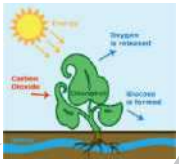


Chapter - 14

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 catalysis synthesis of ATP during oxidative phosphorylation.

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 receive 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.

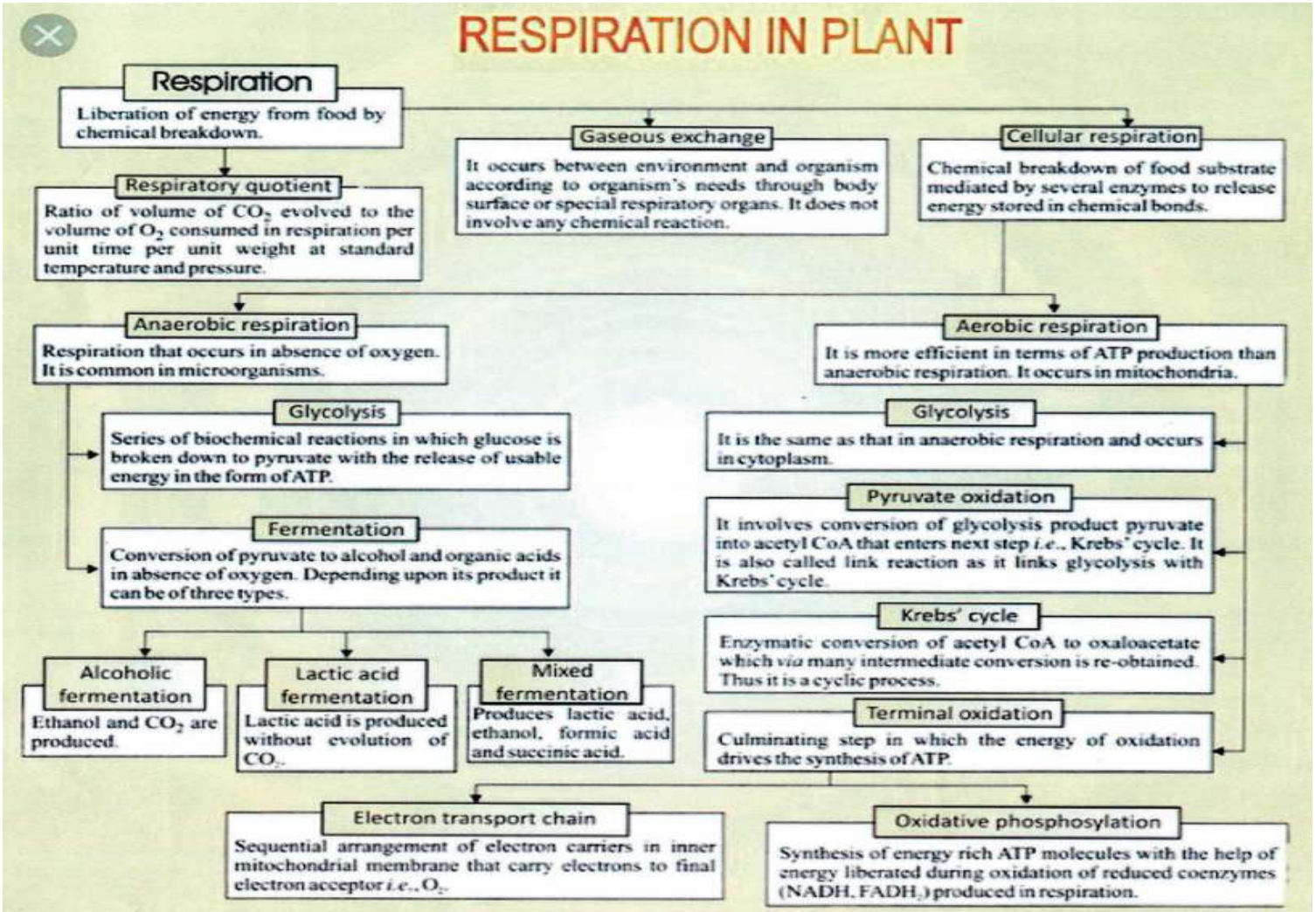
Glycolysis : Enzymatic breakdown of glucose into pyruvic acid that occurs in the cytoplasm.

Oxidative phosphorylation : Process of formation of ATP from ADP and P*i* (Inorganic phosphate) 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.


RESPIRATION IN PLANT
Respiration
Liberation of energy from food by chemical breakdown.
Respiratory quotient
Ratio of volume of CO_2 evolved to the volume of O_2 consumed in respiration per unit time per unit weight at standard temperature and pressure.
Gaseous exchange
It occurs between environment and organism according to organism's needs through body surface or special respiratory organs. It does not involve any chemical reaction.
Cellular respiration
Chemical breakdown of food substrate mediated by several enzymes to release energy stored in chemical bonds.
Anaerobic respiration
Respiration that occurs in absence of oxygen. It is common in microorganisms.
Glycolysis
Series of biochemical reactions in which glucose is broken down to pyruvate with the release of usable energy in the form of ATP.
Fermentation
Conversion of pyruvate to alcohol and organic acids in absence of oxygen. Depending upon its product it can be of three types.
Alcoholic fermentation
Ethanol and CO_2 are produced.
Lactic acid fermentation
Lactic acid is produced without evolution of CO_2.
Mixed fermentation
Produces lactic acid, ethanol, formic acid and succinic acid.
Aerobic respiration
It is more efficient in terms of ATP production than anaerobic respiration. It occurs in mitochondria.
Glycolysis
It is the same as that in anaerobic respiration and occurs in cytoplasm.
Pyruvate oxidation
It involves conversion of glycolysis product pyruvate into acetyl CoA that enters next step i.e., Krebs' cycle. It is also called link reaction as it links glycolysis with Krebs' cycle.
Krebs' cycle
Enzymatic conversion of acetyl CoA to oxaloacetate which via many intermediate conversion is re-obtained. Thus it is a cyclic process.
Terminal oxidation
Culminating step in which the energy of oxidation drives the synthesis of ATP.
Electron transport chain
Sequential arrangement of electron carriers in inner mitochondrial membrane that carry electrons to final electron acceptor i.e., O_2.
Oxidative phosphosylation
Synthesis of energy rich ATP molecules with the help of energy liberated during oxidation of reduced coenzymes ($NADH, FADH_2$) produced in respiration.

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
OAA	—	Oxalo acetic acid
FMN	—	Flavin mono nucleotide
PPP	—	Pentose phosphate pathway

Cellular Respiration—The process of oxidation/breakdown of food materials within the cell to release energy. Respiratory substrate to be oxidized during respiration is usually glucose, but these can also be proteins, fats or organic acids. In plants, respiratory gaseous exchange occurs through stomata and lenticels :

Overall cellular respiration is :

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy (36ATPs)}$$

Aerobic Respiration

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

(A) Glycolysis (EMP pathway) in cytoplasm

(B) Oxidative Decarboxylation—(Gateway Reaction)—in Mitochondrial matrix

(C) Kreb's cycle (TCA—cycle)—Matrix of mitochondria

(D) Oxidative phosphorylation

A. Glycolysis : The term has originated from the Greek word, *glycos* = glucose, *lysis* = splitting, or breakdown means breakdown of glucose molecule to pyruvic acid. It was given by Embden Meyerhof and Parnas. It is a chain of 10 reactions to convert glucose into pyruvate. It is common for aerobic and anaerobic respiration.

Steps for Glycolysis—(EMP Pathway)

1. Phosphorylation of Glucose into Glucose-6-phosphate (ATP used)
2. Isomerisation of Glucose-6-Phosphate into fructose-6-phosphate
3. Second phosphorylation in which Fructose-6-phosphate changes into Fructose-1, 6-biphosphate (ATP used)
4. Splitting of Fructose-1, 6-biphosphate into DHAP (dihydroxy acetone phosphate) and PGAL
5. Isomerisation of DHAP into PGAL
6. Oxidation of PGAL into 1, 3-biphosphosphoglycerate (NADH Produced)
7. Synthesis of ATP and converssion of 1, 3-biphosphoglycerate into 3-phospholycerate
8. Isomerisation of 3-phosphoglycerate into 2-phospholycerate
9. Dehydration of 2-phosphoglycerate into PEP (Removal of water)
10. Substrate level ATP synthesis and formation of Pyruvic Acid.

- It is also called Embden—Meyerhof—Paranas 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 molecules 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 molecules
2.	2 ATP	2 ADP
3.	4 ADP + 2 P*i*	4 ADP + $2H_2O$
4.	2 NAD^+	2 NADH (H^+)

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

The pyruvate, so produced, may under go (i) Lactic acid fermentation, (ii) Alcoholic fermentation (iii) Aerobic Respiration (Krebs Cycle)

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

$$\text{Pyruvic acid} + \text{CoA} + \text{NAD}^+ \xrightarrow[\text{pyruvate dehydrogenase}]{Mg_2} \text{Acetyl CoA} + CO_2 + \text{NADH} + H^+$$

$$\xrightarrow[\text{pyruvate dehydrogenase}]{Mg^{2+}} \text{The Acetyl CoA enters in TCA cycle.}$$

C. Tri Carboxylic Acid Cycle (Kereb's cycle) or Citric acid Cycle : This cycle starts with condensation of acetyl group with oxaloacitic acid and water to yield citric acid which under goes a series of reactions.

- It is aerobic and takes a 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.

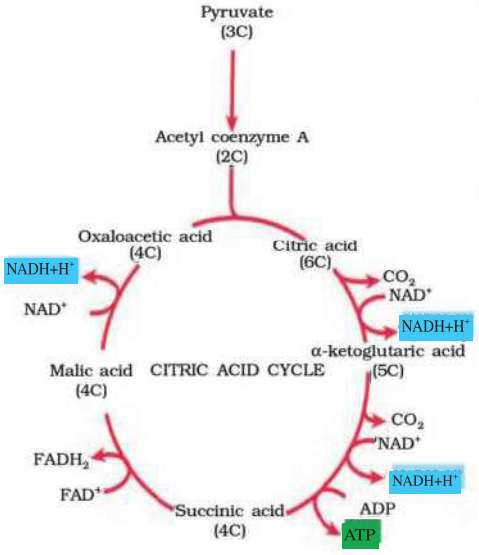


Figure 14.3 The Citric acid cycle

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 photorespiration so that there is not net exchange of gases between the phtosynthetic 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 is zero.

(D) Oxidative Phosphorylation

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 synthestase (complex V). This complex has two major components F_0 and and F_1- F_0 acts a channel for proton and F_1 acts as an ATP synthetase.

Electron Transport System and Oxidative Phosphorylation

Name of Complex	Components of ETS
Complex I	FMN and FeS are prosthetic groups and NADH dehydrogenase
Complex II	$FADH_2$ dehydrogenase (succinate dehydrogenase), FeS, UQ
Complex III	Cytochrome bc, complex–cytochrome b, cytochrome C, FeS, UQ
Complex IV	Cytochrome oxidase–Cytochrome a_1, cytochrome a_3 which posses two copper centres.
Complex V	F_0–F_1 particles, Flow of protein through F_0 channel induces F_1 partcile to function as ATP synthetase.

Respiratory Balance Sheet :

$$\text{Glucose} + 6O_2 + 36ADP + 36Pi \rightarrow 6CO_2 + 6H_2O + 36\ ATP$$

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) = 24 ATP

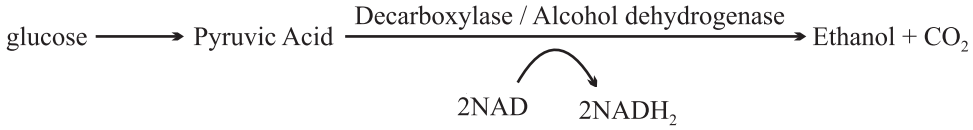
Energy production in prokaryotes during aerobic respiration = 38 ATP

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

In eukaryotes 2 ATP are used in transporting 2 molucules of NADH + H^+ formed in glycolysis from cytoplasm to mitochandria for oxidation through ETS shuttle.

(2) **Anaerobic Respiration**—In anaerobic respiration, Glycolysis is followed by formation of ethanol or lactic acid in the cytoplasm.

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



(i) Conversion of Acetyl CoA into fatty acid and PGA.

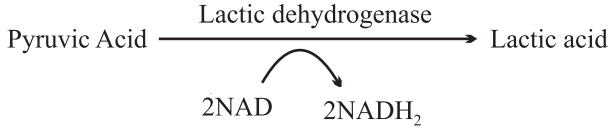
(ii) Synthesis of chlorophyll and cytochromes from Succinyl CoA

(iii) Synthesis of Amino acids from OAA and α-ketoglutaric acid

(iv) Synthesis of Alkaloid from OAA.

Enzymes involved-Pyruvic acid decarboxylase, Alcohol dehydrogenase

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



During rest lactic acid is reconverted to pyruvic acid.

Amphibolic Pathway :

During the process of cellular respiration Carbohydrates, fats and proteins 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. Some anabolic processes are formation of pyruvic acid from amino acids, and formation of Acetyl CoA from Fatty acid. Thus, Respiratory pathway is involved in both catabolism and anabolism, it is better to consider the respiratory pathway as an amphibolic pathway.

RQ (Respiratory quotient)

(a) RQ = 1 (When carbohydrate is used as substrate)

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

(b) RQ is less than 1 (*i.e.,* < 1) (When fats are used as substrate)

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

Tripalmitin

$$\text{R.Q.} \Rightarrow \frac{102\ CO_2}{145\ O_2} = 0.7$$

(c) RQ is 0.9 for proteins.

(d) RQ is more than 1 (*i.e.,* > 1) for organic acids.

(e) RQ is inifinite in case of anerobic respiration, because CO_2 is evolved but O_2 is not consumed.

Questions

(SRT) Select Response Type Question (1 mark each)

1. Which of the following is the terminal acceptor of electrons?
   (a) Cytochrome-b (b) Carbon-di-oxide
   (c) Hydrogen (d) Oxygen
2. Which of the following is correct name of the molecule which acts as the acceptor and substrate entrant in Kreb cycle?
   (a) Oxaloacetate and acetyl Co-A
   (b) Acetyl Co-A and Oxaloacetate
   (c) Citric acid and malic acid
   (d) Pyruvic acid and Acetyl Co-A
3. Respiratory quotient is ..... and RQ of fats and proteins is ..... and ..... respectively.
   (a) Ratio between the volume of oxygen consumed to the volume of carbon-di-oxide evolved, 0.5, 0.9
   (b) Ratio between the volume of carbon-di-oxide consumed to the volume of oxygen evolved, 0.5, 0.9
   (c) Ratio between the volume of oxygen consumed to the volume of carbon-di-oxide evolved, 0.9, 0.5
   (d) Ratio between the volume of carbon-di-oxide consumed to the volume of oxygen evolved 0.9, 0.5

CONSTRUCTED RESPONSE TYPE (CRT)

Very Short Answer Question (1 mark each)

4. How many ATP molecules are produced from a molecule of glucose on it complete oxidation in eukaryotes ?
5. Where does ETC found in eukaryotic cell ?
6. Name the enzyme which convert sugar into glucose and fructose.
7. How many molecules of ATP are produced by the oxidation of one molecule of $FADH_2$?
8. Why do the person with sufficient white fibres get fatigued in a short period ?
9. Write the name of end product of glycolysis.
10. Name the first product formed in Kreb's cycle.
11. Which intermediate undergoes lysis in glycolysis ?
12. Write the other two names of Krebs cycle.
13. Name the first chemical produced in Krebs cycle.
14. What is Electron Transport Chain ? (ETC).
15. F_0–F_1 Protein complexes participate in the synthesis of .....

Short Answer Questions-I (2 mark each)

16. Differentiate between aerobic respiration and anerobic respiration.
17. Mention two steps of glycolysis in which ATP is utilised.
18. Why does anaeriobic respiration produces less energy than aerobic respiration?
19. Distinguish between glycolysis and fermentation.
20. What are respiratory substrates ? Name the most common respiratory substrate.

Short Answer Questions-II (3 marks each)

21. Pyruvic acid is the end product of glycolysis. What are the three metabolic fates of pyruvic acid under aerobic and anaerobic conditions ?

22. Give the schematic representation of an overall view of TCA cycle.
23. Where does electron transport system operative 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. Exapnd ETC., ETS and TCA.

Long Answer Questions (5 marks each)

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

Answers

(SRT) Select Response Type Question (1 mark each)

1. (d) Oxygen
2. (a) Oxaloacetate and acetyl Co-A
3. (a) Ratio between the volume of oxygen consumed to the volume of carbon-di-oxide evolved, 0.5, 0.9

CONSTRUCTED RESPONSE TYPE (CRT)

Very Short Answers (1 mark each)

4. 36 ATP.
5. Mitochondrial membrance.
6. Invertase.
7. 2 ATP molecules.
8. due to formation of Lactic acid.
9. Pyruvic acid.
10. Citric acid.
11. Fructose, 6-bisphosphate.

12. (i) Citric acid cycle (ii) Tricarboxylic acid cycle.
13. Citrate
14. See text (Points to remember)
15. ATP

Short Answers-I (2 mark each)

16. Refer NCERT Text Book.
17. (i) Phosphorylation of Glucose into Glucose-6-phosphate.

    (ii) Phosphorylation of Fructose-6-phosphate into Fructose-1,6-biphosphate.
18. Refer NCERT Text Book.
19. Refer NCERT Text Book.
20. Refer NCERT Text Book.

Short Answers-II (3 marks each)

21. (i) Aerobic conditions–$CO_2 + H_2O$ + Energy

    (ii) Anaerobic conditions–(fermentation)

    (a) In muscles – Lactic acid + Energy

    (b) Yeast-Ehtanol + CO_2 + Energy
22. Refer NCERT Text Book.
23. Refer NCERT Text Book.
24. Refer notes.
25. Refer NCERT Text Book.
26. Seet text (abbreviations).

Long Answers (5 mark each)

27. Refer NCERT Text Book.

Assertion Reasoning (1 mark each)

The following question consists of 2 statements - Assertion (A) and Reason (R). answer the question by selecting the appropriate option below :

(a) Both A and R are true and the reason is a correct explanation of the assertion

(b) Both A and R are true and the reason is not a correct explanation of the assertion

(c) The assertion is true but the reason is false

(d) Both the assertion and reason are false

(e) The assertion is false but the reason is true

28. **Assertion (A) :** More ATPs are produced during aerobic respiration than anaerobic respiration.
Reason (R) : Site for aerobic respiration is mitochondria and that of anaerobic respiration is cytoplasm.

29. **Assertion (A) :** Respiration is called an amphibolic pathway.
Reason (R) : In respiration both anabolism and catabolism occur on many substrates.

30. **Assertion (A) :** During carbon-di-oxide fixation, the acetyl-coA comes from glycolysis.
Reason (R) : Acetyl-coA gives energy for the formation of glucose.

Solution:

Assertion Reasoning

28. (b)

29. (a)

30. (d)

Source-based/Case-based/Passage-based/Integrated assessment question
(4 marks each)

Read the following and answer any four questions from (i) to (v) given below :

31. Electron transport chain is the final stage of aerobic respiration which is located on the mitochondrial membrane. There are two mitochondrial membranes, outer and inner. All proton pumps are located on the inner mitochondrial membrane which is arranged into folds called cristae. These folds increase the surface area available for the transport chain. Electron

transport chain is the series of redox reactions in which there is transfer of electrons from electron donors to electron acceptors. The energy is released and stored within the reduced hydrogen carriers which are then used to synthesise ATP. This is called oxidative phosphorylation. Oxidative phosphorylation occurs in distinct steps. First, the proton pumps create an electrochemical gradient called as proton motive force, second, ATP synthase uses the subsequent diffusions of protons, this step is called chemiosmosis. ATP is synthesised in this step. Third and final, oxygen accepts electrons and protons to form water.

(i) The correct series of electron acceptors present in mitochondrial membrane is

(a) Cyt c, b, a, a3

(b) Cyt b, c, a, a3

(c) Cyt a, a, b, c

(d) Cyt b, c, a3, a

(ii) How may ATPs will be produced from three molecules of NADPH and two molecules of $PADH_2$?

(a) 5

(b) 9

(c) 13

(d) 18

(iii) In amphibolic pathway fatty acids will produce

(a) Glucose-6-phosphate

(b) Glucose-1-6-phosphate

(c) Pyruvate

(d) Acetyl coA

(iv) The F_0-F_1 complex acts as a site for ATP synthesis when protons enter inner membrane space. (T/F)