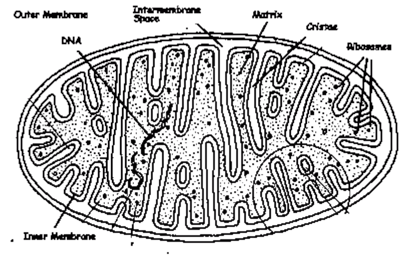
# <u>Cellular Respiration</u>

Aerobic respiration is the overall name of the metabolic pathway that converts glucose to energy for cellular processes. Because Eukaryotes complete this process within the various parts of the mitochondrion, it is important first to have an understanding of the physical locations wherein the stages take place.
Respiration can be divided into four major steps, the first of which is fully anaerobic and is referred to as glycolysis.

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The overall net equation for aerobic respiration is:

$$\textbf{6Glucose} + 6CO_2 \rightarrow 6CO_2 + 6H_2O + \textbf{ATP}$$

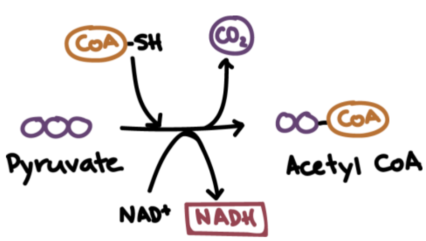
## ***Glycolysis***

Glucose, a six-carbon monosaccharide, is broken down into two three-carbon pyruvate molecules. This, in itself, is a rather complicated and multi-step procedure that requires ten steps for completion. With a net result of four ATP molecules along with the final two privates, the glycolytic pathway is considered energy-producing, and can be utilized by cells when under anaerobic conditions. The overall reaction takes place in the cytosol and can be simplified as:

$$\text{Glucose} + 2NAD^+ + 2P_i + 2ADP \rightarrow 2\ \text{Pyruvate} + 2ATP + 2NADH + 2H^+$$

## ***Pyruvate Oxidation***

The two pyruvate products in the cytosol then enter the mitochondrial matrix for further processing. Each molecule is cleaved, removing a carboxyl group ($-COO^-$) that exits as $CO_2$. The remaining acetyl group is bound to coenzyme A, resulting in two acetyl CoA molecules. Additionally, an $NAD^+$ molecule is reduced, producing 2NADH with the overall reaction:

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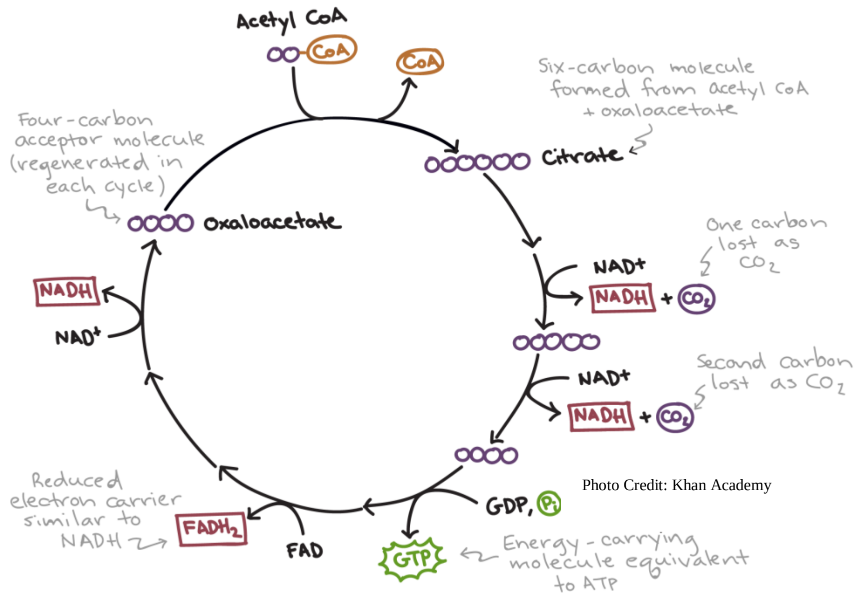
$$2\text{Pyruvate} + 2NAD^+ + 2\text{CoA-SH} \rightarrow 2\text{Acetyl-CoA} + 2NADH + 2CO_2$$

***The Citric Acid Cycle***

The Citric Acid Cycle (also known as the Krebs Cycle) is a series of redox reactions in the mitochondrial matrix involving the oxidation of metabolites by electron carriers $NAD^+$ and FAD, which are reduced to form NADH and $FADH_2$, respectively. As acetyl-CoA enters the cycle, it binds to oxaloacetate to form citrate. Each "turn" of the cycle results in a net of two $CO_2$ molecules and a single ATP, but the importance of the cycle is in the production of three NADH and an $FADH_2$ for each of the acetyl-CoA reactants.



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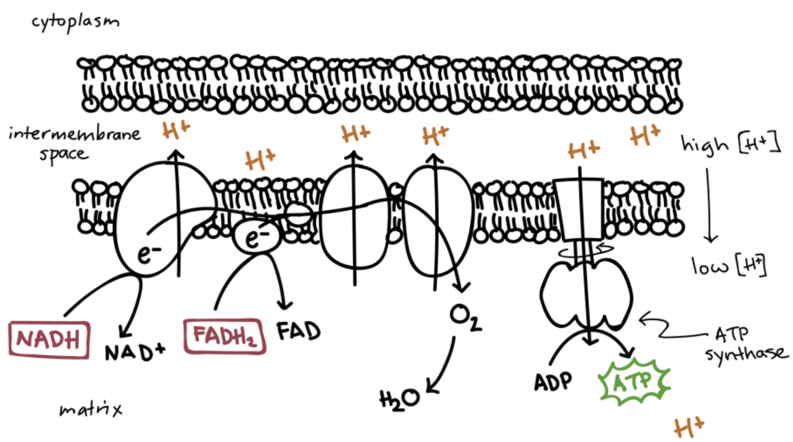
***The Electron Transport Chain***

The final stage of respiration results in the greatest output of energy-containing ATP molecules. It is also referred to as oxidative phosphorylation and is heavily dependent on aerobic conditions for fulfillment. The reduced $FADH_2$ and NADH molecules produced in the Citric Acid Cycle transfer electrons to a series of proteins embedded in the inner membrane of the mitochondria. Thus, FAD and $NAD^+$ are regenerated and can be recycled back to previous stages of the respiration process. The electrons, however, pass along the proteins as the $H^+$ ions accumulate within the inter-membrane space. They are ultimately accepted by $O_2$ to form $H_2O$, and a gradient is established as the $H^+$ concentration increases on one side of the membrane. The pH of this region, therefore, is decreased, and a threshold acidic pH alters the ATP synthase enzyme and opens its component protein channel, generating a proton flux through the membrane. The enzyme harnesses the energy from this process in order to facilitate the phosphorylation of ADP to ATP. In total, this stage of respiration yields approximately 26-28 ATP molecules, resulting in a net total of 30-32 for cellular respiration overall.



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