2.3.3

Energy Source for Muscle Contraction

The ultimate source of energy for muscle contraction is ATP. Recall that each cycle of a myosin head requires an ATP molecule. Multiply that by all of the myosin heads in a muscle and the number of cycles each head completes each twitch and you can start to see how much ATP is needed for muscle function. That estimate doesn't even consider the greatest consumer of ATP, the SERCA pump or the other major consumer, the Na/K ATPase pump. It is estimated that we burn approximately our entire body weight in ATP each day (150 moles or 75kg; each equivalent ATP is recycled 1550 times a day) so it becomes apparent that we need to constantly replenish this important energy source. For muscle contraction, there are four ways that our muscles get the ATP required for contraction.

1. **Cytosolic ATP**: This ATP represents the "floating" pool of ATP, or that which is present and available in the cytoplasm. This ATP requires no oxygen (anaerobic) to make it (because it is already there) and is immediately available but it is short lived. It provides enough energy for a few seconds (1-5 seconds) of maximal activity in the muscle-not the best source for long-term contraction. Nevertheless, for the muscles of the eyes that are constantly contracting quickly, but for short periods of time, this is a great source.

2. **Creatine Phosphate**: Once the cytosolic stores of ATP are depleted, the cell calls upon another rapid energy source, Creatine Phosphate. Creatine phosphate is a high energy compound that can rapidly transfer its phosphate to a molecule of ADP to quickly replenish ATP without the use of oxygen. This transfer requires the enzyme creatine kinase, an enzyme that is located on the M-line of the sarcomere. Creatine phosphate can replenish the ATP pool several times, enough to extend muscle contraction up to about 10 seconds. Creatine Phosphate is the most widely used supplement by weight lifters. Although some benefits have been demonstrated, most are very small and limited to highly selective activities.

3. **Glycolysis**: Glycolysis, as the name implies, is the breakdown of glucose. The primary source of glucose for this process is from glycogen that is stored in the muscle. Glycolysis can function in the absence of oxygen and as such, is the major source of ATP production during anaerobic activity. This series of chemical reactions will be a major focus in the next unit. Although glycolysis is very quick and can supply energy for intense muscular activity, it can only be sustained for about a minute before the muscles begin to fatigue.

4. **Aerobic or Oxidative Respiration**: The mechanisms listed above can supply ATP for maybe a little over a minute before fatigue sets in. Obviously, we engage in muscle activity that lasts much longer than a minute (things like walking or jogging or riding a bicycle). These activities require a constant supply of ATP. When continuous supplies of ATP are required, the cells employ metabolic mechanisms housed in the mitochondria that utilize oxygen. We normally refer to these processes as aerobic metabolism or oxidative metabolism. Using these aerobic processes, the mitochondria can supply sufficient ATP to power the muscle cells for hours. The down side of aerobic metabolism is that it is slower than anaerobic mechanisms and is not fast enough for intense activity. However, for moderate levels of activity, it works great. Although glucose can also be utilized in aerobic metabolism, the nutrient of choice is fatty acids. As described below, slow-twitch and fast-twitch oxidative fibers are capable of utilizing aerobic metabolism.