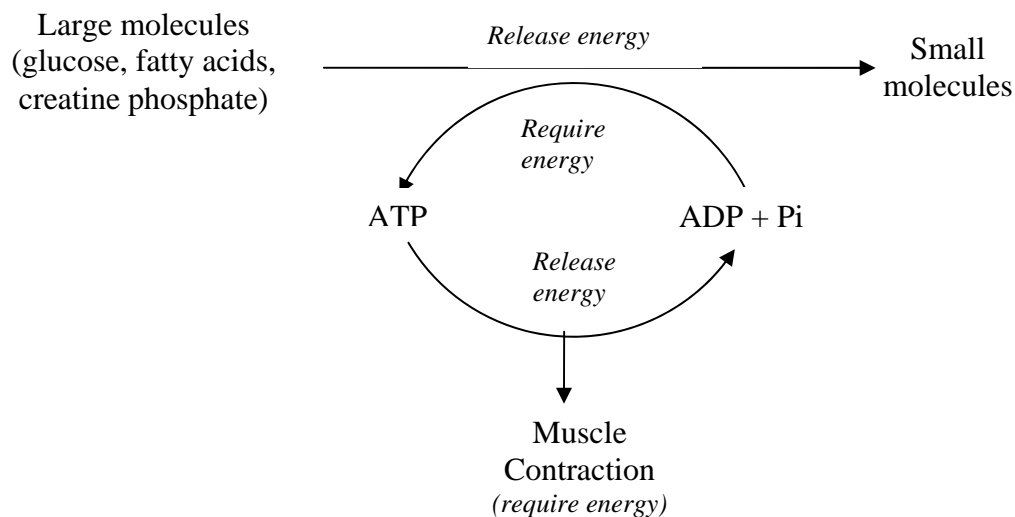


## Aerobic vs Anaerobic Power

Constance Mier

*How does muscle derive its energy?*

Muscle contraction or force production requires energy and that energy comes directly from a molecule called ATP (adenosine triphosphate). When the ATP molecule is split, stored chemical energy is released and that energy is transferred to the mechanical processes involved in muscle contraction. To understand aerobic and anaerobic energy, it must first be understood that ATP is stored in very small quantities within muscle cells, yet it is the only source of energy for muscle contraction. If an ATP molecule is split and releases its energy, it becomes unavailable as an energy source. Thus, split molecules must be rejoined in order to become available again for muscle contraction. This is where aerobic and anaerobic energy processes come in. In order for ATP's energy to be replaced, another energy-providing process must be "coupled" to the resynthesis of ATP. The following diagram illustrates this coupling of chemical energy processes. Energy released from the splitting of large energy-storing molecules is transferred to the synthesis of ATP. During exercise, these processes occur at the same time that ATP molecules are splitting and releasing energy for muscle contraction. Maintaining this balance is important to an athlete because it is what allows him or her to maintain optimal muscle contraction and force or power production.

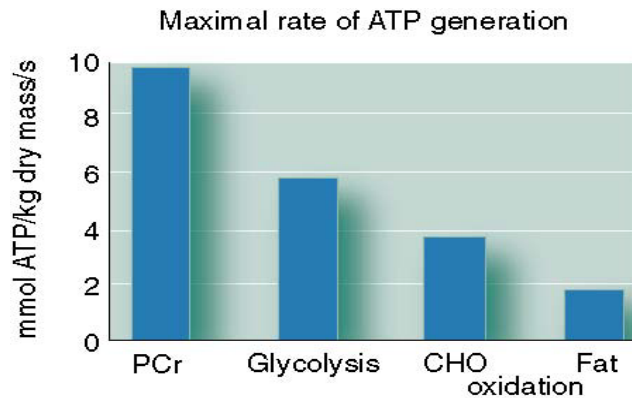


*What is meant by anaerobic power and aerobic power?*

Power, in the context of muscle energetics, can be defined as the rate at which ATP is synthesized during exercise. Anaerobic power refers to the rate of ATP synthesis through energy processes that do not require the presence of oxygen. There are basically two anaerobic energy sources, phosphocreatine and muscle glycogen. Glycogen must first be broken down into glucose molecules, which then provide the energy for ATP synthesis through anaerobic glycolysis. Aerobic power, on the other hand is achieved through oxidative chemical processes that lead to the reduction of an oxygen molecule into water and carbon dioxide. Fuel sources for aerobic energy are glucose (which can come from muscle glycogen as well as glucose from the blood), fatty acids and to a smaller extent, certain amino acids.

*How do anaerobic and aerobic processes differ in muscle power production?*

Since power is the rate of ATP synthesis resulting from aerobic or anaerobic processes, maximal power is the fastest rate at which ATP can be synthesized. As the graph below illustrates, energy derived from phosphocreatine (PCr) results in the highest rate of ATP synthesis or power. The other anaerobic process, glycolysis produces ATP at about half that rate. The slowest rate of ATP synthesis is through aerobic processes, with the fatty acid source being the slowest. In other words, the rate of ATP synthesis is twice as fast when the source of energy is phosphocreatine vs glucose, and anaerobic processes are 2.5 to 5 times faster than aerobic processes.

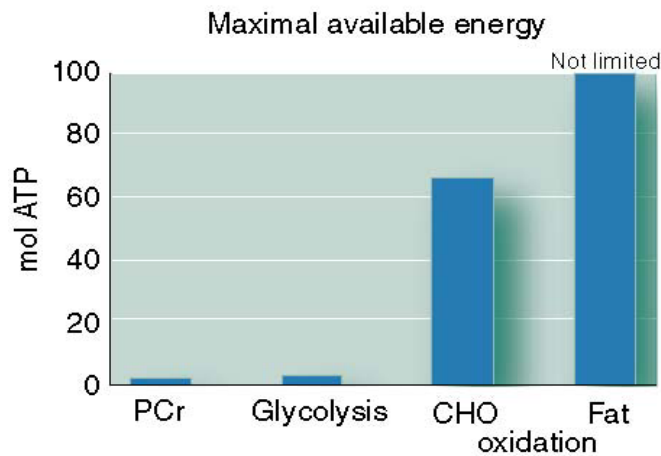


Graph is from Wilmore, Costill & Kenney. Physiology of Sport and Exercise. 4<sup>th</sup> ed. Champaign, IL. Human Kinetics. 2008.

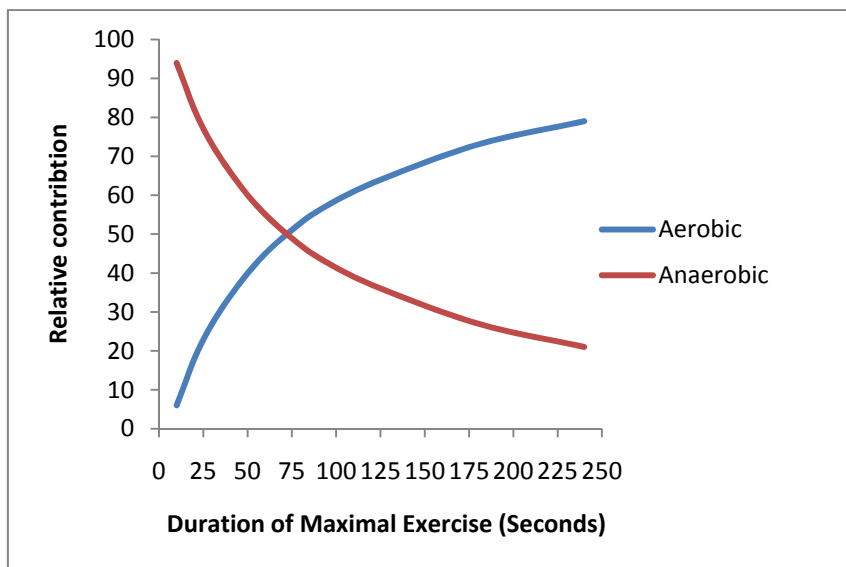
The other way that anaerobic and aerobic energy processes differ from each other is by the fact that the anaerobic sources of energy can sustain high rates of ATP synthesis for only short periods of time. As an energy source, phosphocreatine will run out within seconds of all-out exercise, such as a 100-meter sprint. When phosphocreatine stores run out, ATP levels will drop and this will be the impetus for slowing down or stopping the activity. Anaerobic glycolysis can sustain a high rate of ATP synthesis for several minutes. An example of an activity that relies primarily on this energy system is a 1500-meter or 1-mile run that lasts 3-4 minutes. The limitation of anaerobic glycolysis is not so much the depletion or decrease in glucose sources, but rather the increase in lactate. More specifically, hydrogen ions increase with lactate levels and are known to interfere with muscle contraction and cause fatigue.

On the other hand, while aerobic energy processes are relatively slow in synthesizing ATP, they can provide energy forever, as long as a fuel source exists. A marathon runner relies very much on aerobic processes to sustain muscle activity for several hours continuously. Thus, while anaerobic processes are powerful, aerobic processes have long endurance capacities. As shown in the next graph below, the differences in capacities to produce ATP are great among the energy systems, the least limited being fatty acids and the most limited being phosphocreatine.

The second graph below illustrates the relative contributions of the anaerobic and aerobic energy systems at increasing durations of maximal exercise. An important point to make from this graph is that even during relatively short high intensity durations, the aerobic contribution can be significant. For instance, during an all-out bout of exercise lasting 75 seconds, the aerobic energy processes will supply 50% of the energy required for ATP synthesis.



Graph is from Wilmore, Costill & Kenney. Physiology of Sport and Exercise. 4<sup>th</sup> ed. Champaign, IL. Human Kinetics. 2008.



Adapted from data presented in P. B. Gastin, Energy system interaction and relative contribution during maximal exercise, *Sports Medicine*, 2001.

*Why can't a sprinter rely on aerobic processes for energy?*

Consider a 100-m sprint that lasts less than 10 seconds. World class sprinters run this race at speeds close to 25 mph. Compare this to a world class marathon runner that averages less than 15 mph. Why can't those aerobic energy sources that don't run out provide energy for the sprinter? The short answer to that is, they are not fast enough. In order to synthesize ATP at rates fast enough to run 25 mph, the only source of energy that can readily meet the demand is phosphocreatine. It would be great if a sprinter could rely on a source of energy that does not run out quickly. If that were the case, a 400-meter sprinter could run at the same velocity as a 100-meter sprinter. The reality is, the longer the maximal activity must last, the slower the rate of ATP synthesis.

Aerobic processes are capable of producing very large quantities of ATP, but the rate of synthesis will be much slower than anaerobic processes. The reason for the slowness is partially due to the fact

that oxygen must be delivered to the muscle through the circulation. Another reason is that there are several chemical reactions involved with the oxidation of glucose or fatty acid and these all occur within cell compartments called mitochondria (sometimes referred to as the powerhouses of the cell). Constituents of these chemical reactions must cross the mitochondrial membrane before they can be processed for ATP synthesis. An example of the difference in aerobic and anaerobic readiness occurs at the very beginning of a marathon race. Despite the slower than maximal running velocity, the immediate source of energy for ATP synthesis will be anaerobic because aerobic processes need a bit of time to get up to speed necessary to sustain muscle contraction for the next several hours. During the first couple minutes of exercise, phosphocreatine stores decline and lactate levels increase, indicating the use of anaerobic processes. Once the aerobic processes kick in, so to speak, everything gets back to normal and the runner continues without realizing that he or she was essentially an anaerobic athlete for the first 2 minutes of the marathon race.

*Which is more important to an athlete, anaerobic or aerobic power?*

It depends on the sport. Consider repetitive sports such as rowing, running or cycling. It's easy to quantify the energy demands of these sports because power is largely determined by the duration of the activity. For instance, more power is generated during a 100-m sprint compared to a 1500-m run. Thus, for those types of activities, the longer the race duration, the more reliance there is on aerobic processes and the less there is on anaerobic processes.

Things are not always as black and white as that, however. Consider a sport such as soccer. These athletes run, but the velocity and duration varies throughout a 90-min match. The soccer athlete relies heavily on anaerobic processes because he or she performs short sprints repeatedly. But, in order to meet the demands of the game for 90 minutes, the athlete must also rely on aerobic energy. For these athletes, all the energy systems are important to optimal performance.

*Can an aerobic athlete benefit from training anaerobically?*

By now, it should be clear that the higher the intensity of exercise, the shorter the duration and the greater is the reliance on anaerobic energy for ATP synthesis. Thus, during a long distance race, anaerobic processes will not be the limiting factors in overall performance. However, this is not entirely the case when you consider all the factors that lead to optimal performance during a race. A clear example is the Tour de France, where cyclists sprint for several seconds as they approach the finish line. During the long distance stage, cyclists are also sprinting at various points along the course or attempting to climb very steep mountains. No doubt, this endurance race has an anaerobic component to it.

Anaerobic energy processes do play some role in overall endurance performance, but perhaps where these processes can benefit the athlete most is during training. Despite training for long distances, the endurance athlete will also engage in high intensity training, sometimes at levels equivalent to maximal aerobic power or higher. At such intensities, the athlete must engage in interval training in order to capitalize on these anaerobic processes. Among the benefits of anaerobic training for the aerobic athlete are increased aerobic power, improved lactate threshold and improved efficiency of movement, all of which translate into improved endurance performance. Thus, to gain optimal training benefits, the endurance athlete must balance long distances with high intensity training sessions.

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