Teacher Notes for
Should you drink sports drinks? When? Why?

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adapted from "Why Do Athletes Drink Sports Drinks?" by Carlsen and Marek, The Science Teacher, December, 2010

The questions in this activity help students to understand the physiological and health effects of consuming sports drinks and when and how the consumption of sports drinks can be beneficial or harmful. It provides the opportunity to review some basic concepts related to:

- osmosis
- cellular respiration
- mammalian temperature regulation
- how our different body systems cooperate to maintain homeostasis

This activity is designed for high school or college students. Students should be familiar with osmosis before beginning this activity. If you want to teach osmosis, you may want to use teaching resources available at http://serendipstudio.org/sci_edu/waldron/#osmosis. (You could use the experimental investigation of osmosis presented in the Student Handout and Teacher Preparation Notes, the demonstration of osmosis described in the Teacher Preparation Notes, and/or a discussion/worksheet introduction to osmosis based on pp. 1-2 and 5 of the Student Handout.) If your students are not familiar with all of the relevant aspects of these topics, you can introduce the topic briefly or you can modify the questions or reduce the amount of detail you include in the discussion. For example, if your students are not familiar with cellular respiration, you can refer to the need for energy rather than ATP in discussing questions 1 and 6. If you want to introduce your students to the basics of cellular respiration, you may want to use the discussion/worksheet activity available at http://serendipstudio.org/exchange/bioactivities/energy

Learning Goals

- Diffusion of water across a selectively permeable membrane (osmosis) results in net movement of water from a solution with a low concentration of solutes to a solution with a high concentration of solutes.
- Cell membranes are freely permeable to water. Therefore, in our bodies the extracellular fluids and intracellular fluids normally have the same osmolarity. Thus, the osmolarity of the extracellular fluids must be regulated to prevent swelling or shrinking of cells.
- During strenuous physical activity, particularly in hot weather, our bodies lose water and salt (NaCl) in sweat.
- Our bodies have responses that help to restore water and salt balance, including increases in thirst and salt appetite and decreases in the amount of water and salt excreted in the urine.
- There are limits to the body's ability to regulate water and salt balance. Prolonged vigorous exercise in hot weather, in combination with inadequate water and salt intake, can result in dehydration. Decreased blood volume reduces the effectiveness of the heart's pumping, so circulation and blood pressure decrease. This can result in decreased athletic performance and increased risk of heat stroke. Rapid excessive intake of water or sports drinks without additional salt dilutes body fluids; by osmosis, this increases the amount of water in cells, and this can disrupt brain cell functioning and cause convulsions and even death.
- Physical activity requires ATP to provide the energy for muscle contraction. Glucose (e.g. from carbohydrate consumption) can be used to produce ATP.
- Under most circumstances, water is the recommended beverage for active athletes. Sports drinks may be beneficial for athletes engaged in vigorous physical activity for long durations (when the sugars in sports drinks may be useful to replace the glucose that is metabolized for

[1] These Teacher Notes, the Student Handout, and additional activities are available at http://serendipstudio.org/exchange/bioactivities.

energy), especially in hot weather (when the salt in sports drinks is helpful to partially replace the salt that is lost in sweat).
- Sports drinks can contribute to obesity (especially for individuals who are not highly physically active) and can increase the risk of cavities.

Suggested Answers and Additional Information

Explanations of the information in the box

- The first line in the table in the box shows information for extracellular fluids, which include blood plasma, lymph, and the interstitial fluid that bathes cells.
- Because cell membranes are freely permeable to water, the fluids inside our cells have the same osmolarity as the interstitial fluid. However, the specific solutes differ; e.g., Na+ is the primary cation in extracellular fluids, but K + is the primary cation in intracellular fluids.

Question 1

- Water and NaCl in sports drinks help to replace the water and NaCl lost in sweat.
- Sugars can be metabolized to produce ATP which provides energy in a form that cells can use for their activities. Thus, sugars can provide the energy needed for the muscle contractions and brain activity required for athletic activity.

Additional Information:

- Sports drinks often also contain other ions, caffeine and flavors. Other ions in sports drinks may help to replace other ions lost in sweat. Caffeine may improve athletic performance in endurance activities in athletes. Flavors encourage consumption of fluids, but (as discussed below) overconsumption of fluids can contribute to serious health problems.
- The body's activities produce heat. Temperature regulation by the brain results in sweating and evaporation of sweat cools the body to prevent overheating.
- During vigorous physical activity, carbohydrates from food and glycogen stored in the muscles and liver are broken down to glucose which undergoes cellular respiration to produce ATP which provides energy in the form that can be used for muscle cell contraction and other cell activities.

Question 2

- Sweat is less salty than body fluids, so sweating results in the loss of relatively more water and body fluids become more salty. By osmosis, cells will lose water and shrink.
- Dehydration results in decreased volume of body fluids, including decreased blood volume. As a result, not enough blood returns to the heart and the heart can't pump enough blood to maintain adequate circulation, so blood pressure drops. This can result in decreased athletic performance and increased risk of heat cramps, heat exhaustion, and in extreme cases heat stroke.

Additional information:

- Cellular dehydration can increase symptoms of sickle cell anemia (by increasing the tendency for sickle cell hemoglobin to clump in long rods).
- Heat cramps are painful muscle spasms during heavy exercise in hot environments. Low fluid intake contributes to the risk of heat cramps.
- Heat exhaustion occurs when copious sweating without adequate fluid intake has reduced blood volume so the heart cannot pump enough blood; blood pressure falls which can result in fainting.

- Heat stroke occurs when the drop in blood pressure triggers decreased sweating and constriction of peripheral blood vessels which helps to maintain adequate blood pressure and blood flow. Unfortunately, these responses allow body temperature to escalate, which can result in denaturation of proteins and death.

Question 3

- Body fluids would become less salty since the athlete is replacing water but not salt. Water would enter cells by osmosis, cells swell up and may become too dilute to function properly.

Additional Information:

- When a person rapidly consumes large quantities of water, this can result in hyponatremia (low blood Na+ concentration) and hypotonic extracellular fluid, because the influx of water is too rapid to allow the normal osmotic regulation by the kidneys. The consequent osmotic effects can result in swollen cells, with the most harmful effects on the brain cells, which are especially prone to malfunction due to increased mechanical pressure as the swollen brain cells press against the skull. Therefore, over-hydration with hyponatremia can result in water intoxication, including disoriented behavior, convulsions and in extreme cases death.

Question 4

- Since sports drinks have a lower concentration of salt than sweat, an athlete who drinks sports drinks replaces proportionally more water than salt, so body fluids become hypotonic. Consequently, water diffuses into cells by osmosis. If carried to an extreme, consumption of too much sports drink in a short time can have similar effects to excessive consumption of water, including osmotic effects that cause brain cells to malfunction.
- If a person drinks sports drinks and does not engage in enough physical activity to burn off the calories, he or she will tend to become obese.
- The sugars in sports drinks increases the risk of cavities.

Additional Information:

- Drinks with a higher concentration of salt would be better physiologically but don't taste good.
- Many sports drinks also contain citric acid which further increases the risk of cavities.

Question 5

- The body has multiple built-in regulatory mechanisms to maintain optimum water and salt balance. If water and salt balance deviate from optimum, changes in thirst, salt appetite, and the excretion of water and salt will usually restore balance.

Additional Information:

- Body regulatory mechanisms use negative feedback to maintain optimum extracellular fluid volume (important for maintaining optimum blood volume which is needed to maintain adequate circulation) and ion concentrations (important so osmotic effects do not disrupt cell functioning). For example, if a person has been sweating, negative feedback responses that help to restore water and salt balance include increases in thirst and salt appetite and decreases in the amount of water and salt excreted in urine. The brain and hormones play crucial roles in the negative feedback regulation of water and salt balance.
- This is just one example of the multiple physiological negative feedback mechanisms that maintain homeostasis in our bodies; another example is negative feedback regulation of body temperature.

-These types of negative feedback regulatory mechanisms allowed humans to maintain homeostatic balance during vigorous physical activity in the heat over the millennia before sports drinks were invented and they allow other mammals to maintain homeostasis (e.g., dogs naturally maintain water and salt balance when they have been active and panting on a hot day).
- Problems with water and salt balance are most likely under extreme conditions which exceed the capacity of the body's regulatory mechanisms. For example, excessive heat and extreme endurance events can result in excessive loss of water and salt due to copious sweating. At the other extreme, when a person drinks an excessive amount of fluids, this can result in problems due to over-hydration and hyponatremia.

Question 6

- The athlete may not have enough glucose (or other organic molecules) available to produce the ATP needed for muscle contractions. (The athlete may "run out of energy".)

Additional Information:
- During prolonged vigorous activity, glycogen stores in the muscles and liver are depleted as glycogen is broken down to supply glucose which undergoes cellular respiration to produce the large amounts of ATP needed for physical activity. Research studies indicate that consuming carbohydrates during vigorous physical activity lasting more than an hour can increase athletic performance by 2-7%, and the amount of time an athlete can maintain vigorous physical activity (time to exhaustion) can be increased by 15-54%. However, it should be mentioned that some studies have not found a significant effect, especially when the athletes have consumed substantial carbohydrate before beginning the physical activity. Interestingly, recent evidence suggests that even rinsing the mouth with carbohydrate solutions (without swallowing) enhances performance in fasting athletes engaged in long-duration, high-intensity physical activities, apparently by effects on the central nervous system.

Question 7

- Sports drinks would be expected to be beneficial for an athlete engaged in vigorous physical activity for a long duration (when it is important to replace carbohydrates that have been used for energy), especially in hot weather (when the salt is helpful to partially replace salt lost in sweat).
- An athlete who rapidly consumes very large amounts of sports drink is at risk for hyponatremia and water intoxication because sports drinks are hypotonic relative to sweat and body fluids. This risk can outweigh the benefit of fluid replacement (which would be minimized in chilly weather due to reduced sweating) and the benefit from consuming carbohydrates.
- A sedentary person drinking sports drinks increases their risk of obesity and cavities. If the person is thirsty, water would be a much better choice.

Additional Information:
- Current evidence suggests that athletes perform best if they drink when thirsty rather than trying to meet some external standard for fluid consumption. Current evidence indicates that drinking to thirst produces better performance than drinking any prescribed amount. The emphasis on the need to drink fluids appears to have contributed to increased risk of illness and even death due to hyponatremia among marathon participants.

- For high intensity physical activities lasting longer than an hour, consuming the amount of carbohydrate typically provided in sports drinks may improve performance. Alternatively, athletes can eat foods or gels to replace carbohydrates.
- For activities lasting an hour or less, plain water is good for replacing the fluids lost in sweat. The Na+ in sports drinks is recommended for exercise lasting more than an hour because it helps to replace Na+ lost in sweat, maintain thirst, reduce urine output, and increase glucose uptake. However, it should be noted that the only randomized trial carried out in an actual marathon race found no significant advantage of sports drinks relative to water. Na+ can be replaced by food consumed during or after the athletic event.
- If the weather is very hot and humid, sustained vigorous physical activity may make it impossible for bodies to avoid overheating and excessive fluid loss, so sports competitions should be postponed or canceled. High humidity exacerbates the risk of overheating since evaporation is reduced and sweat drips off the body without contributing to cooling.
- You can easily make your own sports drink equivalent; see simple instructions available at www.brianmac.co.uk/drinks.htm

Sources for Additional Information and Student Reading

- Sports Drinks, available at www.brianmac.co.uk/drinks.htm
- Dehydration, available at http://www.mayoclinic.com/health/dehydration/DS00561
- Extreme Heat: A Prevention Guide to Promote Your Personal Health and Safety, available at http://www.bt.cdc.gov/disasters/extremeheat/heat_guide.asp
- Exploring myths and facts surrounding sports drinks, available at http://www.utsandiego.com/news/2011/Feb/22/exploring-myths-and-facts-surrounding-sports/
- "Lack of evidence" sports nutrition products work says BMJ; GSK responds", available at http://www.nutritionhorizon.com/news/Lack-of-Evidence-Sports-Nutrition-Products-Work-Says-BMJ-GSK-Responds.html

Additional Activities

- "How do muscles get the energy they need for athletic activity?" (available at http://serendipstudio.org/exchange/bioactivities/energyathlete)
- In this analysis and discussion activity, students learn about the similarities and differences between aerobic cellular respiration and anaerobic fermentation and learn how these processes contribute to ATP production in muscle cells during different types of athletic activity. In addition, students gain understanding of general principles such as the conservation of energy and conservation of matter, the constant dynamic activity in cells, and the importance of interactions between body systems to accomplish functions such as supplying the energy that muscles need for physical activity.
- "A Can of Bull – Do energy drinks really provide a source of energy?" (available at http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=203&id=203 and http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=506&id=506)