**UNIT – 3 CARBON OXIDATION/RESPIRATION**

1. All living organism respire to desire energy. 2. Respiration is a vital process, which helps in the liberation of stored energy from the food. 3. Therefore respiration is an exothermic oxidative reaction, which comprises the process of breakdown of complex carbon containing substance into simple substances with the release of energy. 4. This process in which complex carbon substance is breakdown into simple substance is called Carbon oxidation. 5. It is of two types :- I. Aerobic Carbon oxidation/Reaction II. Anaerobic Carbon oxidation/Reaction

**I. Aerobic Carbon oxidation/Reaction** :- 1. This type of carbon oxidation occurs in the presence of oxygen. 2. Here the complex carbon substance is completely oxidized. 3. The process can be represented by the following equation :-

In pr. Of Oxygen C**6**H**12**O**6**  6H**2**O + 6CO**2**  + Energy

**II. Anaerobic Carbon oxidation/Reaction** :- 1. This type of carbon oxidation occurs in the absence of oxygen. 2. Here the complex carbon substance is not completely oxidized. 3. The process can be represented by the following equation :-

In ab. Of Oxygen C**6**H**12**O**6**  2C**2**H**5**OH + 2CO**2** + Energy

**MECHANISM OF CARBON OXIDATION/RESPIRATION** 1. In the carbon oxidation mechanism, the complex compound substances are broken down into simple substances, which later on enters into respiratory chain. 2. There are two common pathway by which carbon oxidation (respiration) is completed. i. Glycolysis ii. Kreb’s cycle. 3. After these pathways the ETC occurs. 4. In some plants an alternative pathway can be seen called Pentose Phosphate Pathway (PPP). 5. The common stage in the carbon oxidation (respiration) is Glycolysis.

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**GLYCOLYSIS (OXIDATION OF GLUCOSE/FORMATION OF PYRUVIC ACIPYRUVATE)**

1. Glycolysis process was 1st traced by three German scientist Embden, Mayerhof and Parhes. So it is also known as EMP patyway. 2. This process takes place in the cytoplasm. 3. It  is the first step in the breakdown of glucose to extract energy for cellular metabolism. 4. Here 1 molecule of Hexose sugar (C**6**H**12**O**6**) is oxidized to form 3 molecule of Pyruvic acid (C**3**H**4**O**3**), which is a 3 – Carbon compound. 5. The process takes place under the two sub – stages, which are :- [A]. PHOSPHOYRLATION REACTION [B]. BREAKDOWN OF FRUCTOSE – 1,6 – DIPHOSPHATE

**[A]. PHOSPHOYRLATION REACTION** 1. The 1st step of glycolysis consist of the combination of Hexose (Glucose) (C**6**H**12**O**6**) with Phosphate and transform into Glucose – 6 – Phosphate (C**6**H**13**O**9**P). 2. The process is called Phosphorylation of Hexose sugar (Glucose). 3. In this reaction ATP and ADP plays an important role in the transfer of 1 molecule of carbohydrate. 4. The ATP acts as a donor of Phosphate group and is converted into ADP. 5. The Phosphorylation reaction takes place by following steps :-

**I. Step** :- **Formatioin of Glucose – 6 – Phosphate from Hexose sugar** :- The 1st step is the Phosphorylation of Hexose sugar, which transform into Glucose – 6 – Phosphate. The enzyme Hexokinase takes part in this reaction. In this reaction ATP transforms into ADP.

Hexokinase Hexose sugar (Glucose) Glucose – 6 – Phosphate

ATP ADP

**II. Step** :- **Formatioin of Fructose – 6 – Phosphate (C6H13O9P) from Glucose – 6 – Phosphate** :- The next Phosphorylation is of Glucose – 6 – Phosphate, which produces its isomer (Two compounds with the same formula but a different structural arrangement of atoms) Fructose – 6 – Phosphate (C**6**H**13**O**9**P). The enzyme Phosphohexoisomerase takes part here.

Phosphohexoisomerase Glucose – 6 – Phosphate Fructose – 6 –Phosphate

**III. Step** :- **Formatioin of Fructose – 1,6 – diphosphate (C6H14O12P2) from Fructose – 6 – Phosphate :-** Now Fructose – 6 – Phosphate is Phosphorylated by a phosphate group of ATP and forms Fructose – 1,6 – diphosphate (C**6**H**14**O**12**P**2**). The enzyme Phosphohexokinase takes part in this reaction. In this reaction 1 molecule of ATP breaks up into ADP and this inorganic phosphate joins Fructose – 6 – Phosphate which ultimately forms Fructose – 1,6 – diphosphate.

Phosphohexokinase

Fructose – 6 –Phosphate Fructose – 1,6 –diphosphate

ATP ADP

The overall reaction of Phosphorylation reaction is :-

ATP ADP

**Hexose sugar** **Glucose – 6 – Phosphate (6C)** Hexokinase

Isomerase

**Fructose – 6 – Phosphate (6C)**

Phosphohexokinase

**Fructose – 1,6 – diphosphate (6C)**

**[B]. BREAKDOWN OF FRUCTOSE – 1,6 – DIPHOSPHATE** The Fructose – 1,6 – diphosphate formed in the Phosphorylation reaction further breaks and forms 2 molecules of Pyruvic acid (C**3**H**4**O**3**). But the formation of Pyruvic acid is completed after several reactions. The reactions are in following steps :- **I. Step** :- **Formatioin of 3 – Phosphoglyceraldehyde (PGA) (C3H7O6P) and DHAP (C3H7O6P) by Fructose – 1,6 – diphosphate** :- The Fructose – 1,6 – diphosphate forms two 3 – Carbon compound, the 3 – Phosphoglyceraldehyde (PGA) and DHAP in the presence of an enzyme Aldolase.

Aldolase Fructose – 1,6 – diphosphate Phosphoglyceraldehyde + DHAP

DHAP can again form 3 – Phosphoglyceraldehyde in the presence of an enzyme Phosphotriase isomerase. They are isomers of each other, but only the 3 – Phosphoglyceraldehyde can directly continue through the next steps of glycolysis.

**II. Step :- Enzymatic oxidation of 3 – Phosphoglyceraldehyde forming 3 – Phosphoglyceric acid (C3H7O7P) :-**  This reaction completes after following stages :-

**1. Formatioin of 1,3 – Diphosphoglyceric acid (C3H8O10P2) from 3 – Phosphoglyceraldehyde** :- The 3 – Phosphoglyceraldehyde (3C) is transformed into 1,3 – Diphosphoglyceric acid in the presence of an enzyme Phosphoglyceraldehyde dehydrogenase. In this reaction NAD+ is reduced to NADH + H+.

Phosphoglyceraldehyde dehydrogenase 3 – Phosphoglyceraldehyde 1,3 – Diphosphoglyceric acid + NADH + H+

**2. Formatioin of 3 – Phosphoglyceric acid from 1,3 – Diphosphoglyceric acid :-** The 1,3 – Diphosphoglyceric acid looses one of the phosphate, grouping with ADP and forms 3 – Phosphoglyceric acid and ATP in the presence of an enzyme Phosphoglycerokinase.

Phosphoglycerokinase 1,3 – Diphosphoglyceric acid + ADP 3 – Phosphoglyceric acid + ATP

**III. Step :- Convertion of 3 – Phosphoglyceric acid into Pyruvic acid** :- This reaction completes after following stages :- **1. Formation of 2 – Phosphoglyceric acid (2PGA) from 3 – Phosphoglyceric acid** :- An isomeric change occurs in 3 – Phosphoglyceric acid, where the phosphate group is transferred from the 3rd carbon atom of the Phosphoglyceric acid to the 2nd  carbon atom forming 2 – Phosphoglyceric acid. The enzyme Phosphoglyceromutase takes part in this reaction.

Phosphoglyceromutase 3 – Phosphoglyceric acid 2 – Phosphoglyceric acid

**2. Formation of 2 – Phosphoenol pyruvic acid (C3H5O6P) from 2 – Phosphoglyceric acid** :- The withdraw of water takes place in the 2 – Phosphoglyceric acid and the enolic form of Phosphoenol pyruvic acid is fromed. The enzyme Enolase participate in this reaction.

Enolase 2 – Phosphoglyceric acid 2 – Phosphoenol pyruvic acid

**3. Formation of Pyruvic acid from 2 – Phosphoenol pyruvic acid** :- The Phosphate grouping of Phosphoenol pyruvic acid is removed and the Pyruvic acid is formed in the presence of an enzyme Phosphopyruvic kinase. In this reaction ADP act as a phosphate donor and produce ATP.

Phosphopyruvic kinase 2 – Phosphoenol pyruvic acid + ADP Pyruvic acid + ATP

The overall reaction of breakdown of Fructose – 1,6 – diphosphate is :-

**Fructose – 1,6 – diphosphate (6C)**

Aldolase

**3 – Phosphoglyceraldehyde (3C) + DHAP (3C)**

NADH + H**3**PO**4**  Phosphotriase isomerase.

NADH + H+ Phosphoglyceraldehyde dehydrogenase

**1,3 – Diphosphoglyceric acid (3C)**

ADP Phosphoglycerokinase

ATP

**3 – Phosphoglyceric acid (3C)**

Phosphoglyceromutase

**2 – Phosphoglyceric acid (3C)**

H**2**O Enolase

**2 – Phosphoenol pyruvic acid (3C)**

ADP Phosphopyruvic kinase

ATP

**Pyruvic acid (3C)**

The further oxidation of Pyruvic acid depends upon the supply of oxygen. If oxidation of Pyruvic acid occurs in the presence of oxygen, it is called Aerobic oxidation. If oxidation of Pyruvic acid occurs in the absence of oxygen, it is called Anaerobic oxidation.

At the primary stage of Glycolysis, when phosphorylation of Glucose to Fructose takes place then 2 molecules of ATP is utilized. 1 molecule of ATP is utilized in the formation of Glucose to Glucose – 6 – Phosphate and other molecule of ATP is utilized when Fructose – 6 – Phosphate converts into Fructose – 1,6 – Diphosphate.

Just its opposite, when 1 molecule of Pyruvic acid formed from Fructose – 1,6 – Diphosphate then 2 molecule of ATP are liberated. The other 2 molecule of ATP are liberated, when 1 molecule of Pyruvic acid is formed. So when 2 molecule of Pyruvic acid is formed then 4 molecules of ATP are liberated. Therefore, Net gain of ATP in Glycolysis = 4 ATP [liberated] – 2 ATP [utilized] = 2 ATP.

The 2 molecule of NAD are reduced to form 2 molecule of NADH2, which later can be oxidized aerobically to yield 6 molecule of ATP.

So the total gain of ATP molecule in the presence of oxygen or net gain of ATP after Glycosis, but before entering the Kreb’s cycle is :- 2 ATP + 6 ATP = 8 ATP.

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