STUDENT GUIDE
EXPLORE 1 LESSON 26

Food and Agriculture Center for Science Education

Part 1: Our Motivation

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

- What happens in muscles during or after exercise that makes them need to recover?
- What happens to make muscles feel sore after exercise?
- Why do muscles get sore after exercise?

Part 2: Obtaining Information About Muscle Contraction

Sort the cards provided in the Lesson 26 Weight Lifting Sequence Cards handout to show the sequence of events that happen in muscles as they are contracted to lift a weight. Record the sequence of cards as decided by you and your group.

1. The person tries to lift a weight. The brain initiates movement.	7. The somatic nervous system sends a nerve signal from the brain to the motor neuron. At the motor neuron, a chemical signal (acetylcholine) is sent to the muscle.
2. The somatic nervous system sends a nerve signal from the brain to the motor neuron. At the motor neuron, a chemical signal (acetylcholine) is sent to the muscle.	8. The chemical signal (acetylcholine) moves into muscle cells, called muscle fibers.
3. The chemical signal (acetylcholine) moves into muscle cells, called muscle fibers.	9. Proteins inside muscle fibers are organized into long chains that slide past one another called sarcomeres. The acetylcholinesterase breaks down acetylcholine, and the proteins in the sarcomere slide apart from one another to relax the muscle fibers.
4. Proteins inside muscle fibers are organized into long chains that slide past one another called sarcomeres. Acetylcholine triggers the proteins in the sarcomere to slide towards one another to contract the muscle fibers.	10. The person's muscles relax, and the person lowers the weight.

5. The person's muscles contract, and the person lifts the weight.	11. The person lifts and lowers the weight repeatedly.
6. The person tries to lower the weight. The brain initiates the movement.	12. The person experiences muscle soreness 24-48 hours later.

Based on what you see in the cards, describe how the structure of the specialized muscle cells and specialized nerve cells contribute to the function of the muscle organ in lifting the weight.

The muscle fibers have long chains of proteins inside of them that, when they are given the signal from acetylcholine from the nerve cells, will slide past one another and allow the muscle to contract. The person lifts the weight. Then, the brain signals via the nerve cells to relax the muscle. When the acetylcholine is removed by acetylcholinesterase, muscle fibers relax, lowering the weight.

Watch the video provided by your teacher. Record any new observations you made about the processes occurring in muscles and muscle cells as they lift a weight.

Skeletal muscles contract and relax to mechanically move the body. There are three steps to the process. Muscle contraction begins when the nervous system generates a signal. Skeletal muscles are composed of cells called muscle fibers. The proteins inside muscle fibers are organized into long chains that can interact with each other, reorganizing to shorten and relax. Acetylcholine is part of the process. Stimulation of the motor neurons plays a part in the chemical reactions that occur in the muscle fibers and result in contracting and relaxing of the muscles.

Record what you think you still need to figure out about how muscles get sore and weak during exercise.

I have seen the structure of a muscle cell and how it contributes to movement during exercise, but I haven't figured out what happens in the muscle to make it sore.

Part 3: Analyzing and Interpreting Data

Review the experiments conducted by scientists and their findings in the two studies on how muscle cells change after exercise. Summarize the methods that they used and the data they collected.

Figure 1	Figure 2

This study was performed on muscles from humans. They had humans do a leg exercise, with one leg doing a real exercise and one leg doing an electrically stimulated exercise. Then, they took a sample of tissue from both legs to analyze the structure of the muscle fiber cells using microscopy. It appears that the structure of the muscle cell changes after exercise. The structures called Z-lines are no longer organized in a straight line and are instead really disorganized.	This study was performed on muscle fiber cells growing in a petri dish (in vitro). They used electrical stimulation to simulate exercise in the muscle fiber cells. They used microscopy to see what happened to the muscle cells after this simulated exercise. It appears that more damage to the muscle cells happens over time with more simulated exercise to the muscle cells. This is shown by the green color becoming more prominent over time in the microscopy images.

Compare the methods and findings from the two studies. Are they similar or different?

The methods were similar, but one experiment used human samples while the other used cells grown in a petri dish. The data that they obtained was similar as well in that both experiments were trying to use microscopy to visualize the changes that might have occurred to the muscle fiber cells after exercise. The structure of the muscle cells seems to be significantly changed after exercise in both studies. The studies were performed differently because one examined the structure of the muscle fibers after exercise, and one examined changes after electrical stimulation. However, the findings of the two studies are showing the same effect on the muscle fiber cells in that the fibers are disorganized in both cases.

What conclusions can you draw from the data sets about the cause of muscle soreness and weakness? In your response, be sure to discuss how the molecular structure of muscle cells is changed when muscles are sore.

Muscle soreness and weakness seem to be caused by exercise that disrupts the structure of the muscle fiber cells. Muscle cells undergo microtears that disrupt the structure of the cells, so this likely impacts the function of the cells because the fibers cannot slide properly past each other.

?? Part 4: Asking New Questions

What new questions do you have that can help us make progress towards answering the Module Question, *How does milk help in muscle recovery from soreness and weakness induced by intense exercise?*

- How do our muscles get back to normal after exercise?
- What are the signals that help muscles recover, and how do they work?
- How does milk help our muscles go back to normal?
- When muscles recover from soreness, do the microtears go away?