How do sports drinks work?

It all started 42 years ago at Louisiana State University, when Bengal Punch was introduced as the first sports drink, followed seven years later by Gatorade. There's a great deal of hype surrounding sports drinks, the question is: how can sports drinks actually help athletes perform better? When people exercise many things are happening to the body including the loss of many nutrients, including water and electrolytes. These nutrients, along with carbohydrates are critical for an athlete's health. Sports drinks' main focus is to replace these critical elements in athletes' bodies.

Beverage	Carbohydrate Ingredient	Carbohydrate % per 8 oz.	Sodium (mg) per 8 oz.	Potassium (mg)
Gatorade ®	sucrose & glucose	6	110	30
Powerade ®	high fructose corn syrup, maltodextrin	8	55	30
AllSport ®	high fructose corn syrup	8	55	55

Figure 1

Water is the most important and obvious nutrient which athletes need to replenish. Water is essential for maintaining almost all of the body's vital processes. Plasma, which makes up 55% of ones blood, is 92% water. It also can keep one cool through perspiration. Water enables the storage of glycogen, an essential source of energy, in one's muscles. This is why it is so important that the water which athletes lose through perspiration and respiration is replaced. During exercise people perspire in order to cool down. Perspiration is 99% water, but also contains some electrolytes (salts). The average person needs to consume at least ten ounces of water per day, athletes require a great deal more. An increased metabolic rate during exercise increases loss of water through perspiration and evaporation. Researchers have found that one can lose up to a gallon of fluid an hour during heavy exercise. If one does not replace the same amount of fluid you lose the body will start to protect itself by limiting its activity. For every liter of sweat lost, the heart rate increases about eight beats per minute. This adds stress to the heart, your core body temperature rises, and impairs the ability to perform at a peak level. In the hot weather, dehydration can occur in 30 minutes if the body doesn't getting the amount fluid it needs. Signs of dehydration are feeling dizzy, light headed, having muscle cramps, feeling nauseated or having a headache. The color of ones urine is also an indicator, if it's not clear or light colored, the person needs more fluids. It is important for athletes to hydrate before, during and after a workout. The general rule is 8-16 ounces of fast absorbing fluid (water or sports drink should be consumed 10-15 minutes prior to exercise, at least 4-10 ounces every 15-20 minutes during exercise and 24 ounces after the activity (www.gssiweb.com). Drinking before even becoming thirsty is key, otherwise one will just be playing catch up. Water is important in the body for various reasons. It works as a solvent, transporting, combining, and chemically breaking down substances. Hydrolysis, the process of water breaking down molecules, plays a key role in breaking down essential molecules such as proteins and carbohydrates. During hydrolysis the H+ ions bonds with the negative part of the molecule and the OH- ion bonds with the positive.

Water is a key part of the chemical reaction which ATP (the primary energy storing molecule in the human body) is broken down to create energy (see ***Figure 2*** for chemical equation). The process of breaking down ATP to produce energy is much more complex than the chemical equation shows.

$$C_{10}H_{16}N_5O_{13}P_3 \text{ (ATP)} + \mathbf{H_2O} \longleftrightarrow C_{10}H_{16}N_5O_{10}P_2 \text{ (ADP)} + H_2O_4P^- + \text{ENERGY}$$

Figure 2

ATP, adenosine triphosphate, is produced by ADP, adenosine diphosphate, by a complex sequence of reactions. In basic terms ATP reacts with water to form ADP, a phosphate ion and energy and vice versa. The process of breaking down the ATP is an exothermic reaction, therefore producing energy. Carbohydrates, namely glucose, are broken down through a complex chain of processes beginning with glycolysis in order to produce ATP. In the absence of oxygen, as often the case is in muscles during sprint events, glycogen (energy produced by glycolysis and stored in the muscles) is the only method by which people can obtain energy. During strenuous activity large amounts of energy are needed quickly, especially by muscles. Breaking down carbohydrates forms ATP which is broken down by water to produce the energy needed by muscles.

The production and use of ATP are just two of the many chemical reactions that goes on inside the body. The general term which refers to all chemical reactions which occur in the body is metabolism. There are two categories in metabolism, anabolism and catabolism. Anabolism refers to any reactions which synthesize new organic molecules for cell maintenance, growth and secretion. Catabolism is the opposite process during which larger molecules are broken down into smaller ones and the energy which is released can be used to form ATP. The catabolic process occurs in two stages. The first stage takes place in the cytoplasm of the cell. For example, carbohydrates are first broken into short carbon chains (represented in ***Figure 3***) in the cytoplasm, this stage does not yield a great deal of ATP. These simple

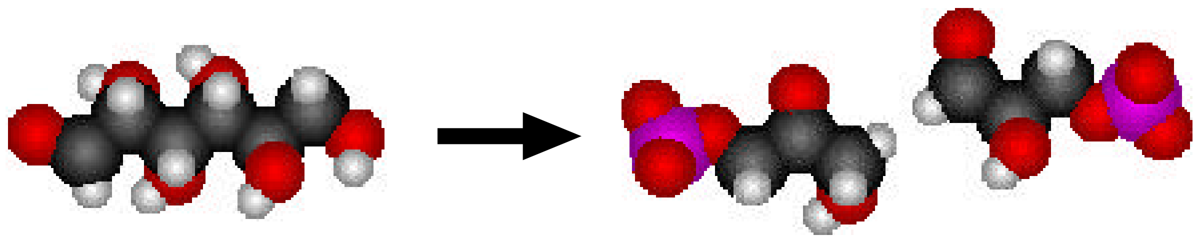


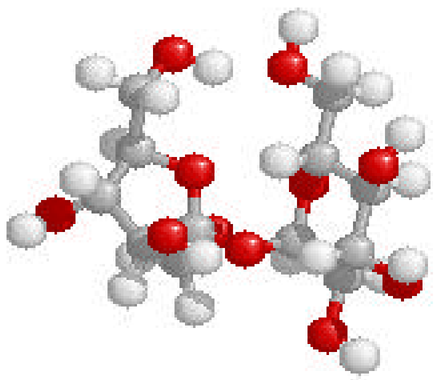
Figure 3

molecules however can then be absorbed and processed by the mitochondria to release large amounts of energy. Ninety five percent of ATP released is produced in the mitochondria by the break down of one glucose molecule. Sixty percent of the energy produced in catabolism is released in the form of heat, the other forty percent is used to form ATP. This ATP can then be used for anabolic reactions or for other functions which require energy such as muscle contraction. Most cells produce ATP through the breakdown of carbohydrates, especially glucose, in a process called cellular respiration. Here is a very simplified chemical equation of the beginning and ending products of this process:

$$C_6H_{12}O_6 + 6O_2 \dashrightarrow 6CO_2 + 6H_20$$

In reality this process is a great deal more complicated and is further explained later.

Carbohydrates are very important to athletes because they supply most energy which athletes use. There are two different forms of carbohydrates, simple and complex carbohydrates. Simple Carbohydrates provide instant energy, whereas complex carbohydrates are stored to be used by muscles in harder or long term activities. Complex carbohydrates are made up of two or more simple sugars linked together (as seen in ***Figure 4***). The simple carbohydrate used by athletes most readily is glucose. If glucose is not used immediately it is converted to glycogen and stored in the muscles. Carbohydrates are primarily stored in the muscles in the form of this complex carbohydrate which is also a polymer of glucose. Glucose is oxidized to either lactate or pyruvate. Under aerobic conditions, meaning that oxygen is present, the dominant product is pyruvate (pyruvic acid) and the pathway is known as aerobic glycolysis. When oxygen is depleted, as for instance during prolonged vigorous exercise, the dominant product is lactate (lactic acid) and the process is known as anaerobic glycolysis. The building up of large amounts of lactic acid in muscle leads to fatigue and can cause cramps. There are no legal ways to prevent lactic acid build up (there are illegal buffers which counteract the acidity of the lactate). Although carbohydrates usually are helpful to athletes, they have their negative effects as well. Extensive studies have shown that sports drinks must contain 5 - 8% carbohydrates in order to be effective. Numerous sports drinks have a greater amount than this, and have been proven to slow down fluid absorption and cause stomach cramps.



Sucrose is an example of a complex carbohydrate.
Figure 4

Glycolysis is the first sequence of reactions in the breakdown of glucose to obtain energy (in the form of ATP). The process begins with one molecule of 6-carbon sugar (glucose) and an input of two ATP molecules (see ***Figure 5*** for diagram). The first of these ATPs converts the sugar into gulcose-6-phosphate, the second forms fructose-1, 6-biphophate. The next step is the splitting up of fructose-1, 6-biphophate into two 3-carbon sugar derivatives. In the next stage these two 3-carbon sugar derivatives are converted into two molecules of pyruvic acid, this conversion uses 4 ADP and produces 4 ATP. The net gain of this process is 2 ATP molecules since it started by inputting 2 and ended by outputting 4 molecules. Once the pyruvic acid is produced there are two possible pathways, depending on if oxygen is present. If there is no oxygen present (anaerobic) the pyruvic

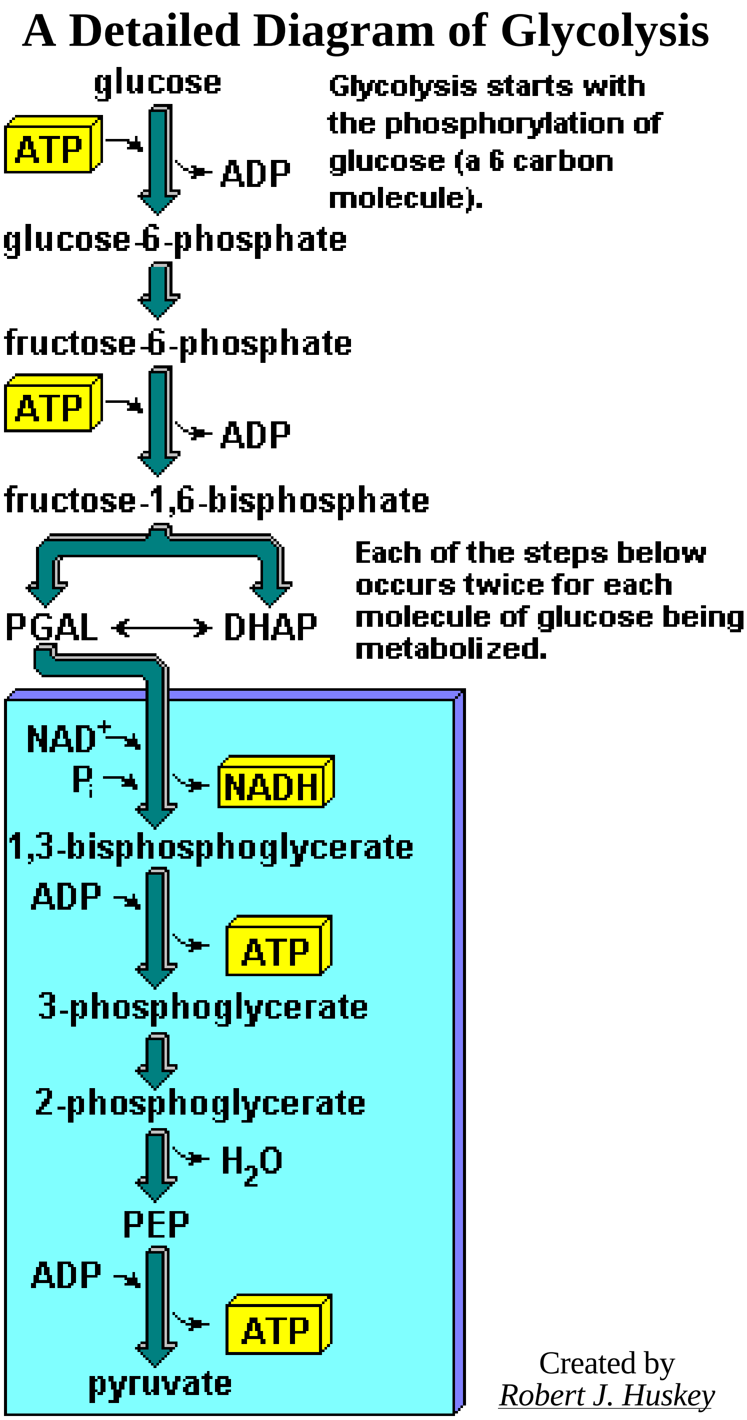


Figure 5

acid is converted to lactic acid and there is no further production of ATP. However if there is oxygen present (aerobic) the pyruvic acid is broken down into two molecules of carbon dioxide, four atoms of hydrogen and two molecules of acetyl-coenzyme A (a two carbon compound). The four atoms of hydrogen go into the hydrogen carrier system where six additional ATPs are produced. The two molecules of acetyl-coenzyme A molecules go into the Krebs or Citric Acid Cycle (see ***Figure 6***) which yields even more ATP.

Although Glycolysis produces two ATPs for every one molecule of glucose degraded, the most significant production of ATP occurs during the Krebs cycle. For every acetyl group oxidized by this cycle 12 ATP molecules are produced. Overall there are 38 molecules formed during complete oxidation (through aerobic glycolysis and the Krebs cycle) of a single glucose molecule. This is quite a comparison compared to the 2 ATPs formed by anaerobic glycolysis in which a great deal of the total glucose energy remains locked up in the lactic acid. This extremely complex process begins when acetyl CoA reacts with the compound oxaloacetate to form citrate and to release coenzyme A (CoA-SH) (see ***Figure 6***). Then citrate is rearranged to form isocitrate which loses a molecule of carbon dioxide. The isocitrate then undergoes oxidation to form alpha-ketoglutarate, in the process 3 ATPs are formed as well. The alpha-ketoglutarate loses a molecule of carbon dioxide and is oxidized to form succinyl CoA, another 4 ATPs are produced in this reaction. This is enzymatically converted to succinate which is oxidized to fumarate and another 2 ATPs are produced. This is hydrated to produce malate and, to end the cycle, malate is oxidized to oxaloacetate and 3 ATPs are used and form 3

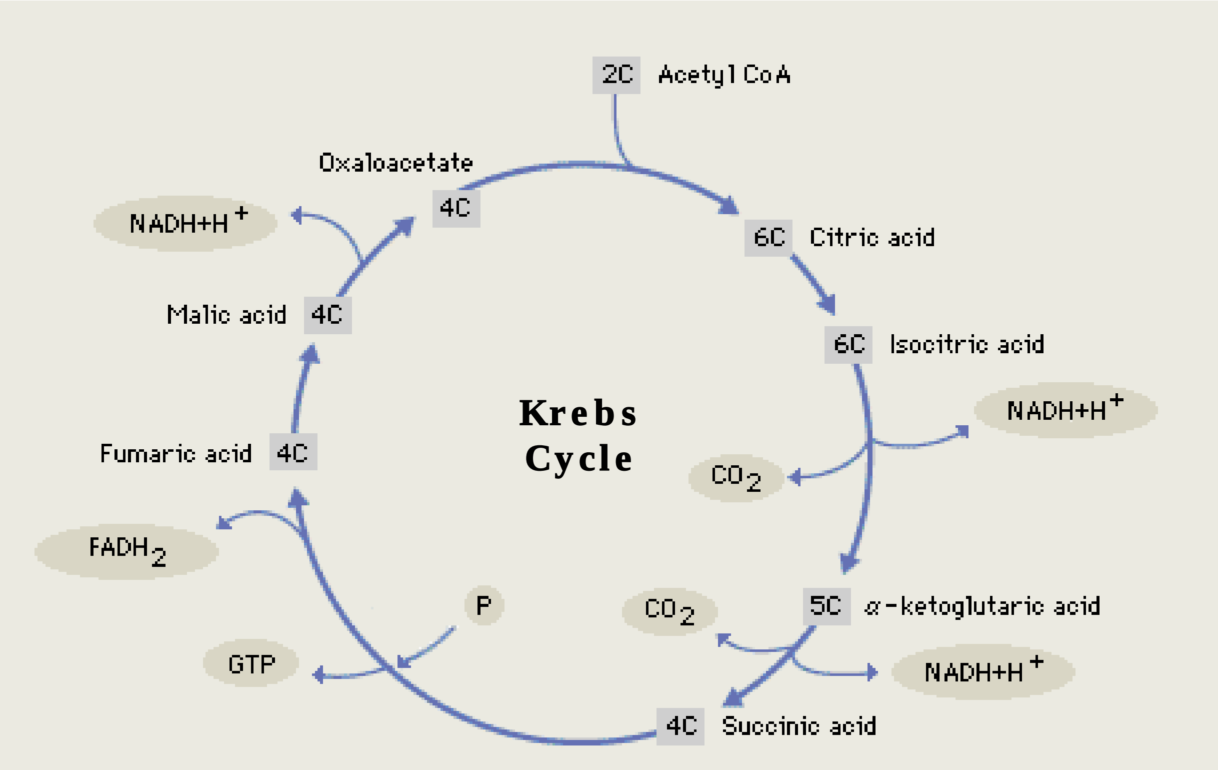


Figure 6

ADPs. Each complete turn of the cycle results in the regeneration of oxaloacetate and the formation of two molecules of carbon dioxide. This cycle repeats and continually producing 12 ATP molecules for every acetyl group oxidized by the cycle. This process is the way that carbohydrates, namely glucose, and broken down to produce energy for the body.

In order for energy producing processes to continue steadily in the body, it is necessary to maintain a balance in the metabolic processes with the help of electrolytes. Besides water and carbohydrates, there are two other essential minerals which athletes need, electrolytes in the form of sodium and potassium. Electrolytes are soluble inorganic compounds whose ions will conduct an electrical current in water. The two most common electrolytes lost by athletes through perspiration are sodium (Na^+) and potassium (K^+). In 90 degree weather young adult tennis players have a sweat concentration of sodium a little above 20 mmol per liter, and sweat potassium losses of approximately 5 mmol per liter. Electrolyte balance is important for two reasons; one, a loss or gain in electrolytes can cause a loss or gain in water and two, the concentrations of various electrolytes affect a variety of cell functions. Changes in body fluid concentrations can seriously impair the body's ability to function properly. Sodium is the most commonly found ion in the extracellular fluid, the fluid in the body which is not inside cells. Since it is so common, changes in sodium's ion concentration have immense effects on the osmotic movement of water from one fluid compartment to another. Aldosterone, a hormone that stimulates water and sodium conservation at the kidneys, helps maintain a steady sodium ion concentration. In order to keep the sodium ion concentration constant when there is an increase in sodium ion there is a corresponding increase of water and vice versa. Potassium is the most commonly found ion in intracellular fluid, the fluid in the body which is inside cells. A declining potassium ion levels can cause general muscular paralysis, and an increased potassium concentration can cause weak and irregular heart beats. Like sodium, potassium ion secretion is also controlled by aldosterone, but in an opposite manner. When there is an decrease in sodium, potassium gets excreted and sodium gets reabsorbed. In order to transmit nerve impulses it is necessary to have normal concentrations of both sodium and potassium ions. For these reasons it is critical that athletes continually replenish electrolytes lost through perspiration.

There are many important nutrients that athletes need which water cannot provide. Sports drinks work by replenishing a person's supply ofelectrolytes, carbohydrates, in addition to fluid (water). They help rehydrate the body quickly, tests have shown that Gatorade rehydrates even better than water. The added element of flavor encourages athletes to drink. Often athletes don't drink enough because they do not feel thirsty. Electrolytes and carbohydrates work to speed up absorption of fluid in the body. But there can still be too much of a good thing. If the carbohydrate percentage is more than 5-8%, it could do more harm than good and cause stomach cramps. It's important to notice the amount of carbohydrates before purchasing a sports drink. This brings up the question, which sports drink will do the job most efficiently? The three most common sports drink on the market are Gatorade®, PowerAde® and AllSport® (see ***Figure 1*** for comparisons). The three most important ingredients in a sports drink are carbohydrates, electrolytes and of course water. Carbohydrates provide energy for muscles throughout the process and glycolysis. Electrolytes, like sodium and potassium are necessary to maintain a balance in many of the systems in the body. Lastly, water makes up over half of our body composition and plays an essential role in the breakdown of glucose for energy. During sporting events, athletes lose these critical nutrients and in order to function to the best of their ability it is necessary to replace them. Personally I have found that drinking a half a bottle of Gatorade at half time of a game actually does replenishe me better than just drinking water.