STUDENT GUIDE
ELABORATE LESSON 23

Food and Agriculture Center for Science Education

Part 1: Our Motivation

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

Some questions we didn't answer, but wonder about are:
- Do fatty acids or amino acids have a role in exercise and/or recovery?
- How can someone run an ultramarathon without running out of glucose?

Part 2: Observing a New Phenomenon

Record the observations you have as you watch the video of the ultramarathon runner.

- The ultramarathon is a very long race, 56 kilometers.
- The runner completed the race without eating any extra food.
- He seemed to not really get too tired during the race.

Record the question we will investigate based on the results you observed.

Did his body use a fuel source other than glucose, such as fatty acids or amino acids?

Part 3: Analyzing and Interpreting Data

Use the space below to record your observations as you compare and contrast the experiments performed and corresponding data sets collected by scientists.

All Studies

- Participants were five males
- The exercise used was a one-legged knee extension on a machine. The workout was done at 65% of max single power output for 2 hours
- Various measurements were taken using catheters in the blood vessel entering the exercising leg muscle and one exiting it. This allowed the scientists to take measurements continuously before, during, and after exercise.
- Blood samples were taken from the participants at rest, then after 30, 60, 90, 105, and 120 min during exercise and every 30 minutes during the 3 hours after recovery.

Study 1

- Scientists measured the concentration changes of leg artery FA before, during, and after the workout.
- During exercise, fatty acids in the blood dropped slightly in the first 30 min, then started to increase and reached the highest point right after the end of the workout. They remained elevated during the rest period after the workout.

Study 2

- Scientists measured how much fatty acids in the blood vessels are taken into muscle before, during, and after exercise.
- Scientists used a mathematical formula to calculate the amount of fatty acids entering muscles.
- They found that the amount of fatty acids going into the muscles increased significantly during exercise.

Study 3

- Scientists measured how much of the fatty acids were used to make ATP for muscles.
- Participants were injected with isotopic fatty acids before the workout. These were used to track how much of the fatty acids were converted to ATP, producing carbon dioxide as a byproduct, which could be tracked because the participants were wearing breathing masks.
- They found that during exercise, the amount of fatty acids used to make ATP in the muscles increased significantly and then decreased somewhat during rest.

Compare the three data sets. Explain if you think the findings are consistent with one another and why.

The concentration of fatty acids in the leg artery and the percent of fatty acids converted to carbon dioxide were almost opposite patterns during exercise.

The uptake of FA into muscle rate rising steeply for 30 minutes before lowering and leveling out the rest of the workout seems to make sense because when uptake into the muscle was highest, so was the oxidation/amount being used by muscle to make ATP.

Also, it makes sense that the amount in the artery was opposite this at 30 minutes because the FAs were being taken out of the blood and into the muscle.

Overall, these findings seem consistent with one another because they all seem to fit together to tell us about what happens to fatty acids in the body during exercise.

What conclusions about how the body uses fatty acids during long periods of exercise can you make from these three studies?

We can say that for a lower-intensity workout, by 30 minutes, the body is using much more fatty acids to make ATP than at rest.

The amount of FAs in the blood increases throughout the entire workout, and the amount of fatty acids entering the leg muscles from the blood increases. Once the fatty acids get into the muscles, there they are used to produce ATP for cellular energy.

How did scientists use the lens of stability and change in designing and analyzing the results of this study? Is this consistent with how we've seen scientists use this lens previously?

Scientists measured how fatty acid levels in the body change in response to exercise. This is a similar example to what we have seen previously because, yet again, we see that scientists are measuring the changes in the quantity of a molecular factor in the body.

Part 4: Obtaining Information from Scientific Texts

Read the Lesson 23 *The Body's Fuel Sources* article. Determine what you think are the three central ideas of the text that will best help us answer our investigation question. Record a summary of these three ideas in the space below. As you do so, be sure to:

- Summarize the text in simpler but still accurate terms
- Describe how the body gets energy from different fuel sources during exercise.

Central Idea	Summary of What the Text Says About This Central Idea
The foods we eat provide fuel for exercise.	• Carbs, fats, and proteins from the food we eat can all be used for fuel to make ATP • The pathways are different, but they still react and produce ATP and carbon dioxide. • ATP is the only molecule that can be used for energy to contract muscles
Carbohydrates are a primary fuel for exercise.	• Glucose is the body's primary fuel source • Glucose can be stored in the liver and muscle cells as glycogen • Muscle cells can use their own glucose from glycogen, but the liver sends the glucose into the bloodstream for energy for muscle cells and other cells in the body like the brain • There is only enough glucose in the body for about 90-120 minutes continuous, vigorous exercise
Fat is another fuel source that the body can use.	• The potential capacity of fat for fuel is not really limited • Fat can be stored efficiently and doesn't require water like carbs do • It does take a lot of oxygen to use fat as a fuel source • It takes longer to mobilize fat for fuel as compared to glucose. • There is enough fat in the body to be used for over 100 hours of exercise.

Proteins can be used, but not under normal circumstances.	• Our bodies don't keep reserves of proteins that are meant to be used as fuel • It can be used if the body is starving. Muscle proteins can be used for fuel. • Proteins are more for making hormones and enzymes

Part 5: Constructing an Explanation of How Energy Keeps the Body Moving Over Longer Duration Exercise

Using the evidence you have obtained, construct an explanation that answers the question we set out to investigate. In your explanation, be sure to:

- Describe how the ultramarathoner gets energy to exercise in the early stages of his run.
- Describe how the ultramarathoner gets energy to exercise for several hours beyond the early stages of the run.
- Cite evidence from Studies 1-3 in this lesson and/or from the reading to support your response.

The ultramarathoner would engage in exercise and, at first, would get energy from using glucose for aerobic and anaerobic respiration to produce ATP. This would continue until the body runs out of glucose to use in these processes. Afterward, the runner would have needed to use fatty acids, especially since he did not consume glucose during the race. We saw in Study 1 that fatty acids are released into the bloodstream. They increased from about 300 umol/L to about 800 umol/L during exercise. The fatty acids then move into the muscle and are used to make ATP. We saw this in Study 3, where the leg fatty acid oxidation went from about 25% to over 125%.

Part 6: Revising the Effects of Exercise and Recovery Models

As a class, we will update the Effects of Exercise and Recovery Models to help explain the different experiences we have after exercise. 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
- Molecules and where they move

- We can add adipose tissue and how it can release fatty acids into the bloodstream
- We can add how the muscle cells use fatty acids to make ATP
- We can add how the fatty acids in the bloodstream from drinking milk can be used to recover fat stores and for energy.