8.16 ANAEROBIC RESPIRATION

Aerobic respiration can only occur if oxygen is plentiful in the cell. If it is not, then ATP is generated by anaerobic respiration. Anaerobic respiration is also called **fermentation**. No matter what the name, it describes the process of converting glucose into energy (ATP) without using oxygen. Like aerobic respiration, the first step of anaerobic respiration is glycolysis. Instead of entering mitochondria, pyruvate is diverted to the anaerobic pathway when the cell senses there is not enough oxygen present.

Fermentation is a fairly common form of respiration. Many micro-organisms—such as some bacteria and yeast—use it as their sole source of energy production. Also, animal cells use fermentation when short and quick bursts of energy are needed—such as sprinting—since it produces ATP more quickly than aerobic respiration.

Humans have learned to use the fermentation process in the area of food preparation. It is fermentation that is responsible for producing the holes in Swiss cheese and the rising action of yeast. This is because CO_2 gas is released, causing the gas to form spaces, or holes, in the cheese and take up room in the bread dough. Also, fermentation has been used for thousands of years to make wine and beer, since one of the products of yeast fermentation is ethanol (alcohol).

Although fermentation does lead to an overall net production of ATP, it does not produce nearly as much ATP per molecule of glucose as aerobic respiration does. This means that fermentation is a much less efficient process than aerobic respiration. Typically, while aerobic respiration produces thirty-six ATP molecules per molecule of glucose, fermentation produces a net of two ATP molecules.

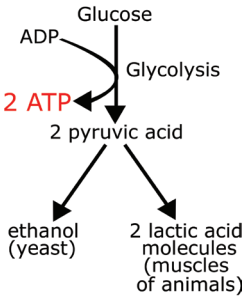

Figure 8.16.1

Anaerobic Respiration
Anaerobic respiration is also called fermentation. Under certain conditions, ATP is made through anaerobic respiration. This process does not use oxygen. In organisms like yeast, fermentation leads to the production of alcohol. In animals, anaerobic respiration commonly occurs in muscles when energy is needed quickly. It results in much less ATP produced per molecule of glucose, but fermentation is able to produce ATP more quickly.

8.17 ADVANCED

We will now discuss the production of ATP in the electron transport chain in more detail. The production of ATP in the Krebs cycle is straight-forward, but exactly how ATP is produced through the electron transport chain is much more complicated, and is not entirely understood, even today.

Hydrogen ions accumulate in high concentrations on one side of the cristae membrane. Hydrogen ions are also called **protons**. This is possible because protein pumps embedded in the cristae, called **proton pumps**, actively pump protons to one side of the membrane (out of the matrix and into the outer compartment). This is done against the hydrogen ion gradient. Since the cell is doing work to actively pump the hydrogen ions against their gradient, this process does require energy—but it uses energy derived from the activated electrons carried by NADH and $FADH_2$, not from ATP. As hydrogen accumulates on one side of the membrane, it flows down its concentration gradient back into the matrix through a gated channel. This gated channel is an enzyme called **ATP synthase**. ATP synthase makes ATP from ADP and Pi. As the protons pass through the ATP synthase, the energy from their movement provides enough heat so that ATP synthase can make ATP from ADP. This is an endergonic reaction which gets the activation energy from the protons flowing through the ATP synthase. This ability of the hydrogen ion gradient to perform work (i.e., to make ATP molecules) is called the **proton motive force**. The process of the hydrogen flowing across the cristae and driving ATP synthase is called **chemiosmosis**.