NAME: JIBRIL HALIMA
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Mechanism in Aerobic Respiration

Aerobic respiration is a process that can completely catabolize a reduced organic energy source to carbon dioxide using glycolytic pathways and TCA (tricarboxylic acid) cycle with oxygen molecule as the terminal electron acceptor for an electron transport chain. Aerobic respiration of Glucose would be considered in this regard.

The catabolism of glucose begins with one or more pathways that yield pyruvate. Next pyruvate enters into the TCA cycle where it is oxidized completely to carbon dioxide with the production of ATP. NADH and FADH2 formed by glycolysis ad the TCA cycle are oxidized by an electron transport chain, using oxygen molecule as the terminal electron acceptor. It is the activity of the electron transport chain that conserves most of the energy used to make ATP during aerobic respiration.

There are several metabolic pathways used by microbes in catabolizing glucose to pyruvate, of which the most common is the Embden- Meyerhof pathway; Entner-Doudoroff pathway and the pentose phosphate pathway.These pathways are collectively called glycolytic pathways.

Embden-Meyerhof pathway is found in all major groups of microbes, plants, animals, and functions in the presence and absence of oxygen.

This pathway may be divided into two parts. In the initial six carbon phase, ATP is used to phosphorylate glucose twice, yielding fructose1,6-bisphosphate.

Breakdown of the first 6 carbon phase of glycolysis

Glucose is broken down to give Glucose 6-phosphate

Glucose 6-phosphate¬---------- fructose 6-phosphate

Fructose 6-phosphate--------- fructose 1,6-bisphosphate.

The 3-carbon phase in glycolysis

The 3-carbon, energy conserving phase begins when fructose 1,6-bisphosphate is cleaved into two halves, each with a phosphate. One of the products, dihydroxyacetone phosphate, is immediately converted to glyceraldehyde 3-phosphate. This yields two molecules of Glyceraldehyde 3-phosphte, which are then catabolized to 2 pyruvate molecules in a five step process. NADH and ATP are produced in the 3- carbon phase of the pathway. NADH is formed when glyceraldehyde 3-phosphate is oxidized with NAD+ as the electron acceptor, and a phosphate is simultaneously incorporated to give a high energy molecule called 1,3-bisphosphoglycerate. This reaction set the stage for ATP production. The phosphate on the first carbon of 1,3-bisphosphoglycerate is donated to ADP to produce ATP. This is an example of substrate-level phosphorylation. Another substrate-level phosphorylation occurs when phosphate on phosphoenolpyruvate is donated to ADP to produce ATP.

Thus the catabolism of glucose to pyruvate can be represented by this equation

Glucose + 2ADP + 2Pi + 2NAD+ ------ 2 Pyruvate + 2ATP + 2NADH +2H+

The NADH is used during aerobic respiration to transport electron to an electron transport.

The Krebs Cycle/ TCA cycle

In the glycolytic pathways, glucose is oxidized to pyruvate. During aerobic respiration, the catabolic process continues by oxidizing pyruvate to three carbon dioxide. The first step of this process employs a multienzyme system called the pyruvate dehydrogenase complex. It oxidizes and cleaves pyruvate to form one carbon dioxide and the 2-carbon molecule acetyl-coenzyme A/acetyl-CoA. Acetyl-CoA then enters the tricarboxylic acid cycle. In the first reaction, acetyl-CoA is added to the 4-carbon intermediate oxaloacetate.

The two remaining carbons of pyruvate are combined with the four carbons of oxaloacetate. This creates the 6-carbon molecule citrate.

Citrate changes the arrangement of atoms to form isocitric acid. Another carbon is removed, creating the 5-carbon precursor metabolite alpha-ketoglutarate in the process, NADH is formed.

The last carbon of glucose is released as carbon dioxide. More NADH is formed for use in the electron transport chain and the 4-carbon precursor metabolite succinyl-CoA is formed.

CoA is cleaved from the high energy molecule succinyl-CoA. The energy released is used to form GTP, which can be used to make ATP.

Succinate is oxidized to fumarate. FAD serves as the electron acceptor. Fumarate reacts with water to form malate.

Malate is oxidized generating more NADH and regenerating oxaloacetate, which is needed to accept the two carbons from acetyl-CoA and continue the cycle.

Electron Transport Chain

During the oxidation of glucose to six carbon dioxide molecules by glycolysis and the TCA cycle, as many as four ATP molecules are generated by substrate- level phosphorylation. Thus, the work done by the cell has yielded relatively little ATP. However, in oxidizing glucose, the cell has also generated numerous molecules of NADH and FADH2. Most of the ATP generated during respiration comes from the energy conserved when these electron carriers are oxidized by an electron transport chain.

The mitochondrial electron transport chain is composed of a series of electron carriers that operate together to transfer electrons from donors, such as NADH and FADH2 to oxygen molecule. The electrons flow from carriers with more negative reduction potentials to those with more positive potentials and eventually combine with oxygen molecule and hydrogen ion to form water. Each carrier is in turn reduced and then reoxidized. Thus the carriers are constantly recycled as electron transport through the chain occurs.

Oxidative Phosphorylation

Oxidative phosphorylation is the process by which ATP is synthesized as the result of electron transport driven by the oxidation of a chemical energy source. The mechanism by which oxidative phosphorylation takes place is best explained by the chemoiosmotic hypothesis, which was formulated by British biochemist Peter Mitchell, states that mitochondrial electron transport chains are organized so that protons move across the inner membrane from the inner mitochondrial matrix to the intermembrane space as electrons are transported down the chain. In bacteria and archaea, the protons usually are moved across the plasma membrane from the cytoplasm to the periplasmic space.

Reference.

Prescott's microbiology textbook. Introduction to Metabolism