Respiration and Fermentation Introduction

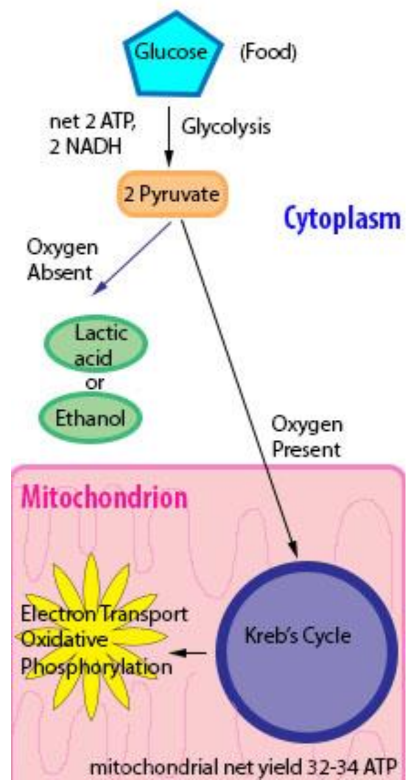
Producers through photosynthesis transform solar energy into an organic form of energy, ATP. ATP or adenosine triphosphate is often called the universal energy currency. It is universal because all living things use ATP to power reactions. For example, producers use ATP formed during the light reactions to fix carbon dioxide and produce carbohydrates. These carbohydrates in turn can serve as energy storage molecules or be used to produce proteins, lipids or nucleic acids. How is energy retrieved from stored carbohydrates? How do consumers (animals, fungi and bacteria) power their metabolism? Cellular respiration and fermentation are two of the metabolic pathways used by organisms to retrieve the energy stored in the bonds of glucose. Keep in mind while this discussion focuses on the metabolism of glucose, all biological macromolecules can be metabolized and enter into cellular respiration at some point.

Summary Reaction for Aerobic Cellular Respiration

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6\,O_2} \longrightarrow \underset{\text{Carbon dioxide}}{6\,CO_2} + \underset{\text{Water}}{6\,H_2O} + \underset{\text{Adenosine triphosphate}}{ATP}$$

Aerobic cellular respiration is a multi-step, energy-yielding process that occurs in the cytoplasm and mitochondrion of all eukaryotic organisms, including plants. During the first step (glycolysis) of the process glucose is 'broken' in half. Enzymes in the cytoplasm perform this initial split of glucose (food/carbohydrate). Enzymes located in the mitochondrion complete the breakdown. The complete breakdown of glucose yields carbon dioxide, water, and ATP, the universal energy currency.

Cellular respiration is fundamentally about getting usable energy from food. Cellular respiration is a multistep process that begins in the cytoplasm and continues in the mitochondrion. The first stage, glycolysis occurs in the cytoplasm. When glycolysis is complete, glucose has been broken into 2 molecules of pyruvate and produced a net 2 ATP and 2 NADH. If oxygen is not present the cell, if capable, will perform fermentation. There are a wide variety of possible end products of fermentation, only two, lactic acid and ethanol are shown to the right. The purpose of fermentation is to regenerate NAD^+. NAD^+ is essential for glycolysis. The cell has a finite amount of cofactors like NAD^+. If all of the NAD^+ in a cell was converted to NADH, glycolysis would stop. Fermentation converts NADH back to NAD^+ which then cycles back to glycolysis so that more ATP can be produced. Lactic acid fermentation converts the 3-carbon molecule pyruvate to the 3-carbon molecule lactate or lactic acid and regenerates NAD^+. This fermentation can be performed by some bacteria (yogurt producers, tooth cavity formers), and in over exerted muscles (feel the burn!). During ethanol fermentation, one of pyruvate's carbons is removed and released as carbon dioxide. Ethanol fermentation is commonly done by yeasts in the production of beers and wines.



When oxygen is present pyruvate binds to a cofactor and is moved into the mitochondrion. In the mitochondrion enzymes continue to breakdown the remnants of the glucose molecule. During this process, carbon dioxide is released and NADH is produced. NADH carries hydrogen atoms and electrons stripped from glucose. It transports these to the electron transport chain located within the inner cristae membrane of the mitochondrion. The actions of the electron transport chain coupled with activity of the membrane ATP synthase results in the production of 32-34 ATP within the mitochondrion from each glucose molecule.