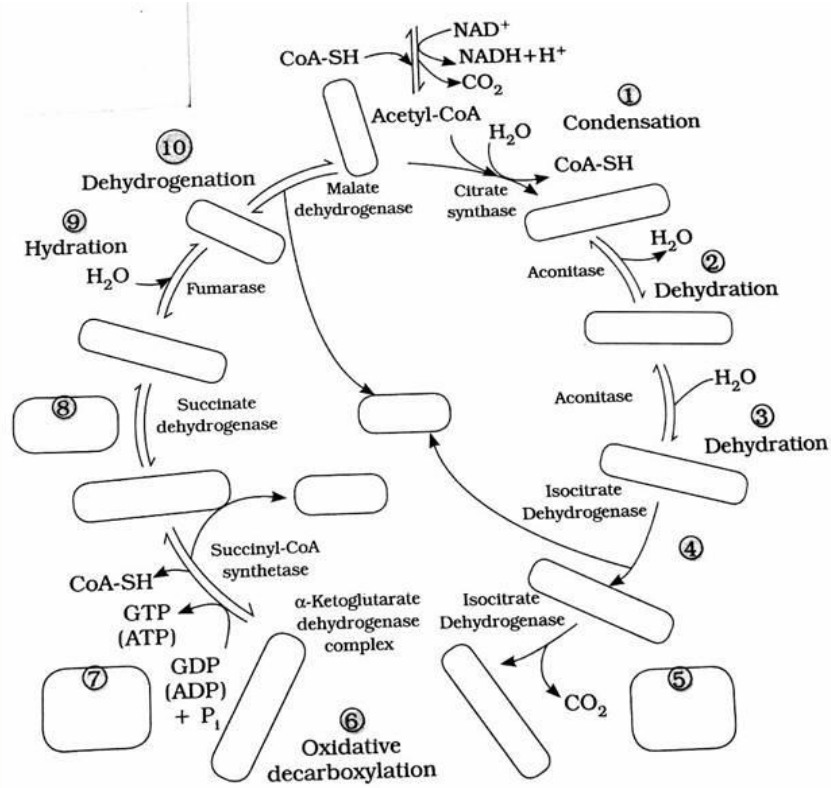
Glycolysis	Krebs cycle
1. Glycolysis occurs in cell cytoplasm.	1. It occurs inside the matrix of mitochondria.
2. It occurs in both aerobic and anaerobic respiration.	2. It occurs only in aerobic respiration.
3. It is a linear pathway.	3. It is a cyclic pathway.
4. Two ATPs are consumed in glycolysis.	4. ATPs are not consumed in Krebs cycle.
5. CO_2 is not evolved.	5. CO_2, is evolved.
6. Glycolysis leads to synthesis of two molecules of ATP, two molecules of NADH+H+ and two molecules of pyruvic acid per glucose molecule.	6. Each Krebs cycle leads to synthesis of 3NADH+H+, one $FADH_2$ and one ATP is produced by substrate level phosphorylation.

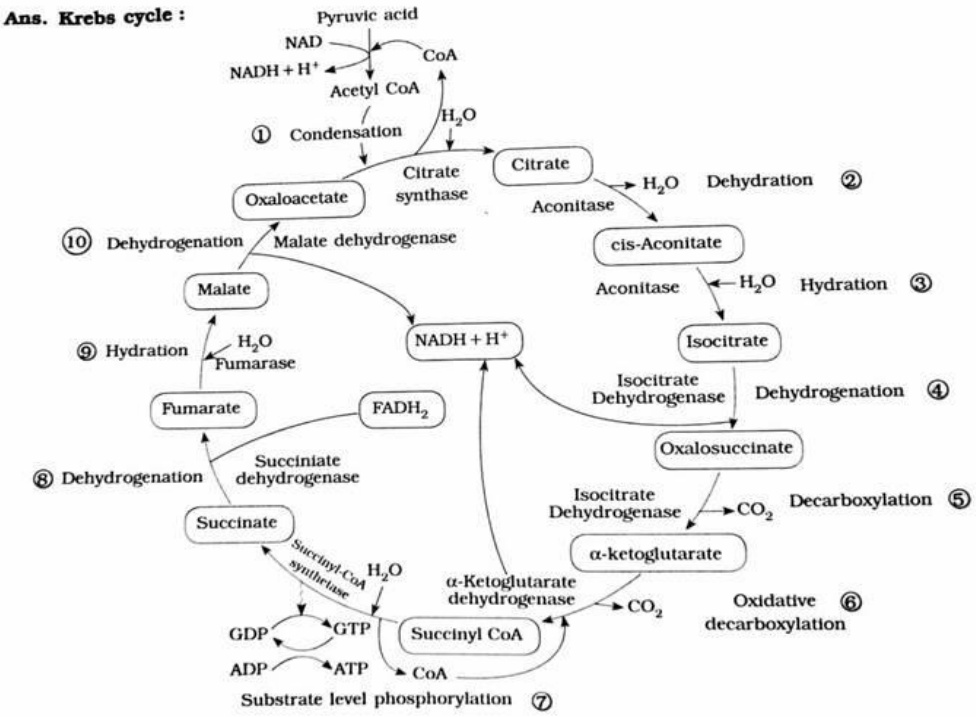
C . Aerobic respiration and fermentation .

Ans : refer Q.4 B

6. Identify the cycle given below. Correct it and fill in the blank and write description of it in your own words.

Ans:





(Click here to see for better view) (1) For each molecule of glucose, to Krebs cycle operate in mitochondrial matrix.

(2) Each Krebs cycle involves two decarboxylations and four oxidation or dehydrogenation steps.

(3) During each Krebs cycle, three NADH+H+, one $FADH_2$ and one ATP are generated.

(4) During each Krebs cycle, three water molecules are used up and two molecules of CO, are released

(5) The main steps in the Krebs cycle are as follows.

(A) Condensation :

(1) Acetyl CoA, after entering the Krebs cycle, reacts with oxaloacetic acid (4-C) in the mitochondria to form Citric Acid (6-C) and CoA is released for recycling.

(2) A water molecule is used and reaction is catalyzed by enzyme citrate synthase.

(B) Dehydration : Citric acid undergoes dehydration to form cis-Aconitate (6-C). The reaction is catalyzed by enzyme acid undergoes aconitase.

(C) Hydration :

(1) On hydration, cis-aconitate is converted into isocitrate (6-C). The reaction is catalyzed by aconitase enzyme in the presence of Fe++.

(2) These two reaction (2 and 3) bring about the isomerization of citric acid to isocitrate.

(D) Oxidation or dehydrogenation :

(1) Isocitrate is oxidized to form oxalosuccinate (6-C) in the presence of enzyme isocitrate dehydrogenase.

(2) The hydrogen released during the process is accepted by NAD to form NADH+H+.

(E) Decarboxylation I: Oxalosuccinate is further decarboxylated to form a-ketoglutarate (aaKG, 5C), in the presence of enzyme. Isocitrate dehydrogenase.

(F) Oxidative decarboxylation :

(1) α-KGA undergoes oxidative decarboxylation and combines with CoA to form succinyl CoA (4C), in the presence of enzyme a-ketoglutarate dehydrogenase.

(2) Hydrogen liberated during the process is accepted by NAD to form NADH+H+.

(3) CO_2 is released.

(G) Hydration and substrate level phosphorylation:

(1) Succinyl CoA releases CoA and gets converted into succinate (4-C), in the presence of enzyme Succinyl-CoA synthetase.

(2) In the process energy liberated is accepted by GDP (Guanosine triphosphate). GTP is transformed to ATP using ADP.

(H) Oxidation - (dehydrogenation) :

(1) Succinate is further oxidized to form fumarate (4-C) in the presence of enzyme succinate dehydrogenase (in the presence of Fe++).

(2) The hydrogen released during the process is accepted by FAD (flavin adenine dinucleotide) to form $FADH_2$.

(I) Hydration : Fumarate undergoes hydration to form malate (4-C), in the presence of enzyme fumarase.

(J) Oxidation - (dehydrogenation) :

(1) Malate is further oxidized to regenerate oxaloacetate (4-C) in the presence of enzyme malate dehydrogenase and Mg++.

(2) Hydrogen liberated during the process is accepted by NAD to form NADH+H+.

(3) Oxaloacetate reenters the cycle.