Have you ever wondered how you are able to keep working after running so much? Or why your muscles are so sore after moving around a lot? What about how bread rises after starting from such a small ball of dough? How is alcohol made? All of these processes are surprisingly related to one another through a method called anaerobic cellular respiration. Normally most cells require the presence of oxygen and pyruvate, a product of glycolysis to be further explained, to produce ATP, the energy source that is used in nearly every process in the human body. Anaerobic cellular respiration is the process that provides energy when cells are in the absence of oxygen. This chapter will consist of describing the process in further detail about two types of anaerobic respiration; lactic acid fermentation and alcoholic fermentation.

Before we even start trying to look at fermentation, we must look at what happens first to get us to where we need to be to start, glycolysis. The first step of fermentation starts with pyruvate, a product of the glycolysis cycle. Glycolysis is the process of chemically breaking down glucose into two molecules of pyruvate. Pyruvate will then go on in the presence of oxygen to the citric acid cycle to produce ATP and restock necessary electron carriers for glycolysis required for our body to keep going. Through breaking down glucose into pyruvate there are 10 steps involving various enzymes and electron carriers to complete the process. Once glycolysis has completed its course and pyruvate has been produced, there are two paths to continue down; aerobic respiration or anaerobic respiration.

Aerobic respiration is the process that requires oxygen for pyruvate to continue its journey on to becoming energy; in this chapter we have no oxygen. With no oxygen the pyruvate molecules produced from glycolysis will go through anaerobic respiration (fermentation). If aerobic respiration is not happening then no electron carriers are being restocked for glycolysis. The process of anaerobic respiration is for the purpose of restocking those electron carriers in the absence of oxygen to allow glycolysis to continue.

There are two different types of fermentation that both stem from the process of glycolysis. The two different fermentation paths that pyruvate can take are lactic acid fermentation and ethanol fermentation. Lactic acid fermentation is a process in animals that uses pyruvate to convert it into lactic acid and NAD+. NAD+ is an electron carrier that is needed for glycolysis to continue. Alcoholic fermentation is a process mostly done with the fermentation of yeast to make alcohol. This type of fermentation starts with the same precursor pyruvate and regenerates NAD+ but its final product is different. Alcoholic fermentation, as the name suggests, produces a type of alcohol called ethanol.

When you work out, your body needs energy to help your muscles perform the actions. Any sort of exercise uses ATP to move whether it be running, lifting weights or whatever. Running long distance v.s. running short distance makes a difference in the energy that your body uses. When you run quick sprints and use energy really quick, your body needs a way to keep going, which is where fermentation comes in. As you are running your body is utilizing every bit of energy and oxygen it can to keep going, and when it is all used up your body performs fermentation. Lactic acid fermentation is the process of creating more ATP in the absence of oxygen, so when you have none left and you still need to keep going, you can.

Would you believe that muscle color has something to do with your exercise habits? The color in our muscles reflects on what it is specially used for, aerobic or anaerobic respiration. White muscle is more used for quick sprinting or weight lifting. This muscle allows for anaerobic respiration when you need energy really fast and there is not enough oxygen to help. Red muscles are specialized for endurance and are more for long distance running or times when your activity is spread out and not all in one burst. Red muscle has more oxidative fibers in it, allowing for aerobic respiration. Muscle color can be demonstrated well by looking at chickens. Chickens as we all know have dark meat and white meat. A special type of chicken called a grouse, can at times, especially when they are scared, become flushed with a great boost of speed and take off very quickly over short distances. This sprinting depends on anaerobic respiration in the white muscles of the breast and wings.

All this chicken talk is making me hungry, but enough about that, lets get back to the process of fermentation. In the process of lactic acid fermentation we need two things to start, pyruvate and lactate dehydrogenase. Pyruvate, as we talked about earlier, is an organic molecule end product of glycolysis that is the starting point of fermentation. For fermentation to take place we need the enzyme lactate dehydrogenase. I know what you are thinking, what the heck does that mean? An enzyme is something in our bodies that makes a reaction take place. Most enzymes are specific to different reactions; lactate dehydrogenase is specific for lactic acid fermentation. Starting with lactate dehydrogenase a reaction proceeds to happen by turning the pyruvate molecule into lactate. During this reaction NAD+, an electron carrier as we mentioned earlier, is regenerated as a by-product. The NAD+ created then goes on to make more ATP for our body to continue exerting energy and allowing us to keep moving when there is no oxygen for aerobic respiration to happen.

Throughout the process of this type of fermentation, all of this lactic acid that your body produces can build up in your muscle cells and blood, and this is a part of why you feel sore when you over exert yourself. High levels of lactate increases acidity in your muscles, which in turn causes the same processes to make this lactate slow and not perform as well. I know this sounds weird that the product of a process makes the process itself perform poorly, but it has a reason. If you workout too hard and too fast you can cause damage to your body, and the build up of lactic acid that causes the poor performance of processes is a sort of safety mechanism. If your body can’t produce what it needs to keep going then you won’t want to keep using energy, hence preventing extreme damage to your body.

The other type of anaerobic fermentation as mentioned in the beginning is alcoholic fermentation. This type of fermentation is almost identical to lactic acid fermentation in the sense that it too has to start with the glycolysis process to get its initial starting molecule of pyruvate. The difference with alcoholic fermentation is that while lactate comes from a one enzyme reaction, alcohol starts with pyruvate and has to go through 2 reactions with two different enzymes to produce the end product of ethanol. During this process NAD+ is regenerated the same as lactic acid fermentation; as well carbon dioxide is a product.

When most people think about this process of alcoholic fermentation they think about beer and wine and other types of, you guessed it, alcoholic drinks, but that is not the only thing this type of fermentation is good for. Without even knowing it, you might have filled your car up with corn. Many people do not realize the abundance of biodiesel in todays’ society. This is all another aspect of the fermentation process. The term alcohol doesn’t have to mean an alcoholic beverage, although yes alcohol is a massive use of yeast fermentation. Fermentation with yeast produces a byproduct called ethanol, and when you put corn into the equation and mix some things together here and there you get a fuel that certain cars can put into their tank to power their engines.

Anaerobic fermentation in yeast needs the two enzymes pyruvate decarboxylase and alcohol dehydrogenase. These two enzymes are a two-step process from pyruvate to ethanol. The first step starts with pyruvate and uses the enzyme pyruvate decarboxylase to get to acetaldehyde, an intermediate in the alcoholic fermentation process. During this first step, carbon dioxide is produced as a byproduct and is released. From acetaldehyde, with the addition of the enzyme alcohol dehydrogenase, the product ethanol is produced while restoring stocks of NAD+.