

## Chapter - 14

# Respiration in Plants

### Points To Remember

**Aerobic respiration** : Complete oxidation of organic food in presence of oxygen thereby producing  $\text{CO}_2$ , 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 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  $\text{CO}_2$  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  $\text{P}_i$  using the energy from proton gradient.

**Respiration** : Biochemical oxidation food to release energy.

**Respiratory Quotient** : The ratio of the volume of  $\text{CO}_2$  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 Krebs's cycle.

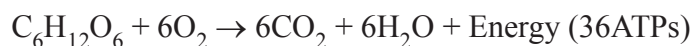
**Electron Transport Chains (ETC)**—A series of co-enzymes and electron carriers where electrons can pass along increasing redox potential losing a bit of energy at every step of transfer.

#### Abbreviations

ATP	—	Adenosine tri phosphate
ADP	—	Adenosne 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 ( <b>Cycle</b> )
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 respiration gas exchange occurs through stomata and lenticels :

Overall cellular respiration is :



### 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) Krebs'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
  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 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.

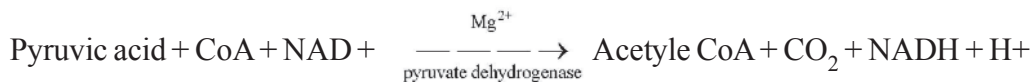
### Input and Output of glycolysis

S. No.	Input	Output
1.	Glucose (6—C) —1 molecule	Pyruvate (3—C) 2 molecules
2.	2 ATP	2 ADP
3.	4 ADP + 2 Pi	4 ADP + 2H <sub>2</sub> O
4.	2 NAD <sup>+</sup>	2 NADH (H <sup>+</sup> )

**Net output ..... 2 Pyruvate + 2ATP + 2NADH (+ H<sup>+</sup>) OR 2 Pyruvate + 8 ATP**

The pyruvate, so produced, may undergo (i) Lactic acid fermentation, Alcoholic fermentation or Aerobic Respiration (Krebs Cycle)

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



The Acetyl CoA enters in TCA cycle.

**C. Tri Carboxylic Acid Cycle (Krebs's cycle) or Citric acid Cycle :** This cycle starts with condensation of acetyl group with oxaloacetic 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<sup>+</sup>, one FADH<sub>2</sub>, one ATP.
- One glucose molecule has been broken down to release CO<sub>2</sub> and eight molecules of NADH + H<sup>+</sup>, two molecules of FADH<sub>2</sub> and 2 molecules of ATP.

**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 no net exchange of gases between the photosynthetic organ and the environment.

At compensation point the photosynthetic tissue manufactures only such amount of food which is 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 elementary 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 F<sub>0</sub> and F<sub>1</sub>, F<sub>0</sub> acts as a channel for proton and F<sub>1</sub> acts as an ATP synthetase.

### Electron Transport System and Oxidative Phosphorylation

Name of Complex	Components of ETS
Complex I	FMN and Fe-S are prosthetic groups and NADH dehydrogenase
Complex II	FADH <sub>2</sub> dehydrogenase (succinate dehydrogenase), Fe-S, UQ
Complex III	Cytochrome bc <sub>1</sub> complex—cytochrome b, cytochrome c, Fe-S, UQ
Complex IV	Cytochrome c oxidase—Cytochrome a <sub>1</sub> , cytochrome a <sub>3</sub> which possess two copper centres.
Complex V	F <sub>0</sub> –F <sub>1</sub> particles. Flow of protons through F <sub>0</sub> channel induces F <sub>1</sub> particle to function as ATP synthetase.

## Respiratory Balance Sheet :



### Total ATP Production

Process	Total ATP produced
1. Glycolysis	$2\text{ATP} + 2\text{NADH}_2$ (6ATP) = 8ATP
2. Oxidative decarboxylation	$2\text{NADH}_2$ (6ATP) = 6ATP
3. Kreb's Cycle	$2\text{GTP}$ (2ATP) + $6\text{NADH}_2$ (18ATP) + $2\text{FADH}_2$ (4ATP) = 24 ATP

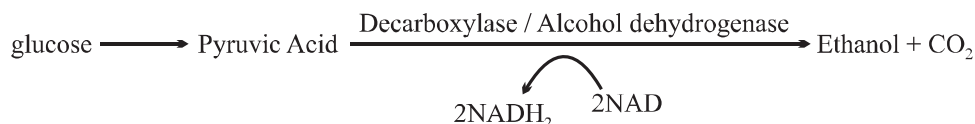
Energy production in prokaryotes during aerobic respiration = 38 ATP

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

In eukaryotes 2 ATP are used in transporting 2 molecules of  $\text{NADH} + \text{H}^+$  formed in glycolysis from cytoplasm to mitochondria for oxidation through ETS shuttle.

(2) **Anaerobic Respiration**—In anaerobic respiration, Glycolysis is followed by formation of Ethyl alcohol, 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 ethanol and carbon-dio-oxide. It results in the production of 2 ATP molecules.



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

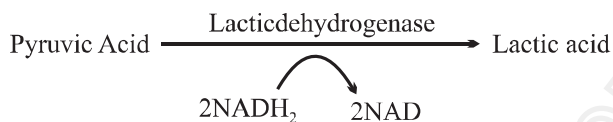
(ii) Synthesis of chlorophyll and cytochromes from Succinyl CoA

(iii) Synthesis of Amino acids from OAA and  $\alpha$ -ketoglutaric acid

(iv) Synthesis of Alkaloid from OAA.

Enzymes involved-Pyruvic acid decarboxylase, Alcohol dehydrogenase

**Anaerobic respiration in muscles** : During vigorous 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 enzyme-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 compounds are withdrawn for synthesis of substrates. Some anabolic processes are—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)



- (b) RQ is less than 1 (*i.e.*, < 1) for fats.



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

- (c) RQ is 0.9 for proteins.  
(d) RQ is more than 1 (*i.e.*, > 1) for organic acids.  
(e) RQ is infinite in case of anaerobic respiration, because  $CO_2$  is evolved but  $O_2$  is not consumed.

### Questions

#### Very Short Answer Question

(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 its 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 Krebs's cycle.
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.  $F_0-F_1$  Protein complexes participate in the synthesis of .....

### Short Answer Questions-I

(2 mark each)

17. Differentiate between aerobic respiration and anerobic respiration.
18. Mention two steps of glycolysis in which ATP is utilised.
19. Why does anaerobic respiration produces less energy than aerobic respiration ?
20. Define Respiration Quotient. What is its value for fat and protein ?
21. Distinguish between glycolysis and fermentation.
22. What are respiratory substrates ? Name the most common respiratory substrate.

### Short Answer Questions-II

(3 marks each)

23. Pyruvic acid is the end product of glycolysis. What are the three metabolic fates of pyruvic acid under aerobic and anaerobic conditions ?
24. Give the schematic representation of an overall view of TCA cycle.
25. Where does electron transport system operate in mitochondria ? Explain the system giving the role of oxygen ?
26. Give a brief account of ATP molecules produced in aerobic respiration in eukaryotes.
27. Discuss the respiratory pathway is an amphibolic pathway.
28. Expand ETC., ETS and TCA.

### Long Answer Questions

(5 marks each)

29. What is glycolysis ? Where does glycolysis take 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. Fructose, 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)
16. ATP

### Short Answers-I

(2 mark each)

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



### Short Answers-II

(3 marks each)

23. (i) Aerobic conditions— $\text{CO}_2 + \text{H}_2\text{O} + \text{Energy}$   
(ii) Anaerobic conditions—(fermentation)  
(a) In muscles – Lactic acid + Energy  
(b) Yeast-Ehtanol +  $\text{CO}_2$  + Energy
24. Refer NCERT Text Book Fig. 14.3 Page 232.
25. Refer NCERT Text Book Page no. 232 and page no. 233.
26. Refer notes.
27. Refer NCERT Text Book Page no. 235.
28. Seet text (abbreviations).

### Long Answers

(5 mark each)

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

