STUDENT GUIDE
EXPLORE 1C LESSON 18

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've been able to answer our questions about carbon dioxide and oxygen. We have lots of questions left on the Driving Question Board, but we are not sure what kind of evidence might be out there. If we can see what things can be measured or what evidence already exists, maybe we can figure out what questions make the most sense to answer next.

Part 2: Analyzing and Interpreting Data

Read the Lesson 18 Data Set handout assigned to your group. Use the table below as a key for which variable you will be analyzing, and use it to fill in the blank on the next page.

Data Set #	1	2	3	4	5	6
Variable	Muscle Glycogen	Lactate	pH	Epinephrine	Glucose Released by the Liver	Blood Glucose

Review the experiments that scientists conducted to measure the changes in oxygen used in moderate and intense exercise. Summarize the methods that they used and the data they collected.

Compare the methods from the two investigations. How do they compare in what they measure?

Review the data scientists collected and record your observations about how _____ *(variable)* changes over time during exercise and during recovery. Identify if _____ *(variable)* levels return to a stable state during recovery.

Do these studies come to the same conclusion?

Data Set 1 - Muscle Glycogen

Review the experiments that scientists conducted to measure the changes in oxygen used in moderate and intense exercise. Summarize the methods that they used and the data they collected.

Study 1 included workouts at different intensities completed on cycles, and the athletes were not noted as elite athletes. Each participant in that study also had two additional muscle biopsies taken during their workout.

Study 2 used elite athletes who completed a time trial for a cross-country ski course. Muscle biopsies were collected before and after the race to measure the amount of glycogen in the muscles using biochemical analysis.

Compare the methods from the two investigations. How do they compare in what they measure?

Both measure changes to the amounts of muscle glycogen present in muscles before and during a workout.

Review the data scientists collected and record your observations about how **muscle glycogen** changes over time during exercise and during recovery. Identify if **muscle glycogen** levels return to a stable state during recovery.

The data from the first study shows that muscle glycogen decreases more rapidly in higher-intensity exercise, even when the workout is shorter than other workouts. Low-intensity workouts did not use much muscle glycogen compared to other intensities. The second study used a high-intensity workout, and you can see in the data that almost all of the muscle glycogen was used. We can see that glycogen in some areas of the cell was utilized more than others for this particular workout. Muscle glycogen did not return to its stable state during recovery.

Do these studies come to the same conclusion?

Yes, they both show that the higher the intensity of the workout, the faster the muscle glycogen supply decreases.

Data Set 2 - Lactate

Review the experiments that scientists conducted to measure the changes in oxygen used in moderate and intense exercise. Summarize the methods that they used and the data they collected.

In both studies, scientists were looking at the effects of intense exercise on the amount of lactate molecules in the blood. Both studies used blood samples before, in the middle, and during recovery. The first used catheters to measure the blood entering and exiting the muscles of both the active and passive legs. For the second study, they just took blood samples from one location.

The first study participants used a one-legged exercise machine to perform high-intensity exercise for 10 minutes, followed by recovery, some exercise intervals, more recovery, and another 10-minute workout. The second had participants do three types of workouts that were different intensity levels.

Compare the methods from the two investigations. How do they compare in what they measure?

They both measure the concentration of lactate molecules in the blood. The first one is more precise with the muscle biopsies and catheters placed before and after the working muscle in both the active and passive leg. In the second, we just know they took blood samples.

Review the data scientists collected and record your observations about how **blood lactate** changes over time during exercise. Identify if **blood lactate** levels return to a stable state during recovery.

In Study 1, you can see that during each exercise period, the levels of blood lactate increase, then they decrease and return to a stable state during the recovery period.

In Study 2, you can see that high-intensity exercise produces more blood lactate. Levels drop quickly after exercise stops and then at a slower rate as they get closer to the stable state levels.

Do these studies come to the same conclusion?

Yes, they both show that high-intensity exercise produces significantly more lactate molecules and that levels begin to drop back to a stable state as soon as exercise stops.

Data Set 3 - pH

Review the experiments that scientists conducted to measure the changes in oxygen used in moderate and intense exercise. Summarize the methods that they used and the data they collected.

In both studies, scientists were looking at the effects of intense exercise on the pH / H^+ levels of muscle cells. The first measured the pH level of the active muscle cells, and the second measured the concentration of H^+ in the blood that flowed through the muscle in the active exercising leg. They both had participants do different workouts on one-legged extensor machines.

The first study had participants each complete a one-legged extensor workout at three different intensities for 5 minutes. They monitored the pH in the interstitial fluid of skeletal muscle cells using a probe placed in the active muscle and pH-sensitive dye. The second study had all participants do high-intensity exercise but had some groups do passive recovery, and some do active recovery in between workouts. It used catheters to measure the changing concentrations of H^+ in the blood that entered and exited the muscle.

Compare the methods from the two investigations. How do they compare in what they measure?

They used similar methods of exercise, but one looked at the effect of different workout intensities, and the other looked only at high-intensity exercise but two different types of recovery. One measured the pH levels of the muscle cells and the other H^+ levels of the blood that flowed through the muscles.

The first measured pH, and the second measured H+. But pH is calculated based on the concentration of H+. The higher the concentration, the lower the pH. So, both studies are really measuring the same thing.

Review the data scientists collected and record your observations about how **muscle cell and blood pH** changes over time during exercise. Identify if **muscle cell and blood pH** levels return to a stable state during recovery.

Study 1 showed that muscle cell pH decreases between 0.1 and 0.4 during different intensities of exercise. With higher-intensity exercise, the muscle cell pH decreases more. In all cases, the blood pH returned to its stable state during the rest period.

Study 2 showed that blood H^+ increased during exercise and returned to the stable state during the recovery period.

Do these studies come to the same conclusion?

Somewhat. They both show that high-intensity exercise releases more H+ ions / decreases the

pH of the muscle or blood and that recovery returns these levels to the stable state. But one shows how exercise intensity affects pH and the other shows how pH changes over time.

Data Set 4 - Epinephrine

Review the experiments that scientists conducted to measure the changes in oxygen used in moderate and intense exercise. Summarize the methods that they used and the data they collected.

Ultimately, both studies looked at the effects of exercise on epinephrine levels in the blood before, during, and after workouts. The first one used healthy male participants and high- and moderate-intensity workouts. The second incorporated four resistance workouts at different percentages of a given participant's one rep max. The second study also compared data from men and women. For both studies, epinephrine levels were measured using blood samples.

Compare the methods from the two investigations. How do they compare in what they measure?

For each investigation, all participants participated in all workouts. The first one measured epinephrine levels every two minutes, but the second one just compared pre- and post-workout levels, and we didn't see any of the data during the exercise or during the recovery time.

The workouts were different, but not enough information was given to know exactly what type of exercise was being completed in the first investigation. We do know that max effort percent was used to set intensity for the first study, and the second study focused on resistance training and was based on the one rep max. For the second study, you can see the epinephrine levels in the blood before each workout and after for men and women.

Review the data scientists collected and record your observations about how **epinephrine** changes over time during exercise. Identify if **epinephrine** levels return to a stable state during recovery.

Epinephrine levels increase over time during exercise and return to a stable state during recovery. High-intensity exercise or higher amounts of total work correspond with a much higher number of repetitions and amounts of epinephrine released.

Do these studies come to the same conclusion?

Yes. Both studies show that more epinephrine is released when exercise intensity is higher.

Data Set 5 - Glucose Released by the Liver

Review the experiments that scientists conducted to measure the changes in oxygen used in moderate and intense exercise. Summarize the methods that they used and the data they collected.

Both pieces of data came from the same study.

For the first study, a catheter placed in the vein leaving the liver was used to measure the concentration of glucose being added to the blood. Twelve measurements were taken at rest and during the workout. This figure only showed a workout at the highest intensity (1200) for just one participant. It also showed the same workout three months later but took measurements from both the right and left hepatic veins.

For the second study, they compared the average rates of glucose produced by the liver (like in set 1, but with all participants and at all intensities). They compared that amount to the rate that glucose was taken up by the active leg muscle by comparing the amount in the blood entering the muscle and the amount leaving the muscle.

Compare the methods from the two investigations. How do they compare in what they measure?

They used catheters to take measurements of glucose released into the blood from the liver, and they both used a stationary bike at different intensities for the workouts. The first measures glucose released by the liver during exercise. The second compares the amount released by the liver to the amount of blood glucose taken up by the leg muscle for each intensity of workout and at rest. The bars only show the totals for each workout.

Review the data scientists collected and record your observations about how **glucose released by the liver** changes over time during exercise. Identify if **glucose released by the liver** levels return to a stable state during recovery.

Overall, the liver released more glucose into the bloodstream with every increase in exercise intensity. And we can also see that at rest, the liver is not releasing any glucose. But over time as exercise continues, the liver releases more and more glucose until after about 30 minutes and it seems to start to not change. It is unclear if levels of glucose released returned to a stable state during recovery.

Do these studies come to the same conclusion?

Somewhat. They both show that the liver produces/releases more glucose into the blood during exercise. But one measured exercise over time and one measured exercise intensity, so they aren't exactly the same conclusion.

Data Set 6 - Blood Glucose

Review the experiments that scientists conducted to measure the changes in oxygen used in moderate and intense exercise. Summarize the methods that they used and the data they collected.

The studies were similar. They both looked at changes in blood glucose levels from rest, through the exercise of different intensities, and then during recovery time. Both used blood samples to measure blood glucose levels throughout. They both had workouts lasting 40 minutes.

Compare the methods from the two investigations. How do they compare in what they measure?

Both looked at the effects of exercise intensity on blood glucose levels. One looked at just two different intensities (low and high), and the other had three different intensities of cycling workouts. We don't know what type of workout was used in the first set.

Review the data scientists collected and record your observations about how **blood glucose** changes over time during exercise. Identify if **blood glucose** levels return to a stable state during recovery.

Higher-intensity workouts result in higher levels of blood glucose levels than do medium- or low-intensity workouts. In high-intensity workouts, blood glucose levels rise more rapidly than in other workouts, and they take a little bit longer to reach their pre-workout levels.

The low-intensity workouts do not have a steep rise in blood glucose. It looks like the increase is much slower and stabilized during the workout, and then it reaches pre-workout levels a bit sooner than higher intensities.

Do these studies come to the same conclusion?

Yes, they both show participants doing higher-intensity workouts (for the same amount of time) have blood glucose levels that increase quickly and continue to rise throughout the workout. For lower intensity, blood glucose levels do not increase nearly as fast or as much, and they level out at a certain point.

Part 3: Sharing Our Findings

Prepare a brief summary of the data you just analyzed and its conclusions. Your audience will be your classmates who did not interpret and analyze this data. In your summary, be sure to include:

- A one-sentence description of the aims of the studies
- A summary of the investigations that scientists used, including the methods and what was measured.
- A summary of the data and results found by both studies.

- A one-sentence conclusion about the effect of exercise on the variable studied.

Aims of Studies

Both studies were looking at how exercise affects the acidity of muscle and blood. Both studies happened to use six healthy males in their 20s and involved using a one-legged extensor machine during trials and took data before, during, and after the workout(s).

Methods

The first study had each participant complete a 5-minute workout followed by 20 minutes of rest at each intensity (L/M/H) on different days.

The second study was only performed at high intensity. Participants rested for 10 minutes, and then participants did more intense exercise.

The studies differed in how they measured acidity. The first used a probe inserted into the active muscle and used a dye to monitor pH changes in the muscle cells. The second measured the concentration of H+ ions using catheters in the artery that entered the leg muscle and in the vein that exited the muscle and measured the levels of acidity in the blood that flowed through the muscle.

pH is a measure of how acidic or basic something is and has a scale of 0 - 14. Seven is neutral, below seven is acidic, and above seven is basic. Even though one study measured pH and one reported the concentration of H+ ions, both were really measuring how acidic the muscle or blood was. H+ ions lower pH, and pH is calculated based on the concentration of H+ ions.

Results

Both studies showed similar patterns in recovery: acidity decreases when exercise stops. At first, it does so quickly, but it levels out and goes slower after the first few minutes of rest. According to the second study, it looks like most of the time, acidity is back to normal after 20 minutes of rest.

Conclusion

Both studies showed that the muscle cells and the blood become slightly more acidic throughout high-intensity exercise.

The class will share what each group found. Use the table below to capture key details from your classmates about the findings from each data set.

Variable	Trends Observed	Notes

Muscle Glycogen	Decreased with higher-intensity exercise and did not return to a stable state.	Muscle glycogen molecules are stockpiles of extra glucose molecules that are bonded together. Glycogen can be broken down into glucose. Glucose is used by cells for cellular energy.
Lactate	Increased with higher-intensity exercise and returned to a stable state with recovery.	Lactate is a small molecule that can be used as an energy source for cells, similar to glucose.
pH	Decreased with higher-intensity exercise and returned to a stable state with recovery.	pH is a measurement that tells how acidic or basic something is. Normally, our muscles and blood have a pH of around 7.4. pH decreased during the workout, and it started to go back toward normal after the exercise stopped. It was back to normal in about 20 minutes.
Epinephrine	Increased with higher-intensity exercise and returned to a stable state with recovery.	Epinephrine is a hormone, also known as adrenaline, that controls the "fight or flight response."
Glucose Released by Liver	Increased with higher-intensity exercise and did not return to a stable state.	The liver contains glycogen or stored glucose. During exercise, the stored glucose is released into the bloodstream. So this means that the amount of liver glycogen decreases because it is broken down and released into the bloodstream. Glucose is used by cells for cellular energy.
Blood Glucose	Increased with higher-intensity exercise and returned to a stable state with recovery.	Glucose is used by cells for cellular energy.

Reflect on how the lens of stability and change informed the design of these studies. In your response, be sure to describe:

- How did these studies use the lens of stability and change to study how the body responds to exercise?
- What does that tell you about how scientists study the effects of exercise on the human body?

The scientists in these studies measured how the levels of various factors in the body change in response to exercise. We saw that many of them start at a stable state, change, and return to a stable state. But others do not. This is similar to previous studies we looked at where the scientists measured body temperature and blood volume during exercise vs. at rest where the values increased during exercise then returned to a stable state. It seems that scientists study the human body by measuring various factors in the body that change in response to exercise.

Part 4: Constructing Explanations

Use the findings from your investigation to construct an explanation to the Module Questions, *Why are there so many changes to my body during exercise? How does milk help with recovery from these changes?* Be sure to speculate about how the trends you found in this lesson might help you answer the Module Questions.

Blood glucose levels go up during exercise. I think this could be coming from the muscle and liver glycogen because they go down during exercise and glucose might be used during exercise for energy.

Part 5: 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.

- When liver glycogen levels go down, do blood glucose levels go up?
- Is increasing lactate levels the reason my muscles burn?