STUDENT GUIDE

EXPLAIN 1 LESSON 20

Food and Agriculture Center for Science Education

Part 1: Our Motivation

Record what we were trying to figure out that led to this investigation.

We are updating our explanations with the new information. We wanted to figure out questions like:

- What happens in the body to make the breathing rate increase?
- Why does our heart rate increase during exercise?
- How do we get energy during exercise?
- Does muscle burn and fatigue have something to do with running out of energy?

Part 2: Developing an Explanation of Heart Rate and Breathing Rate Changes During Exercise

Using all the evidence you have gathered so far in this module, construct an explanation to answer our Module Questions: *Why are there so many changes to my body during exercise? How does milk help with recovery from these changes?* In your explanations, be sure to:

- Include explanations for the following effects of exercise
  - Increased breathing rate
  - Increased heart rate
  - Muscle burn sensation/muscle fatigue
- Describe how the muscle cells utilize anaerobic and aerobic cellular respiration to produce ATP over the course of an intense workout.
- Cite evidence from the data sets we analyzed and the Science Theater model we used.

As a workout starts, your myocytes in muscles use glucose present in anaerobic respiration to generate 2 molecules of lactate and 2 molecules of ATP, as well as some byproducts. Muscle cells use ATP as a source of energy to contract, which is how they move rapidly during exercise. We saw evidence of this by observing that the levels of lactate in the blood go from 0-1 mmol/L before exercise to over 10 mmol/L during exercise (Parker L et al. 2017).

By the second half of my sprint, I felt out of breath and was breathing faster. My breathing rate increased as a result of epinephrine from the Chromaffin cells of the adrenal glands. Epinephrine was released as a response of the brain interpreting a fight-or-flight type situation when intense exercise was started. Epinephrine increases breathing rate so the body can exchange more carbon dioxide and oxygen across the alveoli epithelial cells. The body needs to exhale the carbon dioxide produced as a result of anaerobic respiration.

At the same time, epinephrine also caused my heart rate to increase and my liver and muscle cells to break down glycogen into glucose. We saw in the Gollnick PD, Piehl K, Saltin B 1974 study that muscle glycogen levels go from over 80 mmol/kg to under 20 mmol/kg in high-intensity exercise. And we saw that glucose was released from the liver at over 4 mmol/min in high-intensity exercise, compared to less than 1 mmol/min at rest (Wahren J, Felig P, Ahlborg G, Jorfeldt L., 1971). Now that oxygen is available, anaerobic respiration is used less. Instead, glucose and oxygen are transported through the bloodstream to muscle cells, where they can undergo aerobic respiration, which uses oxygen and glucose to produce 38 ATP. This process also produces carbon dioxide as waste, which is transported through the bloodstream via red blood cells, through the alveoli epithelial cells, and exhaled due to the increased breathing and heart rates. Aerobic cellular respiration continues as long as there is enough glucose and oxygen to be used.

The reason my muscles started burning during intense exercise was due to decreasing pH in the skeletal muscle. We saw that during intense exercise, we saw muscle pH decrease by between 0.3-0.4 compared to at rest (Street D, Bangsbo J, Juel C. 2001). When the skeletal muscle is using anaerobic cellular respiration as a primary energy source in the earlier stages of an intense workout, H+ ions are an output/byproduct of that process. H+ ions lower the pH of the skeletal muscles. This is detected by receptors in the muscles and they send an electrical signal to alert the brain that pH is dropping from its normal range. The Brain and Somatic Nervous System respond by sending a signal via the motor neurons to the skeletal muscle, triggering a pain/burning sensation. This is an effort by the brain to get you to slow down so pH can return to its normal levels.

Part 3: Updating the Effects of Exercise Model

We will update the class Effects of Exercise Model. List 2-3 additions you would make to the class model in the space below. These may be:

- Organs and their function
- Specialized cells and their function
- Signals or molecules and where they move

Organs

- lungs
- mouth/nose/trachea
- liver
- adrenal glands
- Autonomic NS - nerves

- Somatic NS - motor neurons

Specialized cells
- heart: pacemaker cells and cardiomyocytes
- lungs: epithelial cells of alveoli
- Somatic NS: motor neurons
- Autonomic NS: neurons
- hepatic cells in the liver
- Red blood cells transferring the oxygen through the blood vessels
- Chromaffin cells produce and secrete epinephrine

Molecules
- epinephrine from the adrenal glands
- lactate and H+ ions from anaerobic respiration
- Glycogen in myocytes and hepatocytes
- carbon dioxide and its flow from the muscle cells, to the bloodstream, to the lungs
- cellular respiration as a process that occurs in muscle cells
- oxygen moves from the lungs, to the bloodstream, to muscle cells to be used in cellular respiration
- signals sent from nervous system to pacemaker cells and to myocytes

??? Part 4: Asking New Questions

Record any new questions that you have that might help you:
- Find additional information about the changes in our bodies brought on by exercise and exercise of different intensities.
- "Fill in a gap" in your explanation or our class explanation.
- Settle an area of disagreement that we've identified in our explanations.

- Is it possible to run out of glucose for cellular respiration?
- Does drinking milk after a workout increase performance for a second workout because of the glucose or proteins it has in it?
- Does milk work well as a recovery drink because it refills the glucose, electrolytes, and water that we use during exercise?
- Is the reason milk helps us recover to perform another workout because it has sugars that are broken down to glucose, and it has water in it to replace the water we lose to sweat?
- Can the body run out of glucose eventually?