Chapter 14- RESPIRATION IN PLANTS

Living cells require a continuous supply of energy for maintaining various life activities. This energy is obtained by oxidizing the organic compounds (carbohydrates, proteins, and lipids) in the cells. This process of harvesting chemical energy for metabolic activities in the form of ATP by oxidising the food molecules is called **'respiration'**. The most common substrate used in respiration for oxidation is glucose.

14.1-<u>Types of respiration</u>- There are two types of respirations

<u>Aerobic respiration</u> is one in which molecular oxygen is used for the complete oxidation of glucose to yield CO_2, H_2O and 38 ATP molecules.

<u>Anaerobic respiration</u> is one in which glucose is partially oxidised without using oxygen to yield lactic acid or ethyl alcohol and 2 ATP molecules

<u>Differences between aerobic and anaerobic respiration</u>

Aerobic respiration	Anaerobic respiration
• Oxygen is used for the process • Takes place in the cells of all the higher plants and animals • Glucose is completely oxidized • The end products are carbon dioxide and water • Complete oxidation of one molecule of glucose yields 38 ATP molecules • Process takes place in both cytoplasm and mitochondria of the cell.	• Oxygen is not utilized for the process. • Takes place in some bacteria, fungi and certain endoparasites. • Glucose is partially oxidized • The end products are carbon dioxide and either ethyl alcohol or lactic acid • Partial oxidation of one molecule of glucose yields only 2 ATP molecules. • Takes place only in cytoplasm of the cell

<u>Overall reactions</u>-

<u>Aerobic respiration-</u>

Glucose ($C_6H_{12}O_6$) + $6O_2$----------→$6CO_2$ + $6H_2O$+38ATP

<u>Anaerobic respiration-</u>

Glucose (C_6 H_{12} O_6) ----------→$2C_2$ H_5 OH +2ATP +$2CO_2$ (alcohol fermentation)

OR

Glucose (C_6 H_{12} O_6) ----------→ $2CH_3CHOHCOOH$ +2ATP (Lactic acid fermentation)

14.2.- <u>Aerobic respiration</u> It has three steps-

1. Glycolysis/Embden-Meyerhof-parnas pathway (EMP pathway)

2. Kreb's cycle/Citric acid cycle/Tricarboxylic acid cycle

3. Electron transport system (ETS).

14.2.1. <u>Glycolysis</u>

Glycolysis takes place in the cytoplasm of the cell and is common to both aerobic and anaerobic respirations. In this step, glucose (6C) is broken in a stepwise manner into two molecules of 3C Pyruvic acid, without utilizing oxygen. The major events of glycolysis are given in fig.14.1. The overall reaction of glycolysis is,

Glucose+2ATP+4ADP+2NAD→2 Pyruvic acid+2ADP+4ATP+2NADH

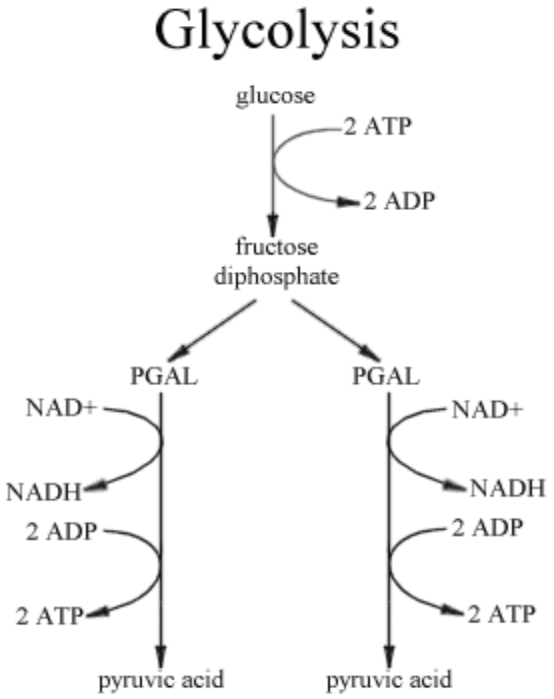

Fig14.1- Glycolysis- Major events

14.2.2 Kerb's Cycle/ citric acid cycle/ tricarboxylic acid cycle

It is the second step in aerobic respiration, named after Sir Hans Krebs, who discovered the intermediate compounds of this cycle. Pyruvic acid, the product of glycolysis, enters the matrix of mitochondria, where it undergoes chemical reaction producing three molecules of carbon dioxide and NADH. At the end the kerbs' cycles starting compound, 4C Oxalo acetic acid (OAA) is regenerated. Before entering the krebs cycle, 3C Pyruvic acid by oxidative decarboxylation gets converted into acetyl Coenzyme A. This is called the preparatory phase.

Pyruvic acid + CoA + NAD.....→Acetyl CoA + CO_2 + NADH (preparatory phase)

Acetyl CoA condenses with a 4C compound called Oxalo acetic acid (OAA), forming a 6C citric acid. As the first compound formed during kreb's cycle is citric acid, this cycle is also called 'citric acid' cycle. Orgnic acids containing three carboxylic acid groups (COOH) are also formed during this cycle. Hence it is also called 'tricarboxylic acid' cycle. The overall reaction of citric acid cycle is,

Pyruvic acid+4NAD+FAD+2H_2O+ADP+Pi → 3CO_2↑+4NADH+4H^++FADH+ATP

Carbon dioxide is released to the atmosphere or green cells may use it for photosynthesis. The hydrogen which is present in glucose will be used for reducing NAD and FAD to NADH and $FADH_2$ respectively. Kreb's cycle is represented in Fig. 14.2.

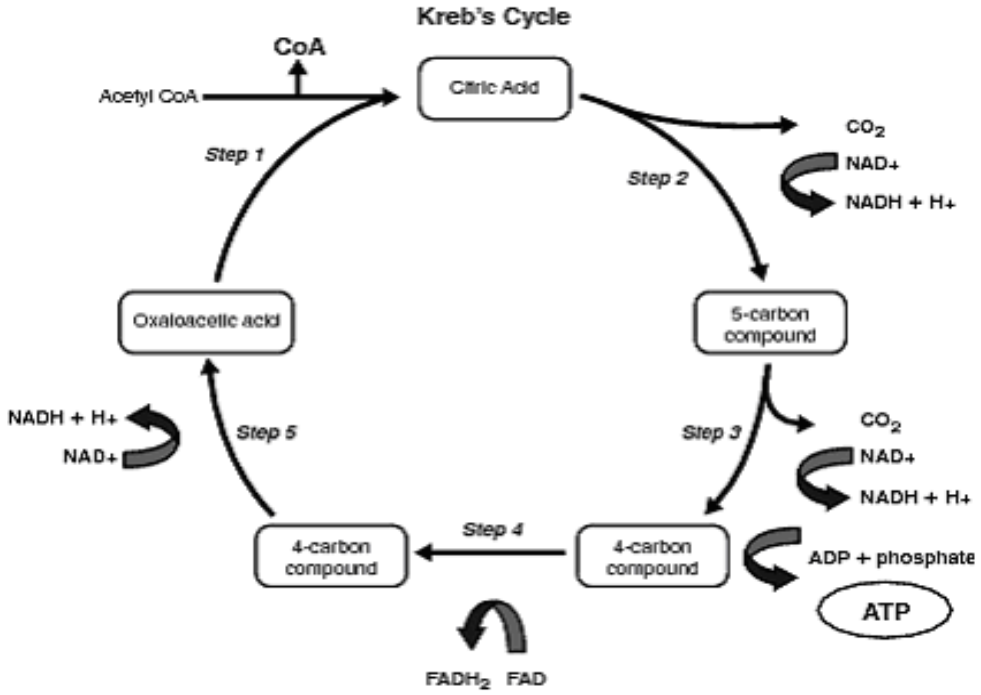

Fig-14.2- Main events in Krebs cycle

(5C compound- α-ketoglutaric acid, 4C compounds- succinic acid and Malic acid)

14.2.3 Electron transport system (ETS)/ oxidative phosphorylation

It is third step of aerobic respiration, taking place in the inner mitochondrial membrane (Cristae). In this step of respiratory process, NADH and $FADH_2$ formed during glycolysis and Kreb's cycle are oxidized to NAD and FAD. During this oxidation process, electrons pass through series of electron carriers (like co-enzyme Q, cytochromes b, c, a and a_3) and ADP is phosphorylated to ATP by the addition of Pi. Since oxidation of NADH and $FADH_2$ is associated with the synthesis of ATP, it is called '**Oxidative Phosphorylation'**(Fig.14.3). Oxidation of one NADH and one $FADH_2$ yields three and two ATP molecules respectively. The hydrogen atom (H^+) and the electron (e^-) of the reduced NADH and $FADH_2$ are accepted by the oxygen to form a molecule of water

and it is called '**terminal oxidation'.** Total gain of ATP molecules at the end of complete oxidation of one molecule of glucose is equal to 38.

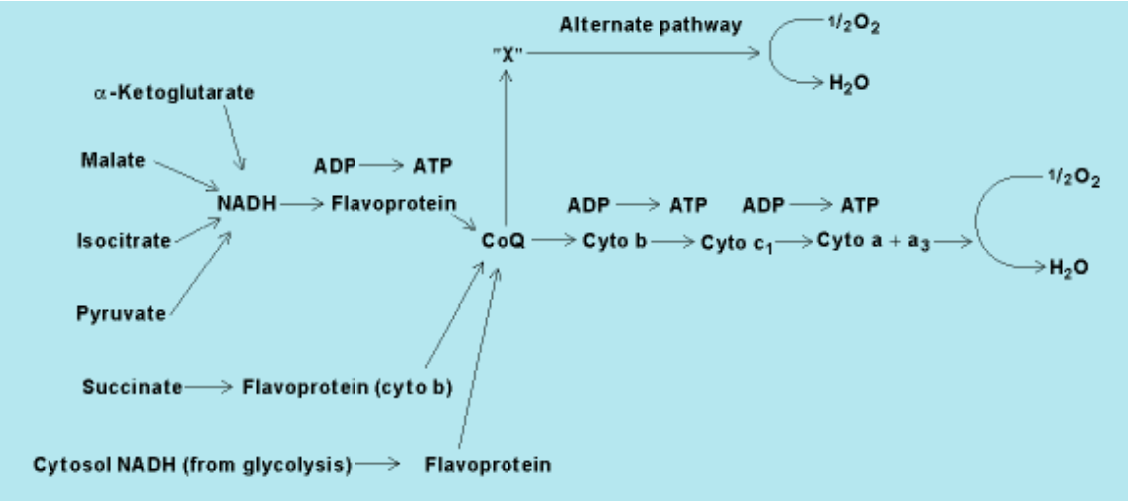

Fig 14.3- Electron transport system (ETS) - showing Oxidative phosphorylation and terminal oxidation

14.3. Anaerobic respiration / fermentation

It is the partial oxidative process of glucose taking place chiefly in microorganisms such as bacterial and yeast cells. It is also called **'fermentation'**. The pyruvic acid formed at the end of glycolysis will further undergo chemical reaction as follows in the cytoplasm itself, without utilizing oxygen, forming ethyl alcohol in yeasts (Fig.13.4) and lactic acid in bacteria. Based on the product the process is called 'ethyl alcohol fermentation' or 'lactic acid fermentation'.

Glucose.....→ Pyruvic acid + NADH+H.....→. Ethyl alcohol+ NAD+CO_2 +2ATP

Glucose.....→ Pyruvic acid+ NADH+H.....→Lactic acid +NAD +2ATP

Fermentation process has wide application in food, pharmaceutical and chemical industries. Both the types of fermentation are inefficient with respect to energy production, as only two ATP are formed per glucose molecule. Roots of the plant in water logged soil and strained human muscle may switch over temporarily to anaerobic respiration when there is no oxygen supply

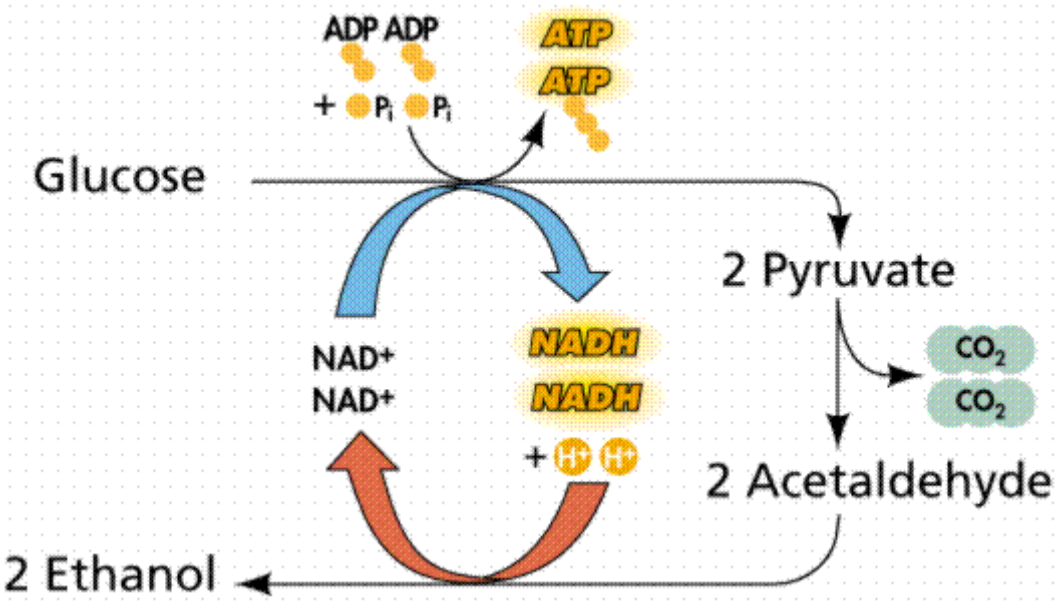

Fig 13.4- Ethyl alcohol fermentation

14.4-Amphibolic pathway During aerobic respiration the organic substrates are broken down into simple substances such as carbon dioxide and water (Catabolism). However it also produces many intermediate organic compounds/acids during kreb's cycle which form the starting compound for the synthesis of other complex substances, needed for the cell. Hence respiration is said to be both catabolic and anabolic and is referred to as **'amphibolic pathway'**.

14.5-.Respiratory quotient (RQ)

Respiratory quotient is defined as the ratio of volume of CO_2 evolved to the volume of Oxygen consumed during respiration. The volume of carbon dioxide released and the volume of oxygen consumed by the cell during respiration depends upon the type of respiratory substrate utilized. Therefore RQ value indicates the substrate type used for respiration.

$$RQ = \frac{\text{Volume of carbon dioxide evolved}}{\text{Volume of oxygen consumed}} \text{ during respiration}$$

SUMMARY

- Respiration is a cellular catabolic process where in glucose is oxidized to produce ATP, carbon dioxide and water.
- It is of two types- aerobic and anaerobic.
- Aerobic respiration is seen in higher plant and animal cells and it involves complete oxidation of glucose producing 38 ATP molecules.
- Aerobic respiration takes place in three stages- Glycolysis, Kreb's cycle and Electron transport system (ETS).
- Glycolysis is common to both aerobic and anaerobic respirations and it takes place in the cytoplasm of the cell. The other two steps are seen only in aerobic respiration and takes place in the mitochondrial matrix and the cristae present in the inner membrane of mitochondria.
- Anaerobic respiration is also called fermentation. It is seen in microorganisms and incomplete oxidation of glucose yields only 2 ATP molecules.
- Aerobic respiration is more efficient than anaerobic in terms of ATP production.
- Value of Respiratory quotient (RQ), indicates the type of respiratory substrate used.

Exercise

1. Define respiration.
2. Name the most common substrate used for respiration.
3. Write the equation for aerobic and anaerobic respiration.
4. Name the two types of respirations. Mention the differences between them.
5. List the three steps of aerobic respiration.
6. What is glycolysis? Where does it take place in the cell?
7. What is the product of glycolysis?
8. What is oxidative phosphorylation?
9. How many ATP are formed for complete oxidation of one molecule of glucose.
10. Name the hydrogen acceptors in respiratory cycle.
11. What is fermentation? Name the different types.
12. Why is anaerobic respiration less efficient than aerobic respiration?
13. Where does ETS operate?
14. Write a note on the application of fermentation process.
15. Define RQ.
16. Why is respiration called an amphibolic pathway?

Exercise- question and answers

17. Define respiration.

The process of harvesting chemical energy for metabolic activities in the form of ATP by oxidising the food molecules is called **'respiration'**

18. Name the most common substrate used for respiration. **Ans**- Glucose.

19. Write the equation for aerobic and anaerobic respirations.

Aerobic respiration-

$$\text{Glucose } (C_6H_{12}O_6) + 6O_2 \text{----------} \rightarrow 6CO_2 + 6H_2O + 38ATP$$

Anaerobic respiration-

$$\text{Glucose } (C_6H_{12}O_6) \text{ ----------} \rightarrow 2C_2H_5OH + 2ATP + 2CO_2 \text{ (alcohol fermentation)}$$

OR

$$\text{Glucose } (C_6H_{12}O_6) \text{ ----------} \rightarrow 2CH_3CHOHCOOH + 2ATP \text{ (Lactic acid fermentation)}$$

20. Name the two types of respirations. Mention the differences between them.

Aerobic respiration	Anaerobic respiration
• Oxygen is used for the process • Takes place in the cells of all the higher plants and animals • Glucose is completely oxidized • The end products are carbon dioxide and water • Complete oxidation of one molecule of glucose yields 38 ATP molecules • Process takes place in both cytoplasm and mitochondria of the cell.	• Oxygen is not utilized for the process. • Takes place in some bacteria, fungi and certain endoparasites. • Glucose is partially oxidized • The end products are carbon dioxide and either ethyl alcohol or lactic acid • Partial oxidation of one molecule of glucose yields only 2 ATP molecules. • Takes place only in cytoplasm of the cell

21. List the three steps of aerobic respiration.

The three steps of aerobic respiration are glycolysis, Kreb' cycle and Electron transport system.

22. What is glycolysis? Where does it take place in the cell?

Glycolysis is the first step in aerobic respiration in which, glucose (6C) is broken in a stepwise manner into two molecules of 3C Pyruvic acid, without utilizing oxygen. It tkes place in the cytoplasm of the cell.

23. What is the product of glycolysis.? **Ans-**Two molecules of 3C pyruvic acid.

24. What is oxidative phosphorylation?

Synthesis of ATP during the oxidation of NADH and $FADH_2$ in electron transport system is called oxidative phosphorylation.

25. How many ATP are formed for complete oxidation of one molecule of glucose.

38 ATP molecules.

26. Name the hydrogen acceptors in respiratory cycle.

NAD (Nicotinamide adenine dinucleotide) and FAD (Flavin adenine dinucleotide)

27. What is fermentation? Name the different types.

The anaerobic respiration that takes place in microorganisms , where glucose is partially oxidized to form ethyl alcohol or lactic acid and 2 ATP molecules is called fermentation. The two types of fermentation are ethyl alcohol fermentation and lactic acid fermentation.

28. Why anaerobic respiration is less efficient than aerobic respiration.

Because in anaerobic respiration only 2 ATP are produced per glucose molecule as against 38 in aerobic respiration.

29. Where does ETS operate? **Ans**- On the F_0- F_1 particles present on the cristae of mitochondria.

30. Write a note on the application of fermentation process.

Fermentation process has wide application in food, pharmaceutical and chemical industries. The process is used in the production of alcohol and in bakeries.

31. Define RQ.

Respiratory quotient is defined as the ratio of volume of CO_2 evolved to the volume of Oxygen consumed during respiration

32. Why is respiration called an amphibolic pathway?

During aerobic respiration the organic substrates are broken down into simple substances such as carbon dioxide and water (Catabolism). However it also produces many intermediate organic compounds/acids during kreb's cycle which form the starting compound for the synthesis of other complex substances, needed for the cell. Hence respiration is said to be both catabolic and anabolic and is referred to as **'amphibolic pathway'**