FATIGUED FINGERS

Have you ever felt "the burn" in your muscles while exercising? What is that? In this activity we'll experience the burn and explore is cellular origin.

Materials *per pair*
- Spring-operated wooden clothespin
- Paper and pencil for recording data

per entire group
- Stopwatch or watch with second hand
- Black/white board or other means to display class data

To Do and Notice
It's best to read all the instructions first before conducting this exploration.

In pairs, one student will first do the activity, while the other records data. Students will then switch roles and repeat the experiment. The teacher (or other person) will fill the role of the timer, and will keep time for the entire group.

- Each student should practice operating the clothespin. Use the tips of your thumb and forefinger of your dominant hand to grasp the open end of the clothespin. Practice opening and closing the clothespin a few times, being sure that it opens *all the way* (important!) and the wooden edges meet under your fingertips.

- The timer will announce the start, and time intervals at 30, 60, and 90 seconds after "start".
- When the timer says "go", one student will open and close the clothespin, all the way, as <u>*rapidly as possible*</u>. They should count the number of times aloud, so that the partner can record the number of contractions you've made at 30, 60, and 90 seconds.
- Reverse roles and repeat the activity
- Calculate the number of clothespin operations during each 30 second time interval. For example, if there were a total of 200 contractions at 90 seconds, 15 at 60 seconds and 80 at 30 seconds, there would be 80 contractions from 0-30 seconds, 70 from 30 - 60 seconds, and 50 from 60 to 90 seconds.

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• Record class results on the board, and engage in a class discussion about the experience. Did the number of complete contractions of the clothespin change between 0 and 30, 30 and 60, and 60 and 90 second? If so, how? How do you describe the feeling in your finger muscles as the activity progressed?

What's Going On?
The rapidly contracting muscles in your wrist, arm and fingers use more glucose, oxygen, and ATP than when they are at rest. At the onset of the activity, the muscle contractions involve primarily the *slow twitch* muscle fibers, which are endowed with numerous mitochondria. These fibers produce lots of ATP through the biochemical pathways of aerobic respiration.

After awhile, oxygen cannot be delivered to the cells fast enough to keep up with the ATP demand of the rapid contractions In addition, glycogen (the muscle storage form of glucose) stored in the slow twitch fibers becomes depleted. Because the fuel and oxygen become limited, the aerobic production of ATP slows considerably..

Gradually, *fast twitch* muscle fibers are recruited to help in squeezing the clothespin. These fibers produce smaller amounts of ATP through glycolysis. The end-product of glycolysis is pyruvate, which is converted into lactate by fermentation. The intracellular accumulation of lactate (the ionized form of lactic acid), leads to a is a slight decrease in the intracellular pH. This manifests itself as pain ("the burn") in muscles, and indirectly affects muscle contraction by interfering with the mechanism by which electrical excitation of muscle cells stimulates contraction (the excitation-contraction coupling).

With the cessation of exercise, oxygen delivery to muscle and glycogen stores in muscle return to normal. Lactate is removed from cells by the blood and taken to the liver, where it is converted into pyruvate.

Few people actually run out of ATP because the muscular fatigue and pain will usually cause them to stop their activity before they reach that point. Marathon runners, however, will sometimes push beyond the pain and collapse when their muscles literally run out of ATP.

Bonus! Physics Connection
What type of lever is the clothespin? Where is the effort, fulcrum, and load?

Going further
• For how long can you squeeze the clothespin before you are no longer able to do it? How long a recovery time does it take before you can squeeze the clothespin again? Before you can squeeze it at the same rate as during the first 30 seconds of the activity?
• Repeat the activity with your non-dominant hand. Are your results similar or different? How do you account for the differences?

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