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CLASS 11&12th

CLASS 11th

Respiration in Plants

01. Introduction

All living cells require continuous supply of energy to perform various vital activities. This energy is released in controlled manner for cellular use *via* the process of respiration. The released energy is stored in cells as ATP. Thus, ATP acts as the **energy currency** of a cell.

02. Cellular Respiration

It is defined as the mechanistic breakdown of C—C bonds of complex organic compounds with the help of oxygen within a cell to release energy. These complex organic compounds are called **respiratory substrates**. In general carbohydrates, lipids and proteins can be used as respiratory substrates.

The generalised chemical reaction representing cellular respiration is as follows

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

03. Aerobic Cellular Respiration

This respiration is completed in two phases

(i) Glycolysis (ii) Breakdown of pyruvic acid

Glycolysis

The word 'Glycolysis" is derived from two Greek words, (*Glycos*-sugar and *lysis*-splitting). Glycolysis is also called as **Embden Meyerhof-Parnas** (EMP) **pathway** on the name of its contributors. It is an oxidative process, in which 1 mole of glucose is converted into 2 moles of pyruvic acid. it is common to both aerobic and anaerobic respiration. Glycolysis occurs in the cytosol of all living organisms.

Net Result of Glycolysis

The overall reaction of glycolysis is as follows

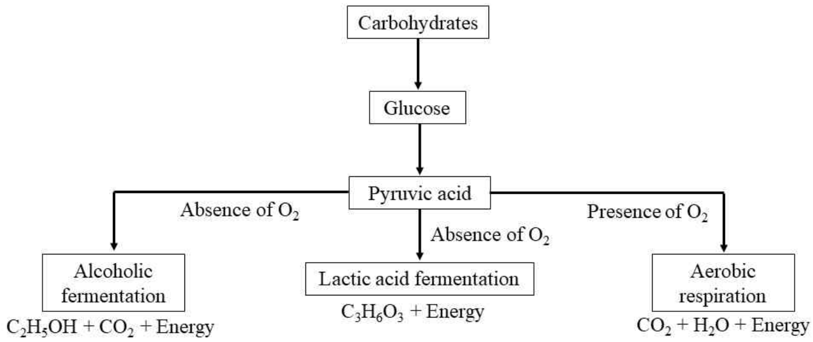
$$\text{Glucose} + 2NAD^+ + 2ADP + 2H_3PO_4 \xrightarrow{\text{Glycolysis}} 2\text{Pyruvate} + 2NADH_2 + 2H^+ + 2ATP + 2H_2O$$

- During glycolysis, two ATP molecules are consumed in the conversion of glucose into fructose-1, 6-diphosphate. On the other hand, it produces 4 ATP and 2 $NADH_2$ molecules.
- The two molecules of NADH + H^+ enter into the mitochondria and get oxidised through ETS to form 3 ATP each, i.e. a total of 6 ATP.
- Thus, the total or net gain of ATP in glycolysis process is (4 ATP produced — 2 ATP consumed) + 6 ATP from $NADH_2$ = **8 ATP** molecules.

> ***NOTE*** ☞ **Substrate level phosphorylation** is a type of chemical reaction. In this reaction a phosphate rich compound (usually ATP) transfers one of its phosphate group to a substrate, e.g. ATP becomes ADP after transferring one of its phosphate group to the substrate. Glycolysis involves two substrate level phosphorylation reactions.

Fate of pyruvic acid

Pyruvic acid is the end product of glycolysis. Its fate depends upon the availability of oxygen in the cell. Three major ways in which cells handle pyruvic acid are lactic acid fermentation, alcoholic fermentation and aerobic respiration. The relationship between aerobic and anaerobic respiration is represented by Pfeffer-Kostychev scheme below



Breakdown of Pyruvic Acid

The breakdown of pyruvic acid formed during glycolysis occurs in following two steps

(i) **Oxidative Decarboxylation of Pyruvic Acid**

The pyruvic acid formed in glycolysis moves into the mitochondria. Here, oxidative decarboxylation of pyruvic acid takes place. During this process, pyruvic acid is first decarboxylated, i.e. releases CO_2. It is then dehydrogenated by removing H-atom. Thus, 3-C pyruvic acid is converted into 2-C acetyl coenzyme-A. This process is catalysed by a large enzyme complex called **pyruvate dehydrogenase.** This enzymes complex consists of Mg^{2+}, thiamine pyrophosphate. NAD, coenzyme-A and lipoic acid as cofactors. This complete process takes place in perimitochondrial, space. The reaction for this process is as follows

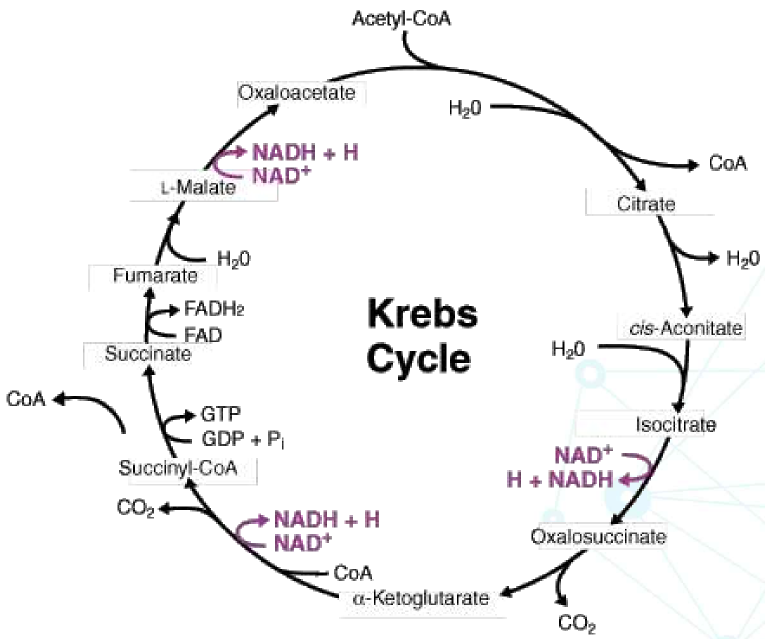
$$\text{Pyruvic acid} + NAD^+ + \text{Co-A} \xrightarrow[Mg^{2+}]{\text{Pyruvate dehydrogenase complex}} \text{Acetyl Co-A} + NADH + H^+ + CO_2\uparrow$$

Acetyl Co-A formed above reacts with oxaloacetate in Krebs' cycle. Thus, this step is considered as the connective link between glycolysis and krebs' cycle.

(ii) **Tricarboxylic Acid or Krebs' Cycle**

This cycle is also called as **citric acid cycle,** because citric acid is the first product of this cycle. It was discovered by Sir Hans Krebs' in 1937. In eukaryotic organisms, all reactions of Krebs' cycle take place in the mitochondrial matrix. Thus, all enzymes of this cycle are also found in matrix except succinic or succinate dehydrogenase. This enzymes is found to be located in the inner membrane of mitochondria. In prokaryotes, Krebs' cycle occurs in cytoplasm. The overall reaction of aerobic degradation of pyruvic acid is as follows. (This indudes oxidative decarboxylation and TCA)

$$\text{Pyruvic acid} + 4NAD^+ + FAD + 2H_2O + ADP + Pi \longrightarrow 3CO_2 + 4NADH + 4H^+ + FADH_2 + ATP$$



(iii) **Electron Transport Chain (ETC)**

Although the degradation of pyruvic acid is completed in above written first two steps. But, the 3rd step, i.e. electron transport system or chain has its own importance in the process. This step is focussed on the generation of ATP from the molecules of hydrogen or proton acceptors, i.e. $NADH_2$ and $FADH_2$ generated in first two steps. It is a series of various enzymes and

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Shuttle system

The inner mitochondrial membrane is impermeable to $NADH_2$. Thus, $NADH_2$ produced as a result of glycolysis cannot enter into mitochondria directly. Thus, to overcome this problem, mitochondrial membrane takes the help of shuttle system. These shuttle system are of following two types

(i) **Malate-Aspartate Shuttle** It is more efficient shuttle system. It transfers electrons from NADH to NAD. In this system, there is no loss of ATP

(ii) **Glycerol-Phosphate shuttle** It is comparatively a less efficient shuttle system. It transfers electrons from NADH to FAD. As a result of this, FAD is reduced to $FADH_2$. It involves loss of one ATP molecule per NADH+ H^+

Thus, there are two routes of electron transfer in mitochondrial membrane, one is through $NADH_2$ and other is through FAD. In simple words, 3ATP molecules are produced through shuttle 1, while only 2 ATP molecules are produced through shuttle 2. These shuttle do not occur in prokaryotes.