Question 1:

Differentiate between

(a) Respiration and Combustion

(b) Glycolysis and Krebs' cycle

(c) Aerobic respiration and Fermentation

Answer

(a) Respiration and combustion

Respiration		**Combustion**	
1.	It is a biochemical process.	**1.**	It is a physiochemical process.
2.	It occurs in the living cells.	**2.**	It does not occur in the living cells.
3.	ATP is generated	**3.**	ATP is not generated
4.	Enzymes are required	**4.**	Enzymes are not required
5.	It is a biologically-controlled process.	**5.**	It is an uncontrolled process.

(b) Glycolysis and Krebs cycle

Glycolysis		**Krebs cycle**	
1.	It is a linear pathway.	**1.**	It is a cyclic pathway.
2.	It occurs in the cell cytoplasm.	**2.**	It occurs in the mitochondrial matrix.
3.	It occurs in both aerobic and anaerobic respiration.	**3.**	It occurs in aerobic respiration.
4.	It generates 2 $NADH_2$ and 2 ATP molecules on the breakdown of one glucose molecule.	**4.**	It produces 6 $NADH_2$, $2FADH_2$, and 2 ATP molecules on the breakdown of two acetyl-CoA molecules.

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(c) Aerobic respiration and fermentation

Aerobic respiration		**Fermentation**	
1.	Oxygen is used for deriving energy	**1.**	Occurs in the absence of oxygen
2.	Occurs in the cytoplasm and mitochondria	**2.**	Occurs in the cytoplasm
3.	End products are carbon dioxide and water	**3.**	End products are ethyl alcohol and carbon dioxide
4.	Complete oxidation of the respiratory substrate takes place	**4.**	Incomplete oxidation of the respiratory substrate takes place
5.	About 36 ATP molecules are produced	**5.**	Only 2 ATP molecules are produced

Question 2:

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

Answer

The compounds oxidised during the process of respiration are called respiratory substrates. Carbohydrates, especially glucose, act as respiratory substrates. Fats, proteins, and organic acids also act as respiratory substrates.

Question 3:

Give the schematic representation of glycolysis?

Answer

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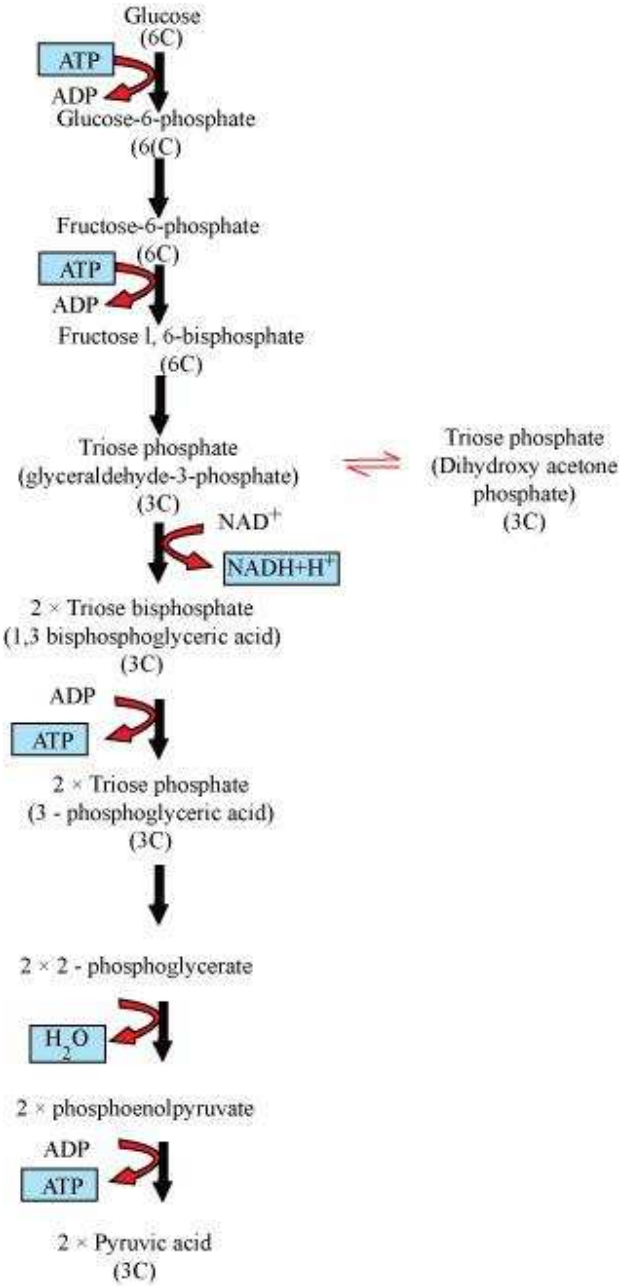

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Question 4:

What are the main steps in aerobic respiration? Where does it take place?

Answer

The major steps in aerobic respiration and the sites where they occur are listed in the given table.

Step		**Site of occurrence**	
1.	Glycolysis	**1.**	Cytoplasm
2.	Krebs cycle	**2.**	Matrix of mitochondria
3.	Electron transport system	**3.**	Inner mitochondrial membrane
4.	Oxidative phosphorylation	**4.**	F_0-F_1 particles in the inner mitochondrial membrane

Question 5:

Give the schematic representation of an overall view of Krebs cycle.

Answer

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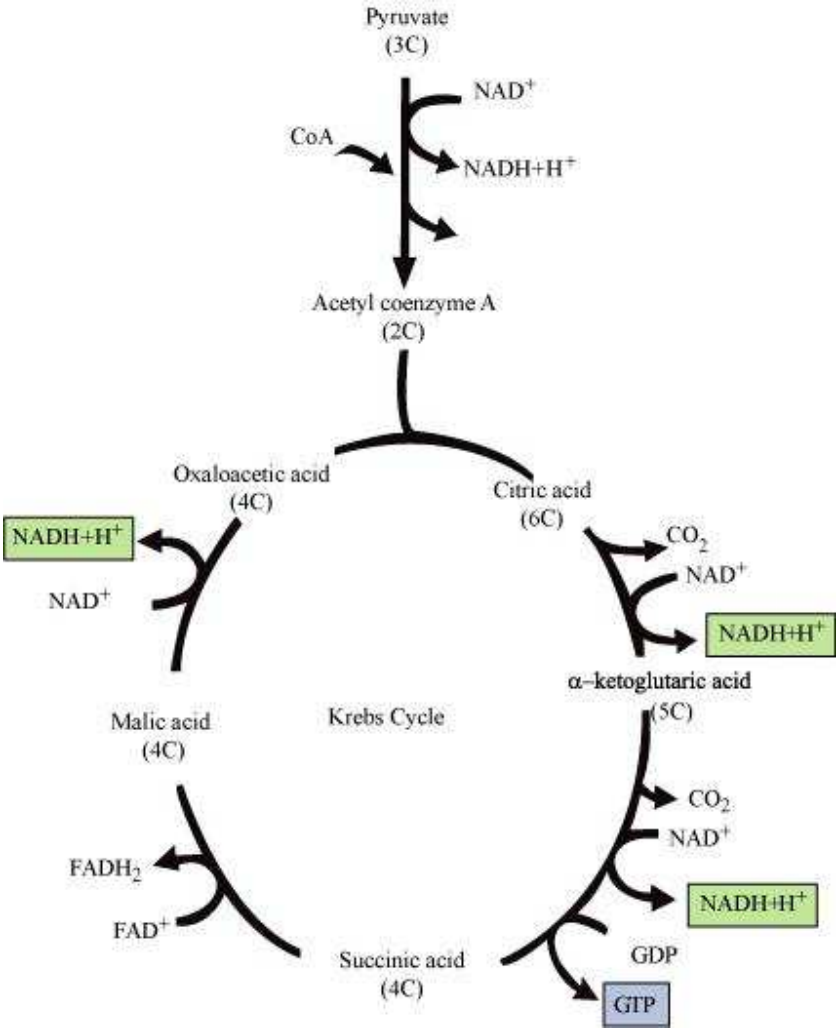

Question 6:

Explain ETS.

Answer

ETS or electron transport system is located in the inner mitochondrial membrane. It helps in releasing and utilizing the energy stored in $NADH+H^+$ and $FADH_2$. NADH + H^+, which is formed during glycolysis and citric acid cycle, gets oxidized by NADH dehydrogenase (complex **I**). The electrons so generated get transferred to

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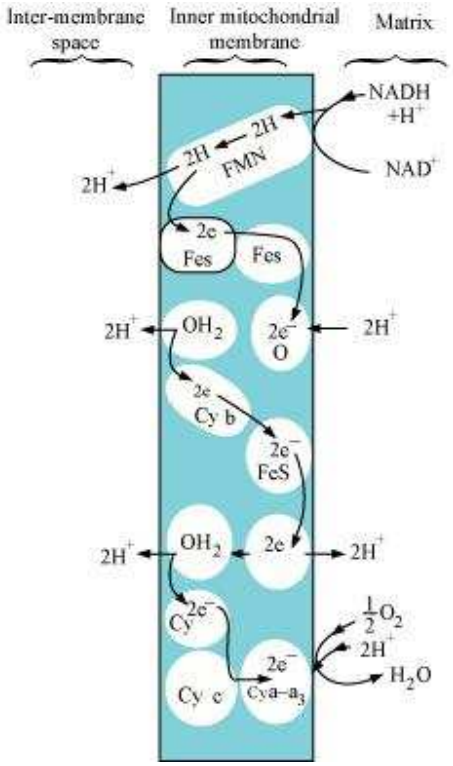
ubiquinone through FMN. In a similar manner, $FADH_2$ (complex **II**) generated during citric acid cycle gets transferred to ubiquinone. The electrons from ubiquinone are received by cytochrome bc_1 (complex **III**) and further get transferred to cytochrome c. The cytochrome c acts as a mobile carrier between complex **III** and cytochrome c oxidase complex, containing cytochrome a and a_3, along with copper centres (complex **IV**).

During the transfer of electrons from each complex, the process is accompanied by the production of ATP from ADP and inorganic phosphate by the action ATP synthase (complex **V**). The amount of ATP produced depends on the molecule, which has been oxidized. 2 ATP molecules are produced by the oxidation of one molecule of NADH. One molecule of $FADH_2$, on oxidation, gives 3 ATP molecules.



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Question 7:

Distinguish between the following:

(a) Aerobic respiration and Anaerobic respiration

(b) Glycolysis and Fermentation

(c) Glycolysis and Citric acid Cycle

Answer

(a) Aerobic respiration and Anaerobic respiration

Aerobic respiration		**Anaerobic respiration**	
1.	It uses oxygen for deriving energy.	1.	It occurs in the absence of oxygen.
2.	It occurs in cytoplasm and mitochondria.	2.	It occurs in cytoplasm.
3.	The end products of aerobic respiration are carbon dioxide and water.	3.	The end products of fermentation are ethyl alcohol and carbon-dioxide.
4.	Complete oxidation of respiratory substrate takes place.	4.	Incomplete oxidation of respiratory substrate takes place.
5.	36-38 ATP molecules are produced.	5.	Only 2 ATP molecules are produced.

(b) Glycolysis and Fermentation

	Glycolysis		**Fermentation**
1.	Glycolysis occurs during aerobic and anaerobic respiration.	1.	Fermentation is a type of anaerobic respiration.
2.	Pyruvic acid is produced as its end product.	2.	Ethanol or lactic acid is produced as its end product.

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(c) Glycolysis and citric acid cycle

Glycolysis		**Citric acid cycle (Krebs cycle)**	
1.	It is a linear pathway.	1.	It is a cyclic pathway.
2.	It occurs in the cell cytoplasm.	2.	It occurs in the mitochondrial matrix.
3.	It occurs in both aerobic and anaerobic respiration.	3.	It occurs in aerobic respiration.
4.	One glucose molecule breaks down to generate 2 $NADH_2$ and 2 ATP molecules.	4.	It produces 6 $NADH_2$, 2 $FADH_2$, and 2 ATP molecules on breakdown of two acetyl-coA molecules.

Question 8:

What are the assumptions made during the calculation of net gain of ATP?

Answer

For theoretical calculation of ATP molecules, various assumptions are made, which are as follows.

(a) It is assumed that various parts of aerobic respiration such as glycolysis, TCA cycle, and ETS occur in a sequential and orderly pathway.

(b) NADH produced during the process of glycolysis enters into mitochondria to undergo oxidative phosphorylation.

(c) Glucose molecule is assumed to be the only substrate while it is assumed that no other molecule enters the pathway at intermediate stages.

(d) The intermediates produced during respiration are not utilized in any other process.

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Question 9:

Discuss "The respiratory pathway is an amphibolic pathway."

Answer

Respiration is generally assumed to be a catabolic process because during respiration, various substrates are broken down for deriving energy. Carbohydrates are broken down to glucose before entering respiratory pathways. Fats get converted into fatty acids and glycerol whereas fatty acids get converted into acetyl CoA before entering the respiration. In a similar manner, proteins are converted into amino acids, which enter respiration after deamination.

During synthesis of fatty acids, acetyl CoA is withdrawn from respiratory pathway. Also, in the synthesis of proteins, respiratory substrates get withdrawn. Thus, respiration is also involved in anabolism. Therefore, respiration can be termed as amphibolic pathway as it involves both anabolism and catabolism.

Question 10:

Define RQ. What is its value for fats?

Answer

Respiratory quotient (RQ) or respiratory ratio can be defined as the ratio of the volume of CO_2 evolved to the volume of O_2 consumed during respiration. The value of respiratory quotient depends on the type of respiratory substrate. Its value is one for carbohydrates. However, it is always less than one for fats as fats consume more oxygen for respiration than carbohydrates.

It can be illustrated through the example of tripalmitin fatty acid, which consumes 145 molecules of O_2 for respiration while 102 molecules of CO_2 are evolved. The RQ value for tripalmitin is 0.7.

Question 11:

What is oxidative phosphorylation?

Answer

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Oxidative phosphorylation is a process in which electrons are transferred from electron donors to oxygen, which acts as electron acceptor. The oxidation-reduction reactions are involved in the formation of proton gradient. The main role in oxidative phosphorylation is played by the enzyme ATP synthase (complex V). This enzyme complex consists of F_0 and F_1 components. The F_1 headpiece is a peripheral membrane protein complex and contains the site for ATP synthesis from ADP and inorganic phosphate. F_0 component is a part of membrane protein complex, which acts as a channel for crossing of the protons from inner mitochondrial membrane to the mitochondrial matrix. For every two protons passing through F_0–F_1 complex, synthesis of one ATP molecule takes place.

Question 12:

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

Answer

The process of aerobic respiration is divided into four phases – glycolysis, TCA cycle, ETS, and oxidative phosphorylation. It is generally assumed that the process of respiration and production of ATP in each phase takes place in a step-wise manner. The product of one pathway forms the substrate of the other pathway. Various molecules produced during respiration are involved in other biochemical processes. The respiratory substrates enter and withdraw from pathway on necessity. ATP gets utilized wherever required and enzymatic rates are generally controlled. Thus, the step-wise release of energy makes the system more efficient in extracting and storing energy.

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Chapter-14

RESPIRATION IN PLANTS

POINTS TO REMEMBER

Aerobic respiration : Complete oxidation of organic food in presence of oxygen thereby producing CO_2, water and energy.

Anaerobic respiration : Incomplete breakdown of organic food to liberate energy in the absence of oxygen.

ATP Synthetase : An enzyme complex that catalyses synthesis of ATP during oxidative phospho-relation.

Biological oxidation : Oxidation in a series of reaction inside a cell.

Cytochromes : A group of iron containing compounds of electron transport system present in inner wall of mitochondria.

Dehydrogenase : Enzyme that catalyses removal of H atom from the substrate.

Electron acceptor : Organic compound which recieve electrons produced during oxidation-reduction reactions.

Electron transport : Movement of electron from substrate to oxygen through respiratory chain during respiration.

Fermentation : Breakdown of organic substance that takes place in certain microbe like yeast under anaerobic condition with the production of CO_2 and ethanol.

Glycolysis : Enzymatic breakdown of glucose into pyruvic acid that occurs in the cytoplasm.

Oxidative phosphorylation : Process of formation of ATP from ADP and Pi using the energy from proton gradient.

Respiration : Biochemical oxidation food to release energy.

Respiratory Quotient : The ratio of the volume of CO_2 produced to the volume of oxygen consumed.

Proton gradient : Difference in proton concentration across the tissue membrane.

Mitochondrial matrix : The ground material of mitochondria in which

pyruvic acid undergoes aerobic oxidation through Kreb's cycle.
Electron Transport Chains (ETC)- A series of co-enzymes and electron/carriers where electrons can pass along increasing redox potential losing a bit of energy at every step of transfer.

Abbreviations

ATP	–	Adenosine tri phosphate
ADP	–	Adenosine di phosphate
NAD	–	Nicotinamide Adenine dinucleotide
NADP	–	Nicotinamide Adenine dinucleotide Phosphate
NADH	–	Reduced Nicotinamide Adenine dinucleotide
PGA	–	Phosphoglyceric acid
PGAL	–	Phospho glyceraldehyde
FAD	–	Flavin adenine dinucleotide
ETS	–	Electron transport system
ETC	–	Electron transport chain
TCA	–	Tricarboxylic acid **(Cycle)**
OAA	–	Oxalo acetic acid
FMN	–	Flavin mono nucleotide
PPP	–	Pentose phosphate pathway

AEROBIC RESPIRATION

The overall mechanism of aerobic respiration can be studied under the following steps :

(A) Glycolysis (EMP pathway)

(B) Oxidative Decarboxylation

(C) Kreb's cycle (TCA-cycle)

(D) Oxidative phosphorylation

Glycolysis : The term has originated from the Greek word, *glycos* = glucose, *lysis* = splitting or breakdown means breakdown of glucose molecule.

Steps for Glycolysis- (EMP Pathway)

1. Phosphorylation of glucose 2. Formation of fructose 6- phosphate 3. Second phosphorylation 4. Lysis (splitting) 5. Isomerisation of DiHAP 6. Oxidation 7. Substrate Level ATP synthesis 8. Isomerisation or Rearrangement 9. Dehydration 10. Substrate Level ATP Synthesis and formation of Pyruvate.

- It is also called Embeden-Meyerhof-Paranus pathway. (EMP pathway)
- It is common in both aerobic and anaerobic respiration.
- It takes place outside the mitochondria, in the cytoplasm.
- One molecule of glucose (Hexose sugar) ultimately produces two molecules of pyruvic acid through glycolysis.
- During this process 4 molecules of ATP are produced while 2 mol−ecules of ATP are utilised. Thus net gain of ATP is of 2 molecules.

Input and Output of glycolysis

S. No.	Input	Output
1.	Glucose (6-C)- 1 molecule	Pyruvate (3-C) 2 molecutes
2.	2 ATP	2 ADP
3.	4 ADP + 2 Pi	4 ATP + 2H2O
4.	2 NAD+	2 NADH (+ H+O)

Net out put ..... 2 Pyruvate + 2ATP + 2NADH (+ H^+) OR 2 Pyruvate + 8 ATP

Oxidative decarboxylation : Pyruvic acid is converted into Acetyle CoA in presence of pyruvate dehydrogenase complex.

$$\text{Pyruvic acid} + \text{CoA} + \text{NAD+} \xrightarrow[\text{Pyruvate dehydrogenase}]{Mg^{2+}} \text{Acetyle CoA} + CO_2 + \text{NADH} + \text{H+}$$

The Acetyle CoA enters in TCA cycle.

Tri Carboxylic Acid Cycle (Kreb's cycle) or Citric acid Cycle : This cycle starts with condensation of acetyle group with oxaloacitic acid and water to yield citric acid which undergoes a series of reactions.

- It is aerobic and takes place in mitochondrial matrix.
- Each pyruvic acid molecule produces 4 NADH + H^+, one $FADH_2$, one ATP.
- One glucose molecule has been broken down to release CO_2 and eight molecules of NADH + H^+, two molecules of $FADH_2$ and 2 molecules of ATP.

Electron transport system and oxidative phosphorylation : The metabolic pathway through which the electron passes from one carrier to another, is called Electron transport system and it is present in the inner mitochondrial membrane.

ETS comprises of the following :

(i) NAD and NADH + H^+

(ii) FAD and $FADH_2$

(iii) UQ (Ubquinone)

(iv) Cyt b, Cyt c_1, Cyt c, Cyt a and Cyt a_3.

Oxygen acts as final hydrogen acceptor. The oxidation of NADH2 or FADH2 occurs by transfer of their electrons to a series of electron acceptors and finally they combine with oxygen to form water and ATP. The oxidation of each molecule of NADH2 and FADH2 give rise to 3 ATP and 2 ATP molecules respectively.

Compensation Point : It is the value of a factor at which the rate of photosynthesis controlled by it is just equal to the rate of respiration and photo respiration so that there is no net exchange of gases between the photo synthetic organ and the environment.

At compensation point the photosynthetic tissue manufacture only such amount of food which of sufficient for it to remain alive. No food is supplied to rest of the plant. Therefore net photosynthesis it zero.

Oxidative Phasphorylation :

The synthesis of ATP from ADP and inorganic phosphate using energy from proton gradient is called oxidative phosphorylation. This takes place in elementry particles present on the inner membrane of cristae of mitochondria. This process in mitochondria is catalysed by ATP synthetase (complex V). This complex has two major components F0 and F1. F0 acts a channel for proton and F1 acts as an ATP synthetase.

Total ATP Production

Process	**Total ATP produced**
1. Glycolysis	2ATP + $2NADH_2$ (6ATP) = 8ATP
2. Oxidative decarboxylation	$2NADH_2$ (6ATP) = 6ATP
3. Kreb's Cycle	2GTP (2ATP) + $6NADH_2$ (18ATP) + $2FADH_2$ (4ATP) = 24ATP

Energy production in prokaryotes during aerobic respiration = 38 ATP

Energy production in eukaryotes during aerobic respiration = 38 – 2 = 36 ATP

(2ATP are used up in transporting 2 molecule of pyruvic acid in mitochondria.)

Fermentation : It is the process of anaerobic respiration which occurs in yeast and some bacteria. Fermentation involves incomplete oxidation of food into ethanol and carbon-di-oxide. It results in the production of 2 ATP molecules.

$$\text{glucose} \rightarrow \text{Pyruvic Acid} \rightarrow \text{Ethanol} + CO_2$$

Anaerobic respiration in muscles : During strenuous exercise a person feels pain and fatigue in his muscles. This is due to accumulation of lactic acid in muscles. When oxygen inadequate pyruvic acid is reduced to lactic acid in presence of enzyne-lactic dehydrogenase

$$\text{Pyruvic acid} \xrightarrow{\text{Lactic dehydrogenase}} \text{Lactic acid}$$

During rest, lactic acid is reconverted to pyruvic acid.

Respiratory pathway as on Amphibolic pathway

During the process of cellular respiration Carbohydrates, fats and protiens are broken down to release energy and hence respiration is a catabolic process/catabolic pathway. From this pathway many compound are withdrawn for synthesis of substrates. Here some anabolic processes are –

– Acetyle CoA is with drawn for the synthesis of fat

– Respiratory intermediate at many places are linked for formation of protien.

Because repiratory pathway is involved in both catabolism and anabolism, it is better to consider the respiratory pathway as an anphibolic pathway

QUESTIONS

Very Short Answer Questions (1 mark each)

1. Name the molecule which is terminal acceptor of electron.

2. How many ATP molecules are produced from a molecule of glucose on it complete oxidation in eukaryotes ?

3. Where does ETC found in eukaryotic cell ?

4. Name the enzyme which convert sugar into glucose and fructose.

5. How many molecules of ATP are produced by the oxidation of one molecule of $FADH_2$?

6. Why do the person with sufficient white fibres get fatigued in a short period ?

7. Write the name of end product of glycolysis.

8. Name the first product formed in Kerb's cycle.

Short Answer Questions-II (2 marks each)

9. Define the term 'Respiratory substrate'.
10. Which intermediate undergoes lysis in glycolysis?
11. Write the other two names of Krebs cycle.
12. Name the acceptor molecule of Krebs cycle.
13. Name the substrate entrant of Krebs cycle.
14. Name the first chemical produced in Krebs cycle.
15. What is Electron Transport Chain ? (ETC)

16. Differentiate between aerobic respiration and anaerobic respiration.

17. Mention two steps of glycolysis in which ATP is utilised.

18 Why does anaerobic respiration produces less energy than aerobic respiration ?

19. Define Respiratory Quotient. What is its value for fat and protein ?

20 Distinguish between glycolysis and fermentation.

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

Short Answer Questions-I (3 marks each)

22. Give the schematic representation of an overall view of TCA cycle.

23. Where does electron transport system oparative in mitochondria ? Explain the system giving the role of oxygen ?

24. Give a brief account of ATP molecules produced in aerobic respiration in eukaryotes.

25. Discuss The respiratory pathway is an amphibolic pathway.

26. Expand ETC, ETS and TCA.

Long Answer Questions (5 marks each)

19. What is glycolysis ? Where does glycolysis takes place in a cell ? Give schematic representation of glycolysis.

ANSWERS

Very Short Answers (1 mark each)

1. Oxygen.

2. 36 ATP.

3. Mitochondrial membrane.

4. Invertase.

5. 2 ATP molecules.

6. due to formation of Lactic acid.

7. Pyruvic acid.

8. Citric acid.

9. The organic substances which is catabolised or broken down enzymatically in cellular respiration for releasing energy.

10. Frutose 1,6- bisphosphate.

11. (i) Citric acid cycle (ii) Tricarboxylic acid cycle

12. Oxaloacetate

13. Acetyl Co-A

14. Citrate

15. See text (Points to remember)

Short Answers-II (2 marks each)

16. Refer NCERT Text Book Chapter 14 (14.3 and 14.4).
17. (i) ATP molecules are formed by direct transfer of Pi to ADP.
    (ii) By oxidation of NADH.
18. Refer NCERT Tex Book Chapter 14, Page 230.
19. Refer NCERT Text Book Page no. 236.
20. Refer NCERT Text Book Page no. 229 and page no. 230.
21. Refer NCERT Text Book Page no. 227.

Short Answers-I (3 marks each)

22. Refer NCERT Text Book, Fig. 14.3 Page no. 232.
23. Refer NCERT Text Book Page no. 232 and page no. 233.
24. Refer notes.
25. Refer NCERT Text Book Page no. 235.
26. See text (abbreviations).

Long Answers (5 marks each)

27. Refer NCERT Text Book Page no. 228 and page no. 229.