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Maharashtra State Board 11th Biology Solutions Chapter 13 Respiration and Energy Transfer

1. Choose the Correct option

Question (A)
The reactions of the TCA cycle occur in
(A) ribosomes
(B) grana
(C) mitochondria
(D) endoplasmic reticulum
Answer:
(C) mitochondria

Question (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
Answer:
(D) 38 molecules of ATP

Question (C)
Which step of Krebs cycle operates substrate-level phosphorylation?
(A) ∝-ketoglutarate → succinyl CoA.
(B) Succinyl CoA → succinate
(C) Succinate → fumarate
(D) Fumarate → malate
Answer:
(B) Succinyl CoA → succinate

2. Fill in the blanks with suitable words.

Question 1.
A. Acetyl CoA is formed from _________ and co-enzyme A.
B. In the prokaryotes _______ molecules of ATP are formed per molecule of glucose oxidised.
C. Glycolysis takes place in _______ .
D. $F_1 – F_0$ particles participate in the synthesis of ________ .
E. During glycolysis ________ molecules of $NADH+H^+$ are formed.
Answer:
A. pyruvic acid
B. 2/38
C. cytoplasm
D. ATP
E. 2
[Note: ii. In prokaryotes, during anaerobic respiration 2 ATPs are formed per glucose and 38 ATPs are formed during aerobic respiration.]

3. Answer the following questions

Question (A)
When and where does anaerobic respiration occur in man and yeast?
Answer:
1. In absence of oxygen, anaerobic respiration takes place in skeletal muscles of man during vigorous exercise.
2. Anaerobic respiration occurs in the cytoplasm of the yeast cell.

Question (B)
Why is less energy produced during anaerobic respiration than in aerobic respiration?
Answer:
Anaerobic respiration produces less energy because:

1. Incomplete breakdown of respiratory substrate takes place.
2. Some of the products of anaerobic respiration can be oxidised 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.

Question (C)
Which is the site for ETS in mitochondrial respiration?
Answer:
The inner mitochondrial membrane is the site for ETS in mitochondrial respiration.

Question (D)
Which compound is the terminal electron acceptor in aerobic respiration?
Answer:
Molecular oxygen is the terminal electron acceptor in aerobic respiration.

Question (E)
What is RQ.? What is its value for fats?
Answer:
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. R.Q. = Volume of CO_2 released / Volume of O_2 consumed

Question (F)
What are respiratory substrates? Name the most common respiratory substrate.
Answer:
Respiratory substrates are the molecules that are oxidized during respiration to release energy which can be used for ATP synthesis. Carbohydrates, fats and proteins are the common respiratory substrate. Glucose is the most common respiratory substrate.

Question (G)
Write explanatory notes on:

Question (i)
Glycolysis
Answer:
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:
1. Preparatory phase (1-5 steps).
2. Payoff phase (6-10 steps).
1. Preparatory phase:
a. In this phase, glucose is phosphorylated twice by using two ATP molecules and a molecule of fructose 1,6-bisphosphate is formed.
b. 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.
c. Dihydroxy acetone phosphate is isomerised to second molecule of glyceraldehyde-3-phosphate.
d. Therefore, two molecules of glyceraldehyde-3- phosphate are formed.
e. Preparatory phase of glycolysis ends.

2. Payoff phase:
a. 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.
b. Both molecules of 1, 3-bisphosphoglycerate are converted into two molecules of pyruvic acid through series of reactions accompanied with release of energy. This released energy is used to produce ATP (4 molecules) by substrate-level phosphorylation.

Question (ii)
Write explanatory notes on: Fermentation by yeast
Answer:
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.

Question (iii)
Write explanatory notes on: Electron transport chain
Answer:

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 inner mitochondrial membrane in the form of various complexes as complex I, II, III, VI and V.
3. $NADH+H^+$ is oxidised by NADH dehydrogenase (complex I) and it's electrons are transferred to ubiquinone (coenzyme Q-CoQ) present on inner membrane of mitochondria. Reduced ubiquinone is called as ubiqunol.
4. $FADH_2$ is oxidised 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 canned forward whereas protons are released into outer chamber of mitochondria (intermembrane space).

6. Ubiquinol is oxidised by complex-III (Cytochrome bcl complex) and it's electrons are transferred to cytochrome C. Cytochrome C is a small, iron-containing protein, loosely associated with inner membrane. It acts as a mobile electron carrier, transferring the electrons between complex III and IV.
7. Cytochrome C is oxidised 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 water molecule called as metabolic water.
9. Protons necessary for this are channelled from outer chamber of mitochondria into inner chamber by F_0 part of oxysome (complex V) present in inner mitochondrial membrane.
10. This proton channelling by F_0 is coupled to catalytic site of F_1 which catalyses the synthesis of ATP from ADP and inorganic phosphate. This is oxidative phosphorylation.
11. As transfer of protons is accompanied with synthesis of ATP, this process is named as '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.

Question (H)
How are glycolysis, TCA cycle and electron transport chain-linked? Explain.
Answer:
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 organic substrate during glycolysis, link reaction and Krebs cycle.
2. During glycolysis, glucose is oxidised to two molecules of pyruvic acid with net gain 2 molecules of $NADH+H^+$.
3. This pyruvic acid undergoes 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 oxidised to $C0_2$ and H_20; 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. The ATPs thus formed are used during glycolysis.
6. The oxidized NAD^+ and FAD^+ will again accept the hydrogen from organic substrate. Thus, reduced coenzymes are converted back to their oxidized forms by dehydrogenation to keep the process going.

Question (I)
How would you demonstrate that yeast can respire both aerobically and anaerobically?
Answer:
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 entry of air and the test tube is closed tightly with 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. 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. Level of the lime water in the delivery tube does not rise, showing that there is no decline in volume of gas in test tube A and consequently no utilization of oxygen by yeast. Preparation is stored for a day or two.
9. When we open the stopper of tube A we will notice a smell of alcohol indicating the formation of ethanol.
10. From this activity it may be inferred that yeast respires anaerobically to ferment glucose to ethanol and carbon dioxide.

Aerobic respiration in yeast: Experiment explained 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.

Question (J)
What is the advantage of step wise energy release in respiration?
Answer:
In ETS energy is released in step wise 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 need of the cell.

3. The same pathway may be utilized for forming intermediates used in the synthesis of other biomolecules like amino acids.

Question (K)
Explain ETS.
Answer:

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 inner mitochondrial membrane in the form of various complexes as complex I, II, III, VI and V.
3. $NADH+H^+$ is oxidised by NADH dehydrogenase (complex I) and it's electrons are transferred to ubiquinone (coenzyme Q-CoQ) present on inner membrane of mitochondria. Reduced ubiquinone is called as ubiqunol.
4. $FADH_2$ is oxidised 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 canned forward whereas protons are released into outer chamber of mitochondria (intermembrane space).
6. Ubiquinol is oxidised by complex-III (Cytochrome bcl complex) and it's electrons are transferred to cytochrome C. Cytochrome C is a small, iron-containing protein, loosely associated with inner membrane. It acts as a mobile electron carrier, transferring the electrons between complex III and IV.
7. Cytochrome C is oxidised 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 water molecule called as metabolic water.
9. Protons necessary for this are channelled from outer chamber of mitochondria into inner chamber by F_0 part of oxysome (complex V) present in inner mitochondrial membrane.
10. This proton channelling by F_0 is coupled to catalytic site of F_1 which catalyses the synthesis of ATP from ADP and inorganic phosphate. This is oxidative phosphorylation.
11. As transfer of protons is accompanied with synthesis of ATP, this process is named as 'Chemiosmosis' by Peter Mitchell.

Question (L)
Discuss "The respiratory pathway is an amphibolic pathway".
OR
Question (M)
Why is Krebs cycle referred as amphibolic pathway?
Answer:

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 C02.
3. However, the breakdown of respiratory substrates provides intermediates like a-ketoglutarate, oxaloacetate are used as precursors for synthesis of fatty acids, glutamic acid and aspartic acid respectively.
4. Thus, as the same respiratory process acts as catabolic as well as anabolic pathway for synthesis of various intermediate metabolic products, it is called amphibolic pathway.

Question (N)
The common pathway for both aerobic and anaerobic respiration is
(A) Krebs cycle
(B) Glycolysis
(C) ETS
(D) Terminal oxidation
Answer:
(B) Glycolysis

4. Compare

Question (A)
Photosynthesis and respiration.
Answer:

Photosynthesis	Respiration
(a) It takes place in the cells containing chlomplasts.	It takes place in all living cells of higher organisms.
(b) It occurs in chloroplast.	It occurs in cytoplasm and mitochondria.
(c) It is an energc trapping process.	It is an energy releasing process.
(d) It is an anabolic process.	It is a catabolic process.
(e) This process requires $C0_2$ and FLO.	This process requires sugar and 0_2.
(f) Light is necessary for photosynthesis.	Light is not necessary for aerobic respiration.

(g) End products are carbohydrates and oxygen.	End products can be $C0_2$ and H_20 or ethanol or lactic acid and energy.

Question (B)
Aerobic respiration and Anaerobic respiration
Answer:

Aerobic respiration	Anaerobic respiration
(a) It takes place in higher organisms.	It takes place in lower organisms.
(b) It takes place in cytoplasm and mitochondria.	It takes place in cytoplasm.
(c) It involves the participation of free molecular oxygen.	It does not involve participation of free molecular oxygen.
(d) Oxidation of food is complete.	Oxidation of food is incomplete.
(e) It produces $C0_2$ and H_20.	It produces $C0_2$ and C_2H_5OH.
(f) It releases more energy, i.e. 38 ATP.	It releases less energy, i.e. 2 ATP.
(g) Overall equation: $C_6H_{12}0_6 + 60_2 \rightarrow 6C0_2 + 6H_20$ + Energy	Overall equation: $C_6H_{12}0_6 \rightarrow 2C_2H_5OH + 2C0_2$ + Energy

5. Differentiate between

Question (A)
Respiration and combustion.
Answer:

Respiration	Combustion
(a) It is a biochemical and stepwise process.	It is physiochemical and spontaneous process.
(b) It occurs inside the cells.	It is a non-cellular process.
(c) Energy is released in steps.	Large amount of energy is released at a time.
(d) No light is produced in respiration.	Light may be produced in combustion.
(e) It is controlled by enzymes.	It is not controlled by enzymes.
(f) A number of intermediates are produced.	No intermediates are produced.

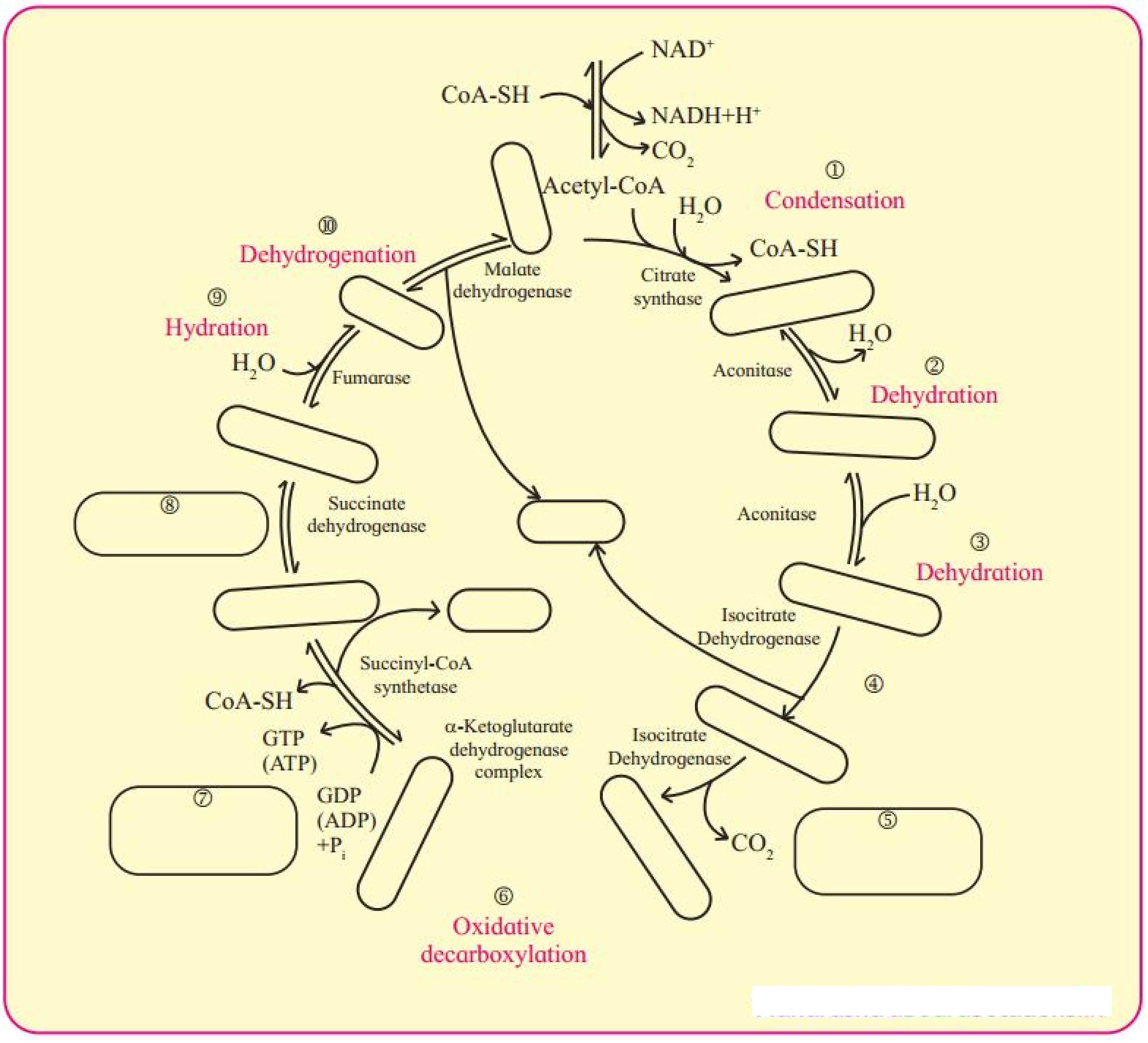
Question (B)
Distinguish between Glycolysis and Krebs cycle.
Answer:

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. $C0_2$ is not released.	$C0_2$ 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.	$C0_2$ and H_2Q are the end products.

Question (C)
Aerobic respiration and fermentation.
Answer:

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 $C0_2$ and H_20.	It produces either ethanol or lactic acid and $C0_2$ depending upon the type of fermentation.
7. It releases more energy, i.e. 38 ATP.	It releases less energy, i.e. 2 ATP.

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



Answer:

1. Krebs cycle or citric acid cycle is the second phase of aerobic respiration which takes place in the matrix of the mitochondria.
2. The acetyl CoA formed during the link reaction undergoes aerobic oxidation.
3. This cycle serves a common oxidative pathway for carbohydrates, fats and proteins.
4. In mitochondria pyruvic acid is decarboxylated and the remaining 2-carbon fragment is combined with a molecule of coenzyme A to form acetyl-CoA.
5. This reaction is an oxidative decarboxylation process and produces H^+ ions and electrons along with carbon dioxide. During the process NAD^+ is reduced to $NADH+H^+$.
6. P-oxidation of fatty acids also produces acetyl-CoA as the end product.
7. Acetyl-CoA from both sources is condensed with oxaloacetic acid to form citric acid. Citric acid is oxidized step-wise by mitochondrial enzymes, releasing carbon dioxide.
8. Regeneration of oxaloacetic acid occurs to complete the cycle.

9. There are four steps of oxidation in this cycle, catalyzed by dehydrogenases (oxidoreductases) using NAD^+ or FAD^+ as the coenzyme.
10. The coenzymes are consequently reduced to $NADH+H^+$ and $FADH_2$ respectively. These transfer their electrons to the mitochondrial respiratory chain to get reoxidised.
11. One molecule of GTP (ATP) is also generated for every molecule of citric acid oxidized.

Practical / Project:

Question 1.
Make Powerpoint Presentation on Glycolysis, Krebs Cycle and Conduct the group discussion on it in classroom.
[Note: Students are expected to perform above activity on their own.]

11th Biology Digest Chapter 13 Respiration and Energy Transfer Intext Questions and Answers

Can you recall? (Textbook Page No. 151)

(i) Which nutrients are used for energy production?
Answer:
Nutrients like carbohydrates, fats and proteins are used for energy production.

(ii) Why do organisms take up oxygen and release carbon dioxide?
Answer:
a. At cellular level, organisms require energy to carry out different metabolic activities.
b. The energy is made available by oxidizing/breaking the food.
Therefore, oxygen is required by aerobic organisms for breaking the food and carbon dioxide is released as a byproduct of oxidation.

Use your brainpower (Textbook Page No. 152)

Why is glycolysis considered as biochemical proof of evolution?
Answer:

1. Glycolysis does not require oxygen. Hence it might have been used by earlier organisms for energy production, as there was no free oxygen in atmosphere of primitive earth.
2. Glycolysis is the first metabolic pathway, an ancient pathway which is common to both aerobic and anaerobic organisms.
3. All cells have glycolysis in their metabolic pathway.
4. Upto pyruvate the pathway is similar to all aerobic and anaerobic organisms. Later, the fate of pyruvic acid can be either $C0_2$ or ethanol or lactic acid depending upon the type of organism.
5. Hence it is considered as a biochemical proof of evolution.

Use your brainpower (Textbook Page No. 152)

(i) What is role of Mg^{++}, Zn^{++} in various steps of glycolysis?
Answer:
a. Mg^{++} and Zn^{++} are the cofactors that are tightly bound to enzymes and helps the enzymes to perform their functions.
b. They regulate the activity of the most important enzymes like Hexokinase, Phosphoffuctokinase, Triose phosphate dehydrogenase, Phosphoglycerate kinase, Enolase, Pyruvate kinase.

(ii) Why some reactions of glycolysis are reversible and some irreversible?
Answer:
Irreversible chemical reactions:
Some chemical reactions can occur in only one direction i.e. these reactions are irreversible reactions. The reactants can change to the products, but the products cannot change back to the reactants.

Reversible chemical reactions:

1. Some chemical reactions can occur in both directions i.e. these reactions are reversible reactions. In this case the reactants change to the products and the products can change back to the reactants, atleast under specific conditions.
2. Out of ten, four are irreversible reactions which involves the enzyme kinase that is required for phosphorylation reactions, these reactions involve large negative energy AG, hence the reactions are irreversible.
3. Other reversible reactions do not involve high negative energy hence are reversible.

Use your brainpower (Textbook Page No. 152)

Why do athletes like sprinters have higher proportion of white muscle fibers?
Answer:
1. The white muscle fibres produce energy in a very short period of time that is required for fast and severe work. Thus, the energy becomes immediately available to the athletes.

2. On the other hand, the red muscle produce energy over a prolonged period of time, hence athletes have higher proportion of white muscle fibers.

Can you recall? (Textbook Page No. 151)

Which steps are involved in aerobic respiration?
Answer:
It involves glycolysis, acetyl CoA formation (connecting link reaction), Krebs cycle, electron transfer chain reaction and terminal oxidation.

Can you recall? (Textbook Page No. 151)

What is aerobic and anaerobic respiration?
Answer:
For anaerobic respiration: Anaerobic respiration is the cellular respiration that does not involve the atmospheric oxygen. It is also called as fermentation. It involves glycolysis where the product of glycolysis i.e. pyruvate is converted to either lactic acid or ethanol and for aerobic respiration.
1. Aerobic respiration occurs in the presence of free molecular oxygen during oxidation of glucose.
2. In this type of respiration, the glucose is completely oxidized to $C0_2$ and H_20 with release of large amount of energy. It involves glycolysis, acetyl CoA formation (connecting link reaction), Krebs cycle, electron transfer chain reaction and terminal oxidation.

Use your brainpower (Textbook Page No. 157)

Do the plants breath like animals? If yes, how and why?
Answer:

1. Yes, plants breath like animals because they also require energy to carry out different metabolic activities. Hence, plants take up oxygen required for respiration and they also give out $C0_2$.
2. Plants take care of their gas exchange needs. The stomata and lenticels are important for this purpose.
3. Leaves are well adapted for gaseous exchange during photosynthesis.
4. Large amount of gases is exchanged. In plants, each living cell is located quite close to the surface of the plants.

Internet my friend (Textbook Page No. 155)

What is effect of carbon monoxide poisoning on cytochromes?
Answer:

1. At sub-cellular level, carbon monoxide is toxic for mitochondria.
2. It alters the mitochondrial respiratory chain at the cytochrome c oxidase level (complex IV of the mitochondrial respiratory chain) and causes inhibition of ETS.
3. This inhibition leads to the development of symptoms observed in acute CO poisoning, and in some diseases related to smoking.
4. These symptoms include headache, nausea, vomiting, dizziness, weakness, difficulty in concentration or confusion, visual changes, syncope, seizures, abdominal pain and muscle cramping.

Can you recall? (Textbook Page No. 151)

Which is most preferred nutrient among carbohydrate, protein and fat for energy production? Why?
Answer:

1. The preferred nutrient is carbohydrate because it quickly supplies energy as compared to other nutrients.
2. Carbohydrates are easy to digest as compared to fats.
3. The RQ of carbohydrate is 1. Hence allows complete oxidation of food. Thus, the preferred nutrient is carbohydrate.

Internet my friend (Textbook Page No. 158)

Calculate the RQ for different respiratory substrates using appropriate formula.
Answer:
The RQ for different respiratory substrates are:
1. Carbohydrates (R.Q. is 1)
When carbohydrates are used as substrate, equal volumes of $C0_2$ and 0_2 are released and consumed respectively, thus its R.Q. is 1.
$C_6 H_{12} O_6 + 6O_2 \rightarrow 6 C0_2 + 6H_20$
R.Q. = $6C0_2 / 60_2 = 1.0$

2. Fats (R.Q. is less than 1)
Substrates like fats are poorer in oxygen than carbohydrates. Thus, more oxygen is utilized for its complete oxidation.
$2(C_{51} H_{98} O_6) + 145O_2 \rightarrow 102CO_2 + 98H_2O$ + Energy
R.Q. = $C0_2 / 0_2 = 102 / 145 = 0.7$

3. Protein respiration (R.Q. is less than 1)

1. When proteins serve as respiratory substrate, they are first degraded to amino acids.
2. Then, amino acids are converted into various intermediates of carbohydrates.
3. However, amino acids have low proportion of O_2 as compared to carbohydrates.
4. Thus, they require more O_2 during their complete oxidation and value of R.Q. becomes less than 1.
5. In case of proteins, the R.Q. is approximately 0.9.