ENERGY GENERATION DURING EXERCISE

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Every single system in the body is involved in satisfying the needs of working muscles. Your heart rate speeds up along with your respirations; blood vessels to your stomach, gut, liver, and kidneys constrict in order to send more blood to the working muscles; you sweat and your muscles let you know they're there!

At the cellular level, there are two primary energy systems in the body. One is dependent on oxygen (aerobic), the other is not (anaerobic). Intense exercise requires more oxygen than is available to the aerobic system; this is when the anaerobic system kicks in and does the trick oxygen-free. Both systems burn carbohydrate in the form of glucose in the blood and glycogen in the muscle. Energy Proportion Graphs http://exrx.net/ExInfo/EnergyGraphs.html

Adenosine Triphosphate (ATP)

ATP is an anaerobic energy system made up of adenosine bound to three phosphate molecules. The breakdown of ATP and the resultant release of energy is catalyzed by the enzyme, adenosine triphosphatase (ATPase). Energy spent obviously requires energy generation, production, and storage and ATP provides that too. Necessarily, but also remarkably, this ATP breakdown is reversible, using the compounds it produces to restore and ready itself once more to provide energy, not only for the muscle contractions that we are all interested in, but also for numerous and eloquent microcellular processes, such as enzyme-catalyzed metabolism and the life-supporting Na⁺/K⁺ATPase pump, which transports and exchanges critical ions across cellular membranes.

You will soon see that all the other energy producing systems described below are bent on restoring ATP. This is why this remarkable molecule is call "the energy currency of the body". This is the bank, the reserve, and our life-support.

ATP stat – 1 to 3 seconds. The amount of ATP available for immediate energy is enough for only about three-seconds, after which, an eloquent three-system back-up is activated in sequence to replenish the ATP. They are the phosphagen system, glycogen-lactic acid system, and aerobic respiration.

The Phosphagen System

Another 8-10 seconds. The first 3 seconds takes care of a short sprint and the single power clean or snatch, but what about the 100 meter sprinter or the weightlifter doing reps for time? There is a backup right there ready and waiting within the cell known as creatine phosphate. With the help of an enzyme, the creatine phosphate gives up its phosphate group to produce energy to replenish the ATP levels for skeletal muscles and brain, but only for another 8-10 seconds.
The cellular levels of ATP and creatine phosphate together are called the **phosphagen system**.\(^1\)

**The Glycogen-Lactic Acid System (anaerobic)**

1 - 3 minutes. Energy for the sprinter and the weightlifter has been taken care of by the phosphagen system, but what about the 100 meter swim or the 200 to 400 meter run? Ten-seconds isn't going to do it.

**Aerobic glycolysis.** At this point, the athlete's body taps into stored glycogen, the main energy source for exercise. The process of glycolysis breaks the glycogen into glucose, releasing energy when the glucose is split into two pyruvic acid molecules. The energy released from this reaction forms ATP. But what happens to the loose pyruvic acid?

There are two possibilities for the fate of the pyruvic acid. i.e. glycolysis with and without oxygen.

1) With oxygen, the pyruvic acid is essentially recycled, entering into the mitochondria to generate more energy through the oxidative stage of glycolysis, which in turn produces ATP.

2) Without oxygen, the pyruvic acid becomes lactic acid, which can diffuse out of the muscle cells into the blood stream, and on to the liver to be reconverted to glycogen, once again a source of fuel.

**The painful burning muscles.** Dr. Mackenzie\(^2\) explains the muscle burn as a result of low pH secondary to a build-up of hydrogen ions, which diffuse into the blood stream along with the lactate. The low pH stimulates the free nerve endings in the muscle, resulting in burning pain.

**The cool-down.** The break-down and removal of lactic acid may take 30 minutes or up to 2 hours, but can be hurried along by an active cool-down, which should obviously be below the intensity of the workout. A more detailed description can be found in the reference.\(^2\)

**Aerobic Respiration**

Until "fuel supply" is gone. We have the energy for the short-lap runner and swimmer taken care of, but what about the marathon runner, rower, and the cross-country skier who's using every muscle group in his body? And there's still the swimmer who's doing his usual mile (1.6 km) every full moon. What? Well, yes. Just ask a swimmer. These guys need oxygen! About two-minutes into the exercise, the athlete's body responds by a process called "aerobic respiration" or "oxidation", during which, through a complex series of chemical reactions, glycogen is transformed into ATP and made available to the "time unlimited" guy as long the fuel supply lasts. Check out this the second graph in this link again. [Energy Proportion Graphs](http://exrx.net/ExInfo/EnergyGraphs.html)
Your Heart First and Foremost – Keeping Up

**Sinus tachycardia.** When the heart rate is more than 100 beats/minute and is generated normally by the sinus node, it is called *sinus tachycardia*. Every day that you do an intense, tough, CrossFit workout, that "tachy" is yours. Although it is called an "arrhythmia" in clinical practice, it is the normal response of the body to the need for more oxygen. But how good can this tachy be for you – for your heart?

Studies have shown that the sinus tachycardia associated with aerobic interval training improves the health of coronary endothelium, as well as myocardial microcirculation and function at the cellular level. In fact, mixed-sports (aerobic and anaerobic) athletes and elite endurance athletes have fewer cases of cardiovascular disease. Even in those athletes with cardiovascular disease who have sustained a myocardial infarction (heart attack), some of the negative effects following the event are reversed in hearts preconditioned with functional sinus tachycardia. At CrossFit we are exercising our hearts every day, creating a sturdy microcirculation and improving the function of our heart muscle--grossly and at the cellular level. You can think of your WODs as a *preconditioning* for your hearts for the rest of your life.\(^3\) \(^4\) \(^5\) \(^6\)

**Differential diagnosis.** Normal sinus rhythms hardly ever do anything suddenly (the stimulus from the sound of a nearby gun shot might be an exception). When you begin your exercises the rate of the sinus node will gradually increase until it reaches a maintenance level. Upon completion of the exertion the rate of the sinus node will gradually decrease; and that rate will depend on the oxygen saturation in your red blood cells. This is not so with tachycardias that begin with a premature beat, establish a reentry circuit, and begin at a high and sustained rate, an explanation of which would require another paper on the subject of paroxysmal supraventricular tachycardia.

**Cardiac Output during Exercise – Heart Rate & Stroke Volume**

Cardiac output is the volume of blood pumped by the heart per minute. It is determined by the product of heart rate and stroke volume (blood volume pumped with each heart beat). At rest, the cardiac output is about 5 liters; approximately 15% goes to muscles. During Olympic cross country skiing, the cardiac output can be as much as 35 liters, 60-70% going to muscles, a "steal" from the gastrointestinal track, liver, and kidneys where there will be vasoconstriction. Initially, there is an increase in both heart rate and stroke volume. The increased blood volume being pumped into the ventricles provides the stretch reflex necessary for a stronger contraction. As the intensity of the workout overtakes the athletes capacity, the stroke volume levels out and the heart rate becomes the primary support for the cardiac output.\(^7\)

**References**


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