7. Respiration

7.0 : Introduction

Q.1. What is respiration? Describe different types of respiration.

Ans: Defmition: Respiration is defined as an intracellular oxidation in which complex organic substances are broken down in step-wise manner with the release of energy which is immediately converted into metabolically usable form of energy, i.e. ATP.

Types of respiration :

i) Aerobic respiration :

When free molecular oxygen is used in respiration to breakdown the organic substrate, the respiration is called aerobic respiration.

It can be represented as follows:

$$C_6H_{12}O_6 + 6O_2 + 6CO_2 + 6H_2O + \text{Energy}$$

ii) Anaerobic respiration :

When free molecular oxygen is not used in respiration to breakdown the organic substrate, then it is called anaerobic respiration.

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + \text{Energy}$$

Q.2. What are respiratory substrates? Name the most common respiratory substrates.

Ans: The compounds that are oxidized during the process of respiration are known as respiratory substrates. They include carbohydrates, proteins, fats, organic acids, etc. Among these, carbohydrates are the main source of energy and glucose is the most preferred substrate because it is easily available and acceptable to all kinds of organisms. However, when the carbohydrates are not available, proteins and fats serve as respiratory substrates.

Q.3. Why is respiration an exergonic and catabolic physio-chemical process ?

Ans: A chemical reaction that proceeds with release of energy is called exergonic reaction. Respiration involves the exchange of oxygen and carbon dioxide and the oxidation of glucose inside the mitochondria to produce energy, which is partly stored in the form of ATP molecules. In this reaction, glucose is broken down, hence it is called catabolic process.

7.1 : ATP as Currency of Energy

Q.4. Why is ATP called as energy currency of a cell? Give its significance.

Ans: ATP (Adenosine triphosphate) is the energy rich organic compound. Whenever energy is released, ATP synthesis takes place from ADP and Pi, and when energy is required, ATP is hydrolysed and energy released as high energy phosphate bond is broken. This energy is used for metabolic activities in the body. Therefore, ATP is called energy currency of the cell.

Significance of ATP :

i) Storage of energy.

ii) Supply of energy to the cell for metabolic processes.

iii) It donates one or two phosphate groups and functions as phosphorylating agent.

Q.5. Write a short note on ATP.

Ans: i) ATP (adenosine tri phosphate) is the biologically usable form of chemical energy. It provides energy for all cellular activities, hence it is called the energy currency of cells.

ii) Structurally, the ATP consists of nitrogenous purine base called Adenine, a pentose sugar called Ribose ($C_5H_{10}O_5$)and 3 Phosphate molecules.

iii) Adenine and ribose sugar together form Adenosine. Adenosine with 1 phosphate, 2 phosphates and 3 phosphates are called AMP, ADY and ATP respectively.

iv) Between the 2nd and 3rd molecules of phosphate, a high energy phosphate bond is present. For the formation of these bonds, energy is given by either light (Photophosphorylation) or oxidative process of respiration (oxidative phosphorylation).

v) Whenever the cell needs energy, ATP is hydrolyzed to produce ADP and Pi (inorganic phosphate) and energy is released as high energy phosphate bond is broken.

vi) Both, synthesis and breakdown of ATP are regulated by enzymes ATP synthetase and ATPase, respectively.

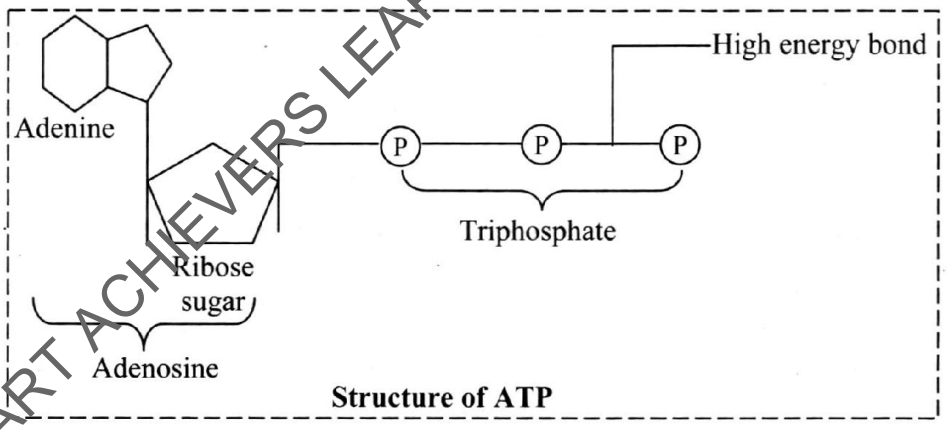
$$ADP + iP \rightleftharpoons ATP$$

Q.6. Describe the structure of ATP. **[Oct 14]**

Ans: i) Structurally, the ATP consists of nitrogenous purine base called Adenine, a pentose sugar called Ribose ($C_5H_{10}O_5$) and 3 Phosphate molecules.

ii) Adenine and ribose sugar together form **Adenosine**. Adenosine with 1 phosphate, 2 phosphates and 3 phosphates are called **AMP, ADP** and **ATP** respectively.

iii) Between the 2nd and 3rd molecules of phosphate, a **high energy phosphate bond** is present. For the formation of these bonds, energy is given by either light (Photophosphorylation) or oxidative process of respiration (oxidative phosphorylation).



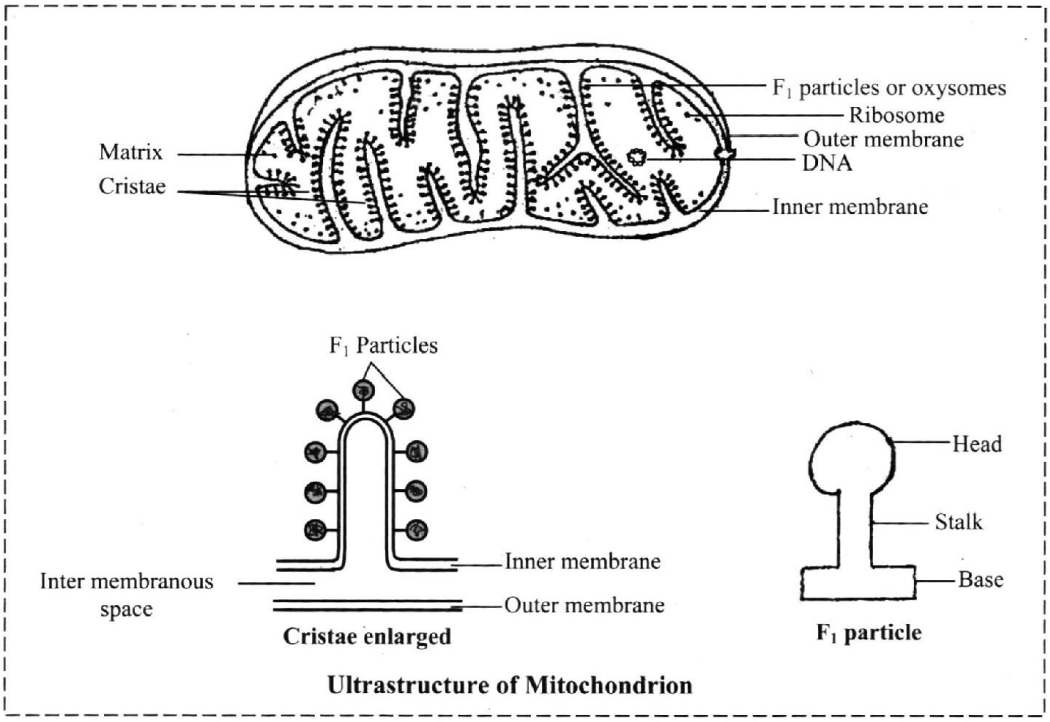
Structure of ATP

Q.7. How much energy is released when one molecule of ATP is hydrolysed to ADP and Pi ?

Ans. When one molecule of ATP is hydrolysed to ADP and Pi, 7.3 Kcal of energy is released.

Q.8. Describe the ultrastructure of mitochondrion.

Ans:



Ultrastructure of Mitochondrion

i) Mitochondria are membrane bound cell organelles, essential for aerobic respiration.

ii) They are present in the eukaryotic cells and absent in prokaryotic cells.

iii) They are randomly distributed in the cytoplasm.

iv) Each mitochondrion is covered by two **lipo-protein membranes** which are separated by a narrow, fluid filled space called **outer chamber.**

v) The outer membrane is smooth and continuous, while the inner membrane has a large number of finger-like folds called cristae.
vi) The space enclosed by the inner membrane is called **inner chamber** and is filled with a colourless fluid called **matrix** which is rich in enzymes and co-enzymes.
vii) Matrix also contains 70S type of ribosome and single, circular DNA molecule. Thus, mitochondria are self-duplicating, self-autonomous cellorganelles.
viii) The inner membrane and cristae bear several small particles called **oxysomes** or elementary particles or F_1 particles.
ix) Each F_1 particle consists of a base, stalk and head.
x) The spherical head contains enzyme ATP synthetase which catalyzes ATP synthesis.

Q.9. Give the functions of mitochondria.

Ans: Functions:

i) The Krebs cycle of respiration takes place in the matrix of mitochondria.
ii) The oxidative phosphorylation takes place in the F I particles of inner membrane.
iii) Mitochondria help in the synthesis of ATP.
iv) These ATP are energy rich compounds and thus mitochondria is called as **"Power house of cell".**
v) Synthesis of fatty acids, amino acids takes place in mitochondria.
vi) It stores and releases calcium.
vii) It provides intermediates for the synthesis of important biomolecules such as chlorophyll, cytochromes, steroids, etc.

Q.10."Mitochondria are called power house of cell". Comment.

Ans: i) Oxidative phosphorylation takes place in F_1 particles to generate ATP molecules.
ii) About 90% ATP is generated in mitochondria to carry out cellular function.
iii) Generated ATP is stored and utilized for active transport, biosynthesis, contraction of muscles and soon. Therefore, mitochondria are called power house of cell.

7.2 : Mechanism of Aerobic and Anaerobic Respiration

Aerobic Respiration

Q.l1.Describe various steps involved in glycolysis.

Ans: Glycolysis is defined as the stepwise, enzymatic breakdown of hexose sugar (glucose) into two molecules of pyruvate in the cytoplasm. Glycolysis is also known as EMP pathway, as its process was discovered by three German scientists

Embden, Meyerhof and Parnas.

The EMP pathway is a common pathway for the degradation of glucose in both aerobic and anaerobic respiration.

Glycolysis consists of two major phases:

a) Preparatory phase and cleavage.
b) Oxidative and payoff phase.

a) Preparatory phase and cleavage :

In this step, glucose molecule is activated by phosphorylation and then cleaved into two molecules of triose phosphates, namely 3-PGAL and DHAP. In the next step, only 3-PGAL participates and hence DHAP gets converted into 3-PGAL. Thus, 2 molecules of3-PGAL are formed.

It includes the following reactions:

i) Phosphorylation I : A glucose molecule is phosphorylated to glucose 6-phosphate in presence of enzyme hexokinase. In this reaction, ATP supplies the phosphate and gets converted into ADP.

ii) Isomerisation : Glucose-6-phosphate IS isomerised to fructose-6-phosphate in presence of enzyme phosphoglucoisomerase.

iii) Phosphorylation II : Fructose-6-phosphate IS phosphorylated to fructose-l,6-diphosphate. Phosphate is supplied by ATP which gets converted to ADP. Reaction is catalyzed by enzyme phosphofructokinase.

iv) Cleavage: Fructose-l,6-diphosphate splits up into two inter-convertible compounds, i.e. Dihydroxy acetone phosphate (DHAP) and 3-phosphoglyceraldehyde (3-PGAL). Reaction occurs in presence of enzyme aldolase.

v) Isomerization : DHAP is isomerised into 3-PGAL with the help of enzyme phospho-triose isomerase, thus two molecules of PGAL are obtained.

b. Oxidative and payoff phase :

In this phase, oxidation or removal of hydrogen takes place and then there is ATP generation.

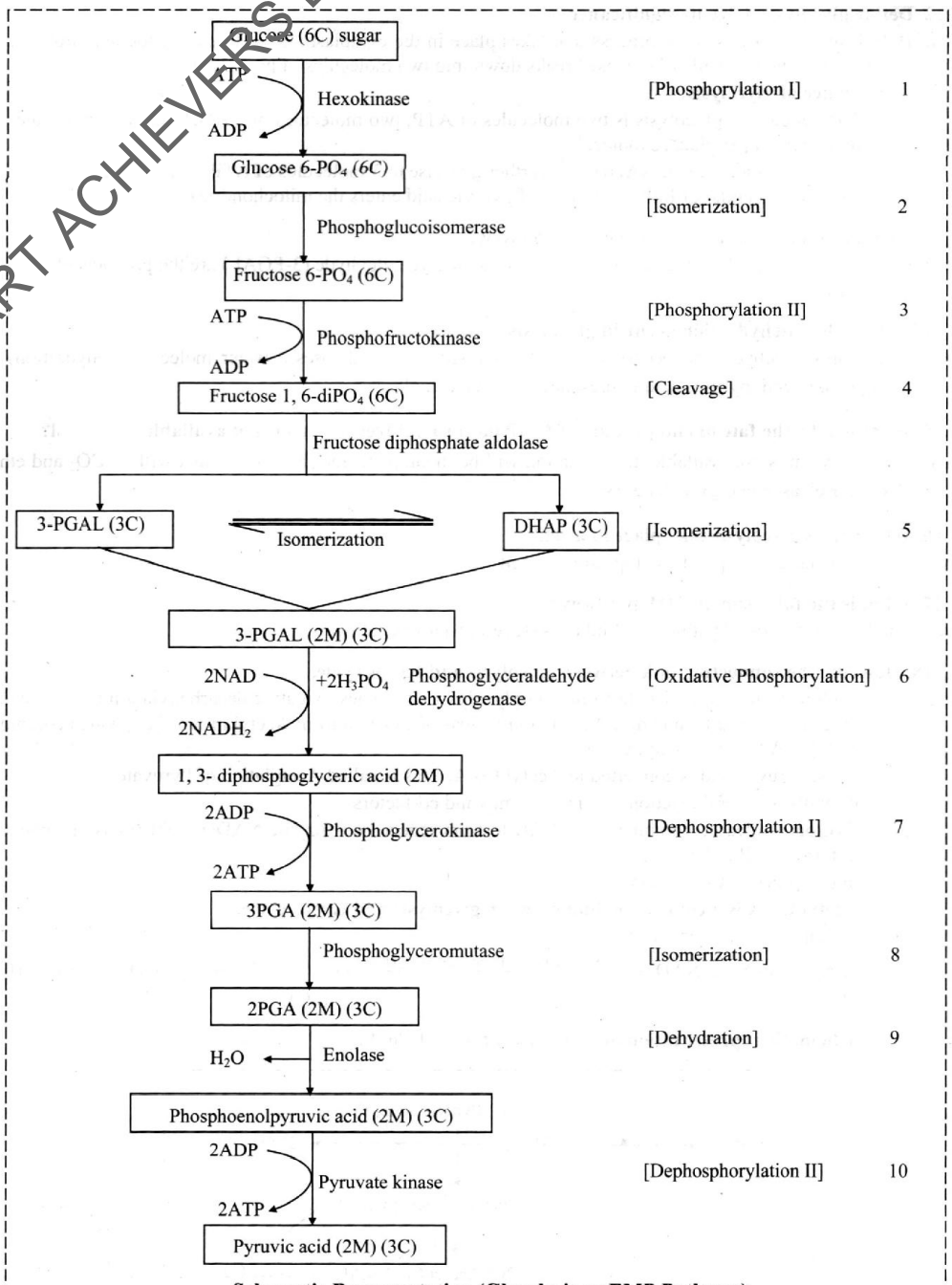
i) Oxidative Phosphorylation : 3-PGAL undergoes oxidation and phosphorylation to form 1,3-diphosphoglyceric acid (l,3-DPGA). Hydrogen released combines with NAD to form $NADH_2$. Phosphate is supplied for the reaction by phosphoric acid (H_3PO_4).

ii) ATP generation I I Dephosphorylation I : 1,3-diphosphoglyceric acid is dephosphorylated to 3-phosphoglyceric acid (3-PGA). Phosphate released combines with ADP to form ATP. Reaction takes place in presence of enzyme phosphoglycero-kinase.

iii) Isomerisation : In presence of enzyme phosphoglycero-mutase, 3-Phosphoglyceric acid IS isomerised to 2-phosphoglyceric acid.

iv) Dehydration: 2-Phosphoglyceric acid loses a water molecule to form phospho enol pyruvic acid. The enzyme enolase catalyses the reaction.

v) ATP generation II / Dephosphorylation II : Phosphoenol pyruvic acid is dephosphorylated to pyruvic acid in presence of enzyme pyruvate kinase. Phosphate released combines with ADP to form ATP.



Schematic Representation (Glycolysis or EMP Pathway)

Q.12. Define glycolysis. Give its significance.

Ans: Definition: Glycolysis is the process that takes place in the cytoplasm of both eukaryotic and prokaryotic cell in which one molecule of glucose breaks down into two molecules of pyruvic acid.

Significance of glycolysis :

i) The net gain of glycolysis is two molecules of ATP, two molecules ofNADH2 and two molecules of pyruvic acid per glucose molecule.

ii) Since each molecule ofNADH2 can further give rise to 3 molecules of ATP, each glucose molecule has a net potential of forming 8 ATP (If pyruvic acid enters the mitochondria).

Q.13.What are the products of cleavage in glycolysis ?

Ans: Dihydroxy acetone phosphate (DHAP) and 3-phosphoglyceraldehyde (3-PGAL) are the products of cleavage in glycolysis.

Q.14.Where does dehydration occur in glycolysis ?

Ans: In glycolysis, dehydration occurs when 2-Phosphoglyceric acid loses a water molecule (dehydration) to form phosphoenol pyruvic acid in presence of enzyme enolase.

Q.15.What will be the fate of end product of EMP pathway, if free oxygen is not available in the cell?

Ans: If free oxygen is not available, the oxidation will be incomplete and the end product will be CO_2 and ethyl alcohol. Released energy will be less.

Q.16. Where does glycolysis take place in a cell ?

Ans: Glycolysis takes place in the cytoplasm in a cell.

Q.17.What is the full form of EMP pathway ?

Ans: The full form of EMP pathway is Embden-Meyerhof-Parnas pathway.

Q.18.Describe the connecting link between glycolysis and Krebs cycle.

Ans: i) Each pyruvic acid molecule formed in glycolysis undergoes oxidative decarboxylation (i.e. oxidation by dehydrogenation and decarboxylation by loss of CO_2), to form Acetyl group (2C), which combines with Co-A to form Acetyl Co-A.

ii) Thus, pyruvic acid is converted to Acetyl Co-A. This is called Acetylation of Pyruvate.

iii) It involves several reactions, many enzymes and co-factors.

iv) Hydrogen released combines with NAD to form reduced co-enzyme $NADH_2$, which has the potential to form 3ATP in ETS.

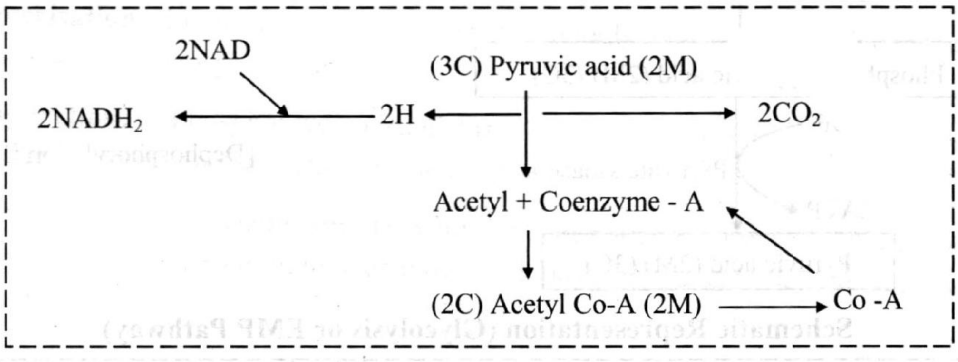
v) In this process, CO_2 is released.

vi) **Acetyl Co-A is a connecting link between glycolysis and Krebs cycle.**

vii) Summary is represented as :

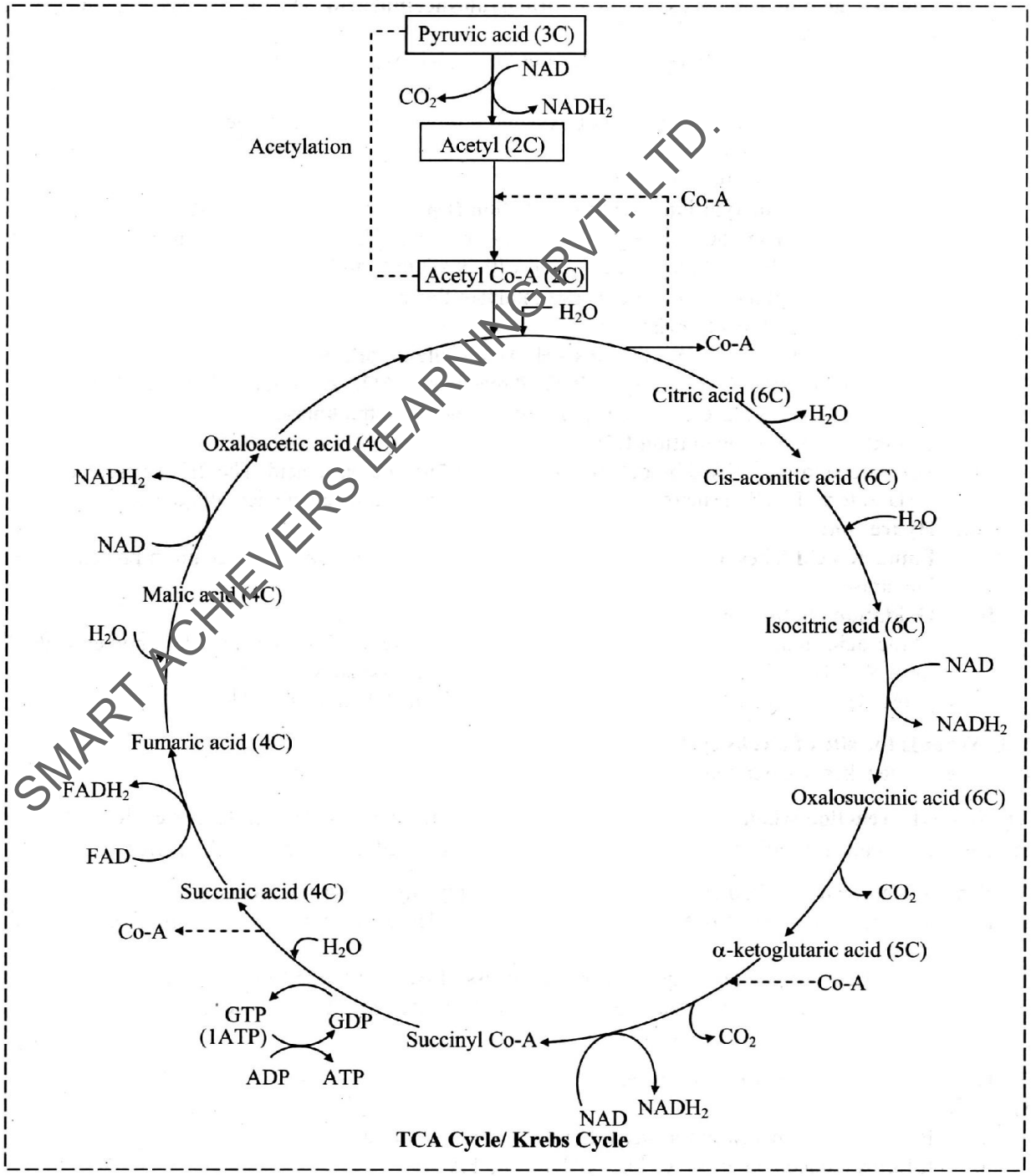
$$\underset{(3C)}{2PA + 2Co\text{-}A + 2\ NAD} \xrightarrow{\text{Enzyme Complex (Pyruvic dehydrogenase)}} \underset{(2C)}{2\ Acetyl\ Co\text{-}A + 2\ CO_2\uparrow + 2\ NADH_2}$$

Schematic representation of formation of Acetyl Co-A :



Q.19. What is TCA cycle? Describe its different steps.

Ans: TCA cycle is a stage of aerobic respiration which takes place in the matrix of the mitochondria. It was discovered by a scientist **Sir Hans Krebs,** hence called as Krebs cycle. It is also called the TCA cycle, i.e **Tricarboxylic acid cycle** because the organic acids formed in the cycle contain 3 COOH groups, i.e. carboxylic groups. It is also called the **Citric acid cycle** because the primary intermediate compound formed is Citric acid.



TCA Cycle/ Krebs Cycle

i) Condensation :

Acetyl Co-A (2C) combines with water and Oxaloacetic acid (4C) to form Citric acid (6C). Thus, Citrate/ Citric acid is the first stable compound of Krebs cycle. The enzyme citrate synthetase catalyses the reaction..

ii) Isomerization :

Citric acid gets converted into its isomer, isocitric acid in presence of enzyme aconitase and Fe^{++}. This happens in two steps:

a) Dehydration : Citric acid loses a molecule of water to' form Cis-aconitic acid.

b) Hydration : Cis-aconitic acid forms **isocitric acid** by the addition of water.

iii) Oxidation (Dehydrogenation I) :

Isocitric acid undergoes oxidation to form **oxalosuccinic acid.** The 2H released combines with NAD to form NADH2.

The enzyme iso-citrate dehydrogenase and Mn^{++} are necessary for this reaction.

iv. Decarboxylation I:

Oxalosuccinic acid (6C) is decarboxylated in presence of enzyme decarboxylase to form α

ketoglutaric acid (5C). CO_2 goes out of the mitochondria.

v) **Oxidative decarboxylation (Dehydrogenation II and Decarboxylation II) :**
α - ketoglutaric add (5C) undergoes oxidative decarboxylation in the presence of Co-A and forms succinyl Co-A (4C). 2H released combine with NAD to form $NADH_2$. Enzyme a-ketoglutarate dehydrogenase catalyses this reaction.

vi) **Hydration and Phosphorylation :**
Succinyl Co-A loses Co-A and gains a H_2O molecule to form **Succinic acid.** During the reaction, GDP forms GTP. GTP reacts with ADP to produce ATP and GDP. The reaction takes place in presence of enzyme succinate thiokinase.

vii) **Oxidation (Dehydrogenation III) :**
Succinic acid is oxidised by dehydrogenation to form Fumaric acid. The 2H released combines with FAD to form FADH2.The reaction is catalysed by enzyme succinate dehydrogenase.

viii) **Hydration :**
Fumaric acid takes a molecule of water and forms **Malic acid.** This occurs in presence of enzyme Fumarase.

ix) **Oxidation (Dehydrogenation IV) :**
Malic acid undergoes oxidation to.form oxaloacetic acid. The 2H released combines with NAD to form $NADH_2$. The reaction is catalysed by enzyme malate dehydrogenase.
[**Note :** GTP is Guanosine Triphosphate. FAD is Flavin Adenine Dinucleotide]

Q.20.What is the site of Krebs cycle in mitochondrion ?
Ans: Krebs cycle takes place in the mitochondrial matrix.

Q.21.Name the reaction when a-ketoglutarate is converted to succinyl Co-A in Krebs cycle. [Oct 2013]
Ans: During Oxidative decarboxylation, a-ketoglutarate is converted to succinyl Co-A in Krebs cycle.

Q.22.Why is acetyl Co-A called connecting link between glycolysis and Krebs cycle ?
Ans:i) Formation of acetyl Co-A from pyruvic acid is called connecting link between glycolysis and Krebs cycle.
ii) End product of glycolysis undergoes the process of Acetylation to form acetyl Co-A.
iii) Pyruvic is first decarboxylated by removal of CO_2 and then it is oxidised by removal of H_2 and gets converted into acetyl Co-A.

Q.23.Give the significance of Krebs cycle.
Ans: Sigmflcance :
i) It is a common pathway for break down of carbohydrates and fats.
ii) It forms reduced co-enzymes like $NADH_2$ and $FADH_2$
iii) Krebs cycle has the potential to produce 24 ATP.
iv) The CO_2 which is liberated is useful in photosynthesis.
v) It forms a number of intermediate products which serves as building blocks for synthesis of other complex organic compounds.

Q.24.What are the main steps in aerobic respiration? Where does it take place ?
Ans: It occurs in most of the plant and animals, inside their mitochondria in the presence of molecular oxygen. It is divided into four major steps:
i) Glycolysis
ii) Oxidative decarboxylation or connecting link or acetylation.
iii) Krebs or TCA cycle
iv) Electron Transport System (ETS)

Q.25. Discuss "The respiratory pathway is an amphibolic pathway".
Ans:i) In respiration, various respiratory substrates are broken down to release energy by the process of cellular respiration. This is called catabolic pathway or catabolism.
ii) However, the breakdown of respiratory substrates provides carbon skeleton for synthesis of various essential plant products .like polysaccharides, proteins, fats, nucleic acids, pigments, cytochromes, etc.
iii) Thus, same respiratory process acts as catabolic as well as anabolic pathway for synthesis of various intermediate metabolic products. Hence, it is called amphibolic pathway.
iv) Some important catabolic processes are as follows :
a) Fats are broken down into glycerol and fatty acid.
b) Fatty acids would enter the pathway only when degraded to acetyl CoA.
c) Glycerol would enter the pathway only after being converted to PGAL.

d. Proteins get degraded into proteases which after deamination get converted into amino acids.

v. Many substrates are withdrawn from the pathway for formation of many substrates. Some anabolic processes are as follows:
   a. Acetyl CoA is withdrawn for formation offatty acids.
   b. a-ketoglutaric acid is converted into glutamate and then it is converted into proteins.
   c. Oxalo acetic acid is converted into aspartate and then into proteins.
   d. Glutamate can also form pigments like chlorophylls, phycocyanins, enzymes like catalase, cytochromes, etc.

Q.26. Explain the mechanism of electron transportation system (ETS) and give its significance. **[Mar 2013 Old Course]**

Ans: Electron Transport System! Terminal oxidation :

The oxidation of reduced coenzymes into their oxidized forms is known as **terminal oxidation.** This process involves electron transfer through various electron carriers which form electron transport system or respiratory chain. During this process, ATP formation takes place which is called as **oxidative phosphorylation.**

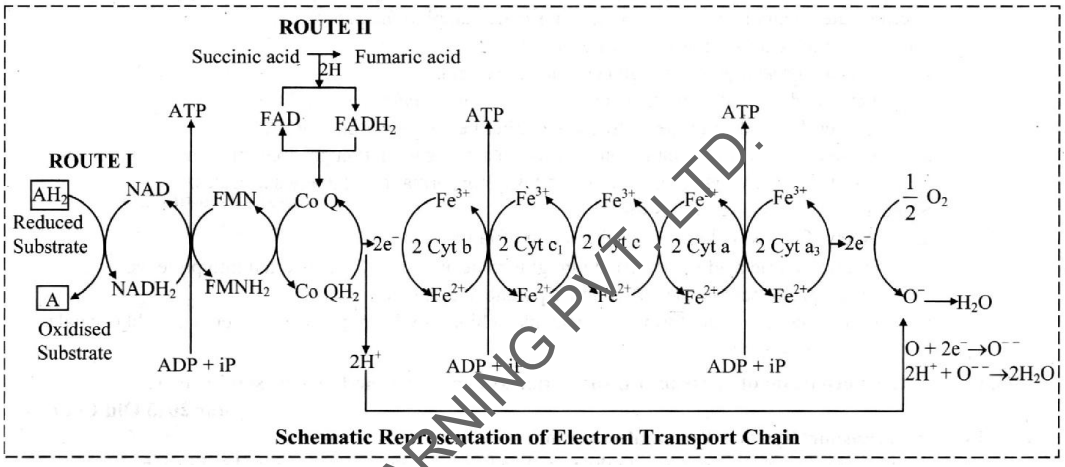
The hydrogen released from the organic compounds during glycolysis and Krebs cycle is accepted by hydrogen acceptors or coenzymes, mostly NAD and sometimes FAD. Thus, NAD and FAD get reduced to form $NADH_2$ and $FADH_2$ respectively. Neither $NADH_2$ nor FADH2 can donate their electrons directly to O_2 to form H_2O.

Mechanism :

i) NAD^+ accepts hydrogen from an organic compound and gets reduced to $NADH_2$.
ii) The $NADH_2$ donates hydrogen to FMN due to which it gets reduced to $FMNH_2$. Energy released during this oxidation reduction step, is utilized in the synthesis of a ATP molecule.
iii) $FMNH_2$ further donates hydrogen to Co-enzyme Q (Ubiquinone) and get oxidised to FMN.
iv) Co-enzyme Q. gets oxidised by releasing hydrogen. The released H_2 splits into protons ($2H^+$) and electrons ($2e^-$).
v) This electron pair ($2e^-$) is transferred through cytochrome b,c_1c and a, a_3 in a sequence. The protons ($2H^+$) remain in the matrix.
vi) Since cytochromes are iron compounds, they are alternatively reduced and oxidized.
vii) On the acceptance of electrons, ferric (Fe^{+++}) is reduced to ferrous (Fe^{++}) and on donating the electrons, ferrous (Fe++)is oxidized back to ferric (Fe^{+++}).
viii) During the electron transfer through the cytochromes, energy is released, which is used to synthesize ATP from ADP and Pi.
ix) The second ATP is formed between cytochrome band C_1. The third ATP IS formed between cytochrome a and a3.
x) Therefore, oxidation of $NADH_2$ produces 3 ATPs.
When the electrons are transferred from cyt. a_3, they combine with oxygen and make it ionized. When $FADH_2$ is reoxidised through ETS, two molecules of ATP are formed.

Significance of ETS :

i) In this process, energy is released in a controlled and stepwise manner to prevent any damage to the cell.
ii) By the end of ETS, H_2 is added to molecular oxygen to form water.
iii) It indicates that each H_2 or electron releases 3 molecules of ATP. In this process, most. of the energy is released, trapped and conserved as ATP.
iv) Thus, per glucose molecule, 38 ATP molecules are formed.



Schematic Representation of Electron Transport Chain

Q.27. In which part of the mitochondria is the electron transport chain located ?

Ans: The electron transport chain is located on the cristae of inner mitochondrial membrane.

Q.28.What is oxidative phosphorylation ?

Ans: Oxidative phosphorylation: It is a metabolic pathway that uses energy released by the oxidation of substrates to produce ATP.

i) Oxidative phosphorylation takes place in the mitochondrial membranes.
ii) Many intermediate products during respiration are oxidised and release 2H.
iii) They are trapped by NAD or FAD.
iv) Such acceptors pass through electron transport system to produce ATP and H_2O.

Q.29. What is the significance of step-wise release of energy in respiration ?

Ans:i) Energy is released in steps and in small amounts, so it prevents sudden increase in body temperature.
ii) Wastage of energy is avoided as more time is available to use and store the energy in ATP molecules.
iii) Energy produced can be regulated according to the needs of the body.
iv) Intermediate products of cell-respiration can be used in different metabolic pathway. e.g. Acetyl Co-A (in the formation of fatty acids, cutin and isoprenoids); α -ketoglutaric acid (in the formation of glutamic acid); Oxaloacetic acid (in the formation of aspartic acid, pyrimidines and alkaloids); Succinyl Co-A (synthesis ofpyrrol compound of chlorophyll).
v) Krebs cycle is a common pathway of oxidative breakdown of carbohydrates, fatty acids arid amino acids.

Q.30. Give the balance sheet of ATP formed in aerobic respiration.

Ans: 1. In Glycolysis

a) ATPs formed (By substrate level phosphorylation)

i)	1,3-diPGA to 3PGA	2ATPs
ii)	PEPA to PA	2ATPs
	Total	**4ATPs**

b) ATPs used

i)	Glucose to Glucose-6 - PO_4	1 ATP
ii)	Fructose-6 PO_4 to Fructose-I,6-diPO_4	1 ATP
	Total	**2 ATPs**

2. Krebs Cycle

ATPs formed: (By substrate level phosphorylation)

Succinyl CoA to Succinate	1 × 2
Total	**2ATPs**

3. Terminal Oxidation (through ETS)

i)	From $NADH_2$: 10$NADH_2$ × 3ATP	30 ATPs
ii)	From $FADH_2$: 2$FADH_2$ × 2 ATP	4ATPs
	Total	**34ATPs**
	Total ATPs formed (4 + 2 + 34)	= 40 ATPs
	Total ATPs used	= 2ATPs
	Net gain	= **38A TPs**

Q.31.What is meant by the statement "aerobic respiration is more efficient"?

Ans: Aerobic respiration leads to complete oxidation of organic substances in presence of O_2 and releases water, CO_2 and large amount of energy. In anaerobic respiration, incomplete oxidation takes place which leads to release ofless amount of energy. Hence, aerobic respiration is more efficient. . Anaerobic Respiration

Q.32.Define anaerobic respiration.Which organisms respire anaerobically ?'

Ans: When free molecular oxygen is not used in respiration to break down the organic substrate, then it is called anaerobic respiration.

OR

Incomplete oxidation of the respiratory substrate in the absence of oxygen to yield CO2 and ethyl alcohol is called anaerobic respiration. Anaerobic respiration takes place in bacteria, yeast and many other microorganisms.

Q.33.Describe the mechanism of anaerobic respiration.

Ans: Process of anaerobic respiration:

i) A Glucose molecule (6C) is broken down into 2 molecules of pyruvic acid (3C) by the process of glycolysis.

ii) Each pyruvic acid (3C) molecule then undergoes decarboxylation, i.e. removal of a CO_2 molecule and forms an acetaldehyde (2C) molecule.

iii) An **acetaldehyde** molecule undergoes reduction to form a molecule of ethyl alcohol. $NADH_2$ provides hydrogen for reduction and gets oxidized to NAD.

Steps involved in anaerobic respiration :

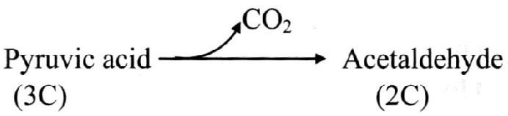
i) Glycolysis :

Glycolysis or EMP pathway is an anaerobic process and occurs in cytoplasm. During glycolysis, each glucose molecule is broken down into two molecules of pyruvate with the formation of two molecules each ofNADH2 and ATP.

Glucose + 2NAD + 2ADP + 2iP $\longrightarrow$ 2 pyruvic acid + 2NADH2 + 2ATP
(6C)

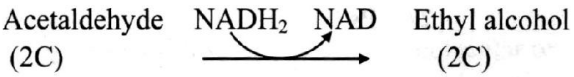
ii. Decarboxylation :

Pyruvate undergoes decarboxylation by removal of a CO2 molecule. It occurs in presence of enzyme pyruvate decarboxylase to give acetaldehyde.



iii) Reduction :

Acetaldehyde reduces to ethyl alcohol by the reduced Coenzyme NADH2 in presence of enzyme dehydrogenase. NADH2 is oxidised to NAD.



Q.34. Name the process which is common to both aerobic and anaerobic respiration.

Ans: Glycolysis is common to both aerobic and anaerobic respiration.

Additional Information

Q.35. Why do some higher organisms including humans sometimes respire anaerobically? How ?

Ans: i) There are some plants and animals, which can use anaerobic respiration also, but only for a short period of time. .

ii. Humans performs aerobic respiration, but in skeletal muscles anaerobic respiration takes place during exercise because more energy is needed and the O_2 is insufficient for cellular respiration.

iii) The pyruvic acid gets reduced to lactic acid by enzyme lactate dehydrogenase.

iv) In plants, sucrose is converted into fructose and glucose by invertase enzyme. Glucose then enters glycolysis.

v) End product of glycolysis is pyruvic acid that may not get sufficient O_2 in higher plants which leads to anaerobic respiration.

Q.36.Why is less energy produced during anaerobic respiration ?

Ans: Anaerobic respiration produces less energy because:

i) Incomplete breakdown of respiratory substrate takes place.

ii) 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.

iii) $NADH_2$ does not produce ATP, as electron transport is absent.

Q.37. Explain fermentation. Give its significance.

Ans: Fermentation (Greek word: fervos = bubbling) :

i) It is the process of anaerobic breakdown (oxidation) of an extracellular organic substrate by the action of enzymes secreted by micro-organisms (which respire anaerobically) resulting in the formation of some important products.

ii) However, substrate breakdown (oxidation) in fermentation is extracellular, while in respiration it is always intracellular.

Mechanism :

It involves glycolysis in which one molecule of glucose (6C) is degraded to two molecules of pyruvic acid (3C), two ATP molecules and two NADH2 molecules. Depending upon the metabolic pathways, the end products of anaerobic respiration are either ethanol and carbon dioxide (as in yeast) or lactic acid (as in animals and some bacteria).

Significance :

i) Production of alcohol by fermentation is used in brewing industry for production of whisky, beer and other types of wines.

ii) CO_2 released during fermentation is used for making bread light in baking industry.

iii) Production of vinegar by acetic acid bacteria.

iv) In milk industry, for production of yoghurt, cheese, etc.

v) Synthesis of organic acids like citric acid and malic acid during fermentation by fungi like *Aspergillus, Penicillium and Rhizopus*.

vi) Tea and tobacco leaves are cured by fermentation with certain bacteria.

vii) Antibiotics and vitamins are also produced by fermentation.

Q.38. What are the two types of fermentation ?

Ans: Fermentation is mainly of two types:

i) Alcoholic fermentation :

This process is involved in brewing industry for producing beverages like beer, rum, whisky, etc. It is done by brewing yeast (Saccharomyces cerevisiae). In alcoholic fermentation, sucrose (molasses) is converted into alcohol. Yeast or a group of enzymes collectively called zymase can bring about the alcoholic fermentation of sucrose. The first step is hydrolysis, in which sucrose is hydrolysed into glucose and fructose as follows:

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

Second step is glycolysis followed by decarboxylation and reduction as in anaerobic respiration.

ii) Lactic acid fermentation :

In case of lactic acid fermentation, milk sugar lactose is converted into lactic acid. The first step is hydrolysis of lactose (disaccharide) into glucose and galactose which is followed by glycolysis and reduction (There is no decarboxylation). Thus, fermentation is similar to anaerobic respiration, but it can be extracellular or intracellular.

Q.39. Name the process of respiration which does not involve intake of oxygen (02) and release of carbon dioxide. (CO_2). [Mar 2014]

Ans: Lactic acid fermentation is the process of anaerobic respiration which, does not involve intake of oxygen (O_2) and release of carbon dioxide (CO_2),

Q.40.Name the products of lactic acid fermentation.

Ans: Lactic acid is the product of lactic acid fermentation.

Q.41. Distinguish between the following :

i) Glycolysis and Krebs cycle.

Ans:

No.	Glycolysis / EMP pathway	Krebs cycle / TCA cycle / Circle acid cycle
a)	Glycolysis is common in both aerobic and anaerobic respiration.	Kerbs cycle occurs only in aerobic respiration.
b)	It takes place in the cytoplasm	It takes place in the mitochondria
c)	CO_2 is not released	CO_2 is released.
d)	Total amount of energy produced = 8 ATP	Total amount of energy produced = 24 ATP
e)	It is linear pathway.	It is cyclic pathway.
f)	Pyruvic acid is the end product	CO_2 and H_2O are the end products.

ii) Aerobic respiration and anaerobic respiration. **[Sept 2009]**

Ans:

No.	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 CO_2 and H_2O.	It produces CO_2 and C_2H_5OH.
f)	Toxic products are not formed.	Toxic products are formed.
g)	It releases more energy, i.e. 38 ATP.	It releases less energy, i.e. 2 ATP.
h)	Overall equation : $C_6H_{12}O_6+6O_2 \rightarrow 6CO_2 + 6H_2O + Energy$	Overall equation : $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + Energy$

iii) Photosynthesis and Aerobic respiration. **[Oct 2013]**

Ans:

No.	Photosynthesis	Aerobic respiration
a.	It takes place In the cells containing chloroplasts.	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 energy trapping process.	It is an energy releasing process.
d.	It is an anabolic process.	It is a catabolic process.
e.	This process requires CO_2 and H_2O.	This process requires sugar and O_2.
f.	Light is necessary for photosynthesis.	Light is not necessary for aerobic respiration.
g.	End products are carbohydrates and oxygen.	End products are CO2, H20 and energy.
h.	Overall equation : $6CO_2+12H_2O \rightarrow C_6H_{12}O_6+ 6H_2O + 6O_2\uparrow$	Overall equation : $C_6H_{12}O_6+6O_2 \rightarrow 6H_2O + 6CO_2+ Energy$

iv. Chloroplast and Mitochondria.

Ans:

No.	Chloroplast	Mitochondria
a.	Structural and functional unit of photosynthesis.	Structural and functional unit of aerobic respiration
b.	Found in plant cells.	Found in all eukaryotic cells, i.e. plants and animals.
c.	It is a energy trapping unit.	It is a energy releasing unit, i.e. power house of cell.
d.	It releases O_2 and absorbs CO_2.	It absorbs O_2 and releases CO_2
e.	In this, organic food is synthesized.	In this, organic food is broken down.

v) Glycolysis and Fermentation.

Ans:

No.	Glycolysis	Fermentation
a.	Works both in aerobic and anaerobic respiration.	Works only in anaerobic respiration
b.	2 molecules of $NADH_2$ are produced per glucose molecule.	$NADH_2$ is not formed.
c.	ATP is produced.	ATP is not produced.
d.	End product is Pyruvic acid	End product is ethyl alcohol / lactic acid/ acetic acid.

vi) Oxidative phosphorylation and Photophosphorylation.

Ans:

No.	Oxidative phosphorylation	Photophosphorylation
a.	It occurs during respiration.	It occurs during photosynthesis.
b.	It takes place in F_1 particle of mitochondria.	It takes place in grana of chloroplast.
c.	It is dependent on O_2.	It is independent of O2.
d.	Released hydrozen is accepted by NAD and FAD.	Released hydrogen is accepted by NADP.

vii) Respiration and Combustion.

Ans:

No.	Respiration	Combustion
a.	Biochemical and stepped process.	Physiochemical and spontaneous process.
b.	Occurs inside the cells.	It is a non-cellular process.
	Energy is released in steps.	Large amount of energy is released at a time.
d.	No light is produced.	Light may be produced.
e.	It is controlled by enzymes.	It is not controlled by enzymes.
f.	A number of intermediates are produced.	No intermediates are produced.

Exchange of gases

Q.42.How does pJant anatomy help in exchange of gases ?

Ans: Plants are well adopted for gaseous exchange as during photosynthesis, large amount of gases are exchanged. In plants, each living cell is located quite close to the surface of the plants. Thus, when cells photosynthesize, availability of O_2 is not a problem. Stems also posses openings called lenticels. The loose packing of parenchyma cells in stems and roots provide interconnected network of air spaces and transport of gases is facilitated.

7.3: Respiratory Quotient

Q.43. What is R.Q.? Write down R.Q. for different nutrients.

Ans:i) Respiratory quotient (R.Q.) is the ratio of volume of CO_2 given out to the volume of oxygen consumed in respiration in the given period of time at standard temperature and pressure.

ii) $$R.Q.\frac{\text{Volume of } CO_2 \text{evolved}}{\text{Volume of } O_2 \text{consumed}}$$

iii) The value of respiratory quotient depends upon the nature of respiratory substrate used during respiration. The value varies as the substrate changes. RQ. value for different nutrients is as follows:

a) Carbohydrates (R.Q. is 1)

When carbohydrates are used as substrate, equal volumes of CO_2 and O_2 are evolved and consumed respectively, thus its R.Q. is 1.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

$$R.O. = \frac{6CO_2}{6O_2} = 1$$

b) 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.

$$2(C_{51}H_{98}O_6) + 145O_2 \rightarrow 102CO_2 + 98H_2O$$

$$R.O. = \frac{CO_2}{O_2} = \frac{102}{145} = 0.7$$

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

When proteins serve as respiratory substrate, they are first degraded to amino acids. Then, amino acids are converted into various intermediates of carbohydrates. However, amino acids have low proportion of O2 as compared to carbohydrates. Thus, they require more O2 during their complete oxidation and value of RQ. becomes less than 1. In case of proteins, the RQ. is approximately 0.5.

d. Anaerobic respiration (R.Q. is infinity)

In anaerobic respiration, CO2 is evolved but O2 is not consumed, therefore RQ. is infinite.

$$C_6H_{12}O_6 \rightarrow 2C_5H_5OH + 2CO_2$$

$$R.O = \frac{CO_2}{O_2} = \frac{2}{\text{No } O_2} = \text{Infinity}$$

7.4 : Significance of Respiration

Q.44. Give the significance of respiration.

Ans: i) It converts chemical energy into metabolically usable form of energy, i.e. ATP.

ii) Along with photosynthesis, it helps to maintain the carbon cycle in nature, i.e. CO2 released during the respiration is used in photosynthesis.

iii) Anaerobic respiration or fermentation is applied in the preparation of a number of commercially important products like alcohol, antibiotics and vitamins.

iv) The intermediate products formed during respiration are also used in the synthesis of organic compounds like fats and proteins.

v) Respiration provides source of energy for cell division, growth and repair, replacement of worn out parts, movements, locomotion, etc.

Additional Theory Questions

Q.1. Define respiration. Write the overall reaction of aerobic and anaerobic respiration. ***Refer Q.1.***

Q.2. What is respiration ? Give the overall equations of aerobic and anaerobic respiration. ***Refer Q.1.***

Q.3. Draw a neat and labelled diagram showing ultrastructure of mitochondrion. [Mar 2013 Old Course] [Oct 2013, Mar 2014] ***Refer Q.8.***

Q.4. Describe briefly the EMP pathway of respiration. ***Refer Q.11.***

Q.5. Explain the common pathway for aerobic and anaerobic respiration. ***Refer Q.11.***

Q.6. Describe the steps involved in formation of pyruvic acid from glucose molecule. ***Refer Q.11.***

Q.7. Give the schematic representation of EMP pathway. ***Refer Q.11.***

Q.8. Give the schematic representation of glycolysis. ***Refer Q.11.***

Q.9. Describe the formation of Acetyl Co-A in respiration. ***Refer Q.18.***

Q.10. Describe Krebs cycle. ***Refer Q.19.***

Q.11. Describe Citric acid cycle. ***Refer Q.19.***

Q.12. Give the schematic representation of an overall view of Krebs cycle. ***Refer Q.19.***

Q.13. Give an account of ATP generation steps during ETS. ***Refer Q.26.***

Q.14. Illustrate the mechanism of electron transport system. ***Refer Q.26.***

Q.15. Explain ETS. ***Refer Q.26.***

Q.16. Explain terminal oxidation. ***Refer Q.26.***

Q.17. Give an account of net gain of ATP during aerobic respiration. ***Refer Q.30.***

Q.18. Explain the process of anaerobic respiration. ***Refer Q.33.***

Q.19.What is fermentation? [Oct 2014] ***Refer Q.37.***

Q.20.Distinguish between Glycolysis and Citric acid cycle. ***Refer Q.41. (i)***

Q.21. Define R.Q. What is its value for fats? ***Refer Q.43 (i) and (b).***

Q.22.What is respiratory quotient (RQ)? Why RQ in anaerobic respiration is infinite? [Mar 2013] ***Refer Q.43***

(i, ii, iii) and (d).

Quick Review

*** Various steps involved in glycolysis :**

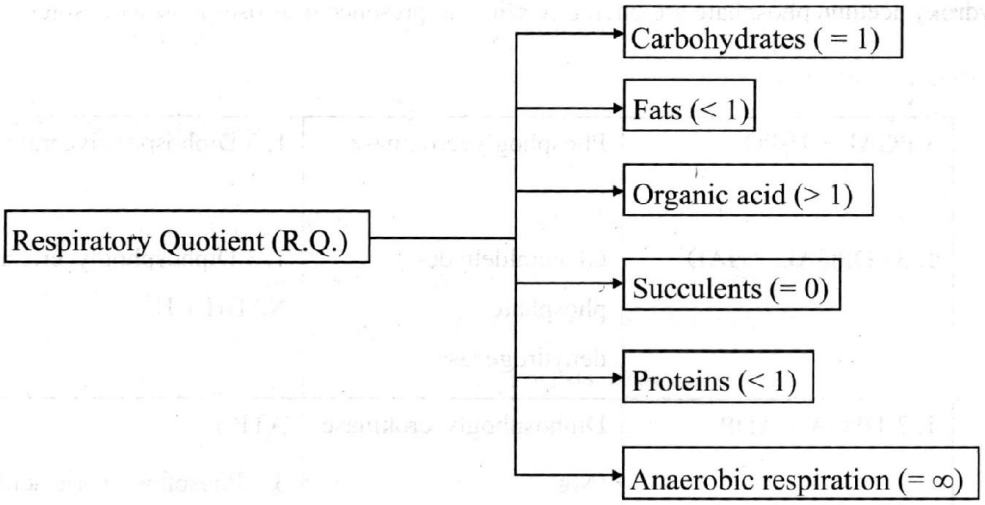
No.	Steps(s)	Substrate	Enzyme	End product(s)
i)	Phosphorylation	Glucose + ADP	Hexokinase	Glucose – 6 - Phosphate + ADP
ii)	Isomerisation	Glucose – 6 -Phosphate	Phosphoglucoisomerase	Fructose – 6 – Phosphate
iii)	Phosphorylation	Fructose – 6- Phosphate + ATP (Phosphate donor	Phosphofructokinase	Fructose 1,6 – Diphosphate + ADP
iv)	Cleavage	Fructose 1,6 – Diphosphate	Fructose diphosphate aldolase	3 – Phosphoglyceraldehyde + Dihydroxy acetone phosphate

(Note: 3 -PGAL and Dihydroxy acetone phosphate are interconvertible in presence of triose-phosphate isomerase).

No.	Steps(s)	Substrate	Enzyme	End product(s)
v)	Phosphorylation	3-PGAL+ H_3PO_4	Phosphoglycerokinase	1,3 Diphosphoglyceraldehyde.
	Dehydrogenation	1,3 -DPGAL+ NAD^+	Glyceraldehyde-	1, 3 Diphosphoglyceric acid +
			phosphate dehydrogenase	$NADH+H^+$
vi)	Dephosphorylation	1, 3-DPGA + ADP	Diphosphoglycerokinase (Mg2+)	ATP + 3 - Phosphoglyceric acid.
vii)	Rearrangement	3-PGA	Phosphoglyceromutase	2- Phosphoglyceric acid
viii)	Dehydration	2-PGA	Enolase	Phosphoenol Pyruvic acid + H_2O
ix)	Dephosphorylation	Phosphoenol Pyruvic acid +ADP	Pyruvate kinase	Pyruvic acid + ATP

*** Various steps involved in Krebs cycle :**

No.	Step(s)	Substrate	Enzyme	End product(s)
i)	Condensation	Acety I-CoA + Oxalo - acetic acid + H_2O	Citric acid synthetase	Citric acid (6C) + Coenzyme-A
iii)	Rearrangement	It is again completed in two steps : a.Citric acid b. Cis-Aconitic acid + H_2O	 Aconitase Aconitase	 Cis- Aconitic acid + H_2O Iso - citric acid (6C) Iso-citric acid (6C)
iii)	Dehydrogenation (-2H)	Isocitric acid + NAD^+	Isocitrate dehydro genase	Oxalo succinic acid(6C) + $NADH+H^+$
iv)	Decarboxy lation ($-CO_2$)	Oxalo succinic acid	Oxalosuccinate decarboxylase	α - ketoglutaric acid(5C) + CO_2
v)	Oxidative Decarboxylation. (-2H) ($-CO_2$).It is also completed in two steps:	a. α -Ketoglutaric acid H_2O + NAD^+ + Coenzyme A b. Succinyl- Co A + GDP+iP	+ α - Ketoglutarate dehydrogenase complex Succinate thiokinase	Succinyl- CoA(4C) + NADH $+H^+$ CO_2 Succinic acid(4C) + Coenzyme-A + GTP
vi)	Dehydrogenation (-2H)	Succinic acid + FAD (H-acceptor)	Succinate dehydro - genase	Fumaric acid (4C) + $FADH_2$
vii)	Hydration($+H_2O$)	Fumaric acid + H_2O	Fumarase	Malic acid (4C)
viii)	Dehydrogenation (-2H)	Malic acid + NAD+ (H-acceptor)	Malate dehydrogenase	Oxaloacetic acid + NADH+ H^+ (4C)



• Scientists and their Contribution

No.	Scientists	Contribution	Year
i)	Embden, Meyerhof and Pamas	Worked out various steps and reactions of glycolytic pathway hence, glycolysis is also called EMP pathway.	-
ii)	Sir Hans Krebs	TCA cycle was discovered by him. He was awarded Nobel Prize in Biochemistry in 1953.	1937

Multiple Choice Question

1. Respiration is regarded as a____ process.
a) catabolic b) anabolic
c) reduction d) synthetic

2. Mitochondria are regarded as semi autonomous organelles, due to the presence of
a) Cristae b) RNA
c) DNA d) ribosomes

3. Which of the following is a 5C compound produced in Krebs cycle ?
a) Citric acid
b) Oxalosuccinic acid
c) a-ketoglutaric acid
d) Succinic acid

4. In glycolysis, dehydration occurs during formation of
a) 3-PGA c) PEPA
b) 2-PGA d) DHAP

5. Which of the following is anaerobic respiration?
a) Glycolysis b) Decarboxylation
c) Reduction d) Phosphorylation

6. Electron carriers of oxidative phosphorylation are present on
a) outer membrane of mitochondria.
b) inner membrane of mitochondria.
c) thylakoid membrane of chloroplast.
d) matrix of mitochondria.

7. During anaerobic respiration, decarboxylation reaction occurs in
a) cytoplasm
b) mitochondrial matrix
c) cristae
d) F_1 particles

8. Which of the following derives maximum energy per molecule of glucose?
a) Glycolysis in liver cells.
b) Alcoholic fermentation.
c) Lactic acid fermentation.
d) Aerobic respiration unicellular organisms.

9. In Krebs cycle, dehydration of substrate occurs
a) once c) thrice
b) twice d) four times

10. Which of the following steps generate ATP without ETS ?
a) Pyruvic acid $\rightarrow$ Acetyl Co-A
b) α - ketoglutarate $\rightarrow$ Succinic acid
c) Iso - citric acid $\rightarrow$ Oxalosuccinic acid
d) Succinyl Co- A $\rightarrow$ Succinic acid

11. The cytochrome which donates de-energised electron to oxygen is
a) cytochrome-a b) cytochrome-b
c) cytochrome-a, d) cytochrome-c

12. In Krebs cycle, the acid which undergoes oxidative decarboxylation is
a) citric acid b) oxalosuccinic acid
c) malic acid d) a-ketoglutaric acid

13. During Krebs cycle, fumaric acid gets converted into malic acid by
a) decarboxylation b) dehydrogenation
c) dehydration d) hydration

14. The net gain of energy from a molecule of glucose in the aerobic respiration is
a) 38 b) 35
c) 70 d) 76

15. Mitochondria are called
a) store house of cell
b) power house of cell
c) energy store of cell
d) repair mechanism of cell

16. The amount of energy lost in respiration in the form of heat is about
a) 40% b) 50%
c) 60% d) 70%

17. Membranes of mitochondria are made up of
a) glycoprotein
b) lipoprotein
c) phospho protein
d) chromoprotein

18. F_1 particles are present on
a) cristae b) inner membrane
c) both a) and b) d) oxysomes

19. Glycolysis is also called
a) HSK pathway
b) Biosynthetic pathway
c) EMP pathway
d) C_3 pathway

20. The first compound formed in glycolysis is
a) Glucose-6-phosphate
b) Glucose-l,6-biphosphate
c) Fructose-6-phosphate
d) Pyruvic acid.

21. Which of the following compounds in last step of glycolysis gives pyruvic acid?
a) 3 - PGAL b) DHAP
c) PEPA d) 2- PGA

22. Oxidation of pyruvic acid occurs in
a) cytoplasm b) matrix
c) F_1 particles d) Golgi bodies

23. Krebs cycle is also called TCA cycle because
a) the first compound formed is citric acid.
b) it was discovered by Sir Hans Krebs.
c) organic acids formed have 3 carboxylic acid groups.
d) acetyl Co-A is formed

24. Which of the following compound is the acceptor of Acetyl Co-A in Krebs cycle ?
a) Oxalo acetic acid
b) Fumaric acid
c) Malic acid
d) Oxalo succinic acid

25. During the conversion of succinic acid to fumaric acid, the hydrogen is accepted by
a) NAD b) FAD
c) α - KGA d) Isocitric acid

26. Which of the following compounds is formed in Krebs cycle from fumaric acid ?
a) Oxalo acetic acid b) Malic acid
c) α - KGA d) Citric acid

27. Enzymes for Krebs cycle are found in
a) cytoplasm b) F_1 particles
c) matrix d) oxysomes

28. Each molecule of $NADH_2$ through ETS yields
a) 1ATP b) 2ATPs
c) 3ATPs d) 4ATPs

29. One glucose molecule, through ETS yields
a) 2ATP molecules b) 3ATP molecules
c) 34ATP molecules d) 38ATP molecules

30. The adenosine triphosphate (ATP) gain during glycolysis, connecting link and Krebs cycle respectively are **[Oct 2013]**
a) 8,6,24 b) 8,24,6
c) 24,8,6 d) 6,8,24

31. In which of the following steps dehydrogenation occurs ?
a) Glucose - Glucose 6-phosphate
b) 3-PGA - 2-PGA
c) PEPA _ pyruvate
d) PGAL - 1,3-diPGA

32. The common pathway for both aerobic and anaerobic respiration is
a) Krebs cycle b) EMP pathway
c) ETS d) Terminal oxidation

33. The only 5-C compound produced in Krebs cycle is
a) Citrate b) α - ketoglutarate
c) Succinate d) Oxalo-acetate

34. During Krebs cycle, decarboxylation occurs____ times.
a) 1 c) 3
b) 2 d) 4

35. The conversion of malic acid to oxalo acetic acid is catalyzed by
a) malate reductase b) malate thiokinase
c) fumarase d) malate dehydrogenase

36. Acetyl CoA produced from pyruvate by
a) oxidative decarboxylation
b) oxidative photophosphorylation
c) oxidative hydrogenation
d) oxidative photorespiration

37. Lactic acid is formed from
a) alcohol b) lactose
c) acetaldehyde d) glucose

38. The compound common to both aerobic and anaerobic respiration is
a) glucose b) pyruvic acid
c) acetyl CoA d) free oxygen

39. On decarboxylation, pyruvate gives
a) acetaldehyde b) lactic acid
c) ethyl alcohol d) methyl alcohol

40. Acetylation takes place in
a) cytoplasm b) matrix
c) oxysome d) ribosome

41. Which compound is found both in respiration and photosynthesis ?
a) PGA b) PGAL
c) Both a) and b) d) Succinic acid

42. The correct sequence of electron carriers during ETS is
a) Co.Q $\rightarrow$ cyto.b.c_1 $\rightarrow$ cyto.c $\rightarrow$ cyto.a.a_3
b) Co.Q $\rightarrow$ cyto.a.a_3 $\rightarrow$ cyto.b.c $\rightarrow$ cyto.c_1
c) Co.Q $\rightarrow$ cyto.b.c $\rightarrow$ cyto.a.a_3 $\rightarrow$ cyto.c
d) Co.Q $\rightarrow$ cyto.c $\rightarrow$ cyto.b.c $\rightarrow$ cyto.a.a_3

43. The overall goal of glycolysis, Krebs cycle and electron transport system is the formation of
a) ATP in large oxidation reaction
b) sugars
c) nucleic acids
d) ATP in small stepwise units

44. Respiratory quotient is one in case of
a) fatty acids b) nucleic acids
c) carbohydrates d) organic acids

45. The respiratory quotient (R.Q.) of carbohydrate is **[Oct 2014]**
a) 0.7 b) 1
c) 0.9 d) 0.1

46. If R.O. is less than 1 in a respiratory metabolism, it would mean that
a) Carbohydrates are used as respiratory substrates.
b) Organic acids are used as respiratory substrates.
c) The oxidation of respiratory substrate consumed more oxygen than the amount of CO_2 released.
d) The oxidation of respiratory substrate consumed less oxygen than the amount of CO_2 released

Answer Keys

1. a)	**2.** c)	**3.** c)	**4.** c)	**5.** c)	**6.** b)	**7.** d)	**8.** d)	**9.** a)	**10.** d)
11. c)	**12.** d)	**13.** d)	**14.** a)	**15.** b)	**16.** c)	**17.** b)	**18.** c)	**19.** c)	**20.** a)
21. c)	**22.** b)	**23.** c)	**24.** a)	**25.** b)	**26.** b)	**27.** c)	**28.** c)	**29.** c)	**30.** a)
31. d)	**32.** b)	**33.** b)	**34.** b)	**35.** d)	**36.** a)	**37.** b)	**38.** b)	**39.** a)	**40.** a)
41. c)	**41.** a)	**43.** d)	**44.** c)	**45.** b)	**46.** c)				