TEACHER GUIDE
ELABORATE LESSON 23

Food and Agriculture Center for Science Education

Module Questions: ***Why are there so many changes to my body during exercise, and how does milk help our bodies recover from these changes?***

What We Figure Out:

If intense exercise or even moderate exercise continues for a long enough duration, fatty acids can be utilized as a fuel source. Fatty acids, either from food molecules in the bloodstream or from adipose tissue, move into the muscle cells and are used in a process called fatty acid oxidation, which is a chemical reaction similar to aerobic and anaerobic respiration. Fatty acid oxidation provides muscle cells energy to exercise for long periods of time, compared to glucose, which provides energy for exercise for shorter periods of time.

3D Learning Objective:	**Time estimate:**	**Materials:**
Students compare findings in three data sets of changes in various molecules in the body to determine that fatty acids can be used as another fuel source during endurance exercise. Students summarize the central ideas from scientific literature to describe how free fatty acids can also be used to provide energy to muscles during periods of extended exercise.	100 minutes	Lesson 23 Student Guide Lesson 23 Student Handout *The Body's Fuel Sources* Article Lesson 23 Student Handout Data Set Lesson 23 Ultramarathon Runner Video

Targeted Elements

SEP:	DCI:	CCC:
DATA-H4:	**LS2.B-H1:**	**SC-H1:**

Compare and contrast various types of data sets (e.g., self-generated, archival) to examine **consistency of measurements and observations.** **INFO-H1:** **Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.**	Photosynthesis and **cellular respiration (including anaerobic processes) provide most of the energy for life processes.**	**Much of science deals with constructing explanations of how things change and how they remain stable.**

Directions

Part 1: Our Motivation

Return to the Driving Question Board. Share a few selected questions that align with what students will investigate in the upcoming lesson.

Example student questions or ideas could include:

- Do fatty acids or amino acids have a role in exercise and/or recovery?
- I don't understand how someone can do really long workouts, like run an ultramarathon without running out of glucose.
- Can we run out of glucose? What happens if we do?
- What happens if someone exercises more than they have glycogen available to use for glucose?

Students can record these questions on their Lesson 23 Student Guide Part 1: Our Motivation. This will help students understand how this lesson connects to what they were trying to figure out about the Module Phenomenon or about the remaining questions they have had that arose in the module.

Part 2: Observing a New Phenomenon

Share with students that they will now observe a new phenomenon to help them figure out how a person who exercises for very long periods of time could get the energy to do so. Show students the Ultramarathon Runner Video of a runner completing a 56-kilometer race and ask them to record their observations on their Lesson 23 Student Guide Part 2: Observing a New Phenomenon.

TEACHER SUPPORT
You may want to ask students to convert 56 km to miles using a calculation or provide the conversion to students (56 km = 34.8 miles). In addition, you may want to provide a quick analogy of how far that distance is using local reference points or landmarks. For example, 34.8 miles = about 139 laps around a running track.

After students have recorded their observations from the video, hold a whole-class discussion for students to share what they have found. Facilitate the conversation so that students agree that:

- 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 along the race.

After agreeing on their observations from the video and data set, introduce the question students will investigate in this lesson, *"How does someone exercising for a long time get the energy their body needs to keep moving?"* Allow time for students to write this question on their Lesson 23 Student Guide Part 2: Observing a New Phenomenon.

Part 3: Analyzing and Interpreting Data

Start by returning to the Class Consensus Recovery Model from Lesson 22. Point out to students that they have figured out how many parts of milk, such as water, electrolytes, and sugars, are used in the body in exercise. But, students have not figured out how fats and proteins help in exercise and recovery. Tell students that they will focus on fats in this lesson.

Next, students will view three figures from a scientific journal article that show what changes occur to fatty acids in the body for athletes who are exercising for very long periods of time. Distribute the Lesson 23 Student Handout Data Set with this information. Students will

compare the findings in these figures to determine if their findings are consistent and what changes occur to fatty acids in the body during long periods of exercise. They can record their answers on their Lesson 23 Student Guide Part 3: Analyzing and Interpreting Data.

Allow students time to analyze the methods of the three experiments and the data presented. As students work, circulate the room to generate students' thinking. Ask pressing questions such as:

- How were the two experiments designed? What methods were used? How are the designs similar/different?
- What were the objectives of the two experiments? How are they similar/different?
- What changes do you notice to the amounts of fatty acids in the blood before, during, and after exercise?
- How do you think you can determine if the outcomes of the two studies are the same? What should you look for?

SEP SUPPORT

DATA-H4: Compare and contrast various types of data sets (e.g., self-generated, archival) to examine **consistency of measurements and observations.** In this lesson, we continue with the progression of reducing scaffolds for students to engage in this practice. In Lessons 18 and 21, students compared the findings from two studies to determine if their outcomes are consistent. In this lesson, students progress on this practice by now comparing the outcomes of three studies. In addition, the number and wording of the prompts on their Student Guide has been further reduced, such that students have a somewhat less scaffolded task compared to previous lessons. If a student is struggling, remind students of scaffolds and prompts from previous lessons, including those below.

1. Determine the goal of each study.
2. Summarize the methods used and the data collected in each study.
3. Determine what each data set is measuring.
4. Compare the methods and findings of each data set.

FORMATIVE ASSESSMENT OPPORTUNITY

Students compare findings in three data sets of changes in various molecules in the body to determine that fatty acids can be used as another fuel source during endurance exercise.

Assessment Artifacts:

- Students' comparisons of findings from a scientific journal showing what changes occur to fatty acids in the body for athletes exercising for long periods of time (Lesson 23 Student Guide Part 3: Analyzing and Interpreting Data).
- Students' summary of conclusions from the three different studies (Lesson 23 Student Guide Part 3: Analyzing and Interpreting Data).

Look Fors:

- Students compare the consistency of findings among the three different studies (DATA-H4).
- Students describe changes occurring to the levels of fatty acids in the blood and muscle and how fatty acids are used by muscles for energy (LS2.B-H1).
- Students compare the changes between resting state and during a workout for the three different data sets. (SC-H1).

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	All of the studies showed that the amount of fatty acids increased. Fatty acids are used in the muscles to make energy.	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. 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. 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.	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. 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, they are used to produce ATP for cellular energy.
How to Achieve This Level	Student completes 0-1 out of 3 Look Fors	Student completes 2 out of 3 Look Fors	Student completes 3 out of 3 Look Fors

To Provide Additional Support for Students

Consider the following supports for students as they analyze the data sets:

- Hold a class discussion addressing the details of the protocol used for the workout so that students have a mental picture of what participants were doing while the sets of data were being collected.
- Redirect students to focus on the changes from the steady state/resting state to exercise and throughout the workout.
- Use prompting questions to help a student connect how scientists were able to use data set three to determine that fatty acids were being used to make ATP.

After students have analyzed the methods and data, hold a whole-class discussion for students to share what they have found. Facilitate the conversation so that students agree that:

- The levels of fatty acids in the blood increase during exercise.
- Fatty acids in the bloodstream are taken up by muscles during exercise.
- The fatty acids taken up by muscles during exercise are used by the muscle cells in a process called beta oxidation that produces ATP for muscles and carbon dioxide as a waste product.

Take a moment to reflect on how the scientists used the lens of stability and change when designing these studies. Use a Think-Pair-Share to have students record and share their reflections. Student responses may vary.

1. Students are given time to think independently about their responses.
2. Students find an elbow partner.
3. Students take turns sharing their thoughts with their partner. Each student should be given time to respond.

Facilitate the conversation such that students agree that:

- 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.

Confirm and build on student responses to share that this is another example of a common approach in exercise science. To see how the body responds to exercise and how it recovers, scientists often measure changes to levels of different molecular markers in the body.

CCC SUPPORT
SC-H1: Much of science deals with constructing explanations of how things change and how they remain stable.

Just as students have done in previous lessons, they see in these data that scientists often measure changes to the levels of various molecules in the body when studying how the body responds to exercise and how it recovers from exercise.

Part 4: Obtaining Information from Scientific Texts

Briefly return to the case of the ultramarathoner and ask students what they now know about what different energy sources are used during exercise. Confirm student responses that share that both fatty acids and sugars like glucose can be used to produce ATP. Ask students which source is used when in a long workout, such as the one that the ultramarathoner is undertaking (e.g., which is used early in the workout, which is used later). Acknowledge student responses and share with students that they will gather evidence from a scientific text to help figure out how the ultramarathoner would get energy at different times in the race.

Students will read the Lesson 23 Student Handout *The Body's Fuel Sources* Article. Instruct students that they will read the text and try to choose and summarize three central ideas from the text that best help answer the investigation questions. They can write their observations on their Lesson 23 Student Guide Part 4: Obtaining Information from Scientific Texts.

Allow time for students to read the text and to determine which central ideas they will choose to record and summarize. As students work, circulate the room and ask pressing questions such as:

- Why did you choose this as a central idea? How does it help answer our investigation questions?
- What changes does the text say are occurring to the muscle cells as they recover and grow larger/stronger?

FORMATIVE ASSESSMENT OPPORTUNITY

Students summarize the central ideas from scientific literature to describe how free fatty acids can also be used to provide energy to muscles during periods of extended exercise.

Assessment Artifacts:

- Students' summary of central ideas obtained from the "The Body's Fuel Sources" article (Lesson 23 Student Guide Part 4: Obtaining Information from Scientific Texts).

Look Fors:

- Students choose three central ideas from the text and summarize/paraphrase them in simpler but still accurate terms (INFO-H1).
- Students articulate that glucose can be used for aerobic and anaerobic respiration for short-duration exercise and that fatty acids can be used by skeletal muscle cells to produce ATP during long bouts of exercise. (LS2.B-H1, SC-H1).

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	The foods we eat provide fuel for exercise. Carbohydrates are a primary fuel for exercise. Fat is another fuel source that the body can use. Proteins can be used, but not under normal circumstances.	The foods we eat provide fuel for exercise ● Carbs, fats, and proteins from the food we eat can all be used for energy Carbohydrates are a primary fuel for exercise ● Glucose can be stored in 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 Fat is another fuel source that the body can use ● 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	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 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

		Proteins can be used, but not under normal circumstances ● Our bodies don't keep reserves of proteins that are meant to be used a fuel ● Proteins are more for making hormones and enzymes	● There is only enough glucose in the body for about 90-120 minutes of 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 a 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
How to Achieve This Level	Student completes 0-1 out of 3 Look Fors	Student completes 2 out of 3 Look Fors	Student completes 3 out of 3 Look Fors

To Provide Additional Support for Students

As students work in groups, approach each group to look at their work. If students need additional support in finding central ideas in the text, consider:

- Using a partner-reading protocol, such as a Read-Aloud-Think-Aloud, to have students unpack the text together.
- Redirecting students' attention to parts of the article they may have missed or overlooked.
- Providing a text annotation strategy, such as for students to help students read and process the text.

- Having students record terms they are not certain about and having the class build definitions for these terms together.
- Engage students in a peer feedback session. Provide students with the Look Fors, and use a protocol such as Tell-Ask-Give or norms such as SPARK. Students can use the Look Fors to provide feedback to each other on how they can improve selected Look Fors in their work.

TEACHER SUPPORT

The first several paragraphs of this text describe each of the different fuel sources for the body, including glucose and fat. This content should be a review for students from Lessons 16-22 and can serve as a helpful summary of these processes for students who may have previously struggled.

After students have completed their reading and recorded central ideas from the text, use a sharing routine such as a Mingle-Pair-Share for students to share the different central ideas they have found with their peers. Students will move around the classroom and find a peer who is not a part of their usual group. Students can record additional central ideas they hear from their peers during this time.

1. Students will take turns sharing their explanations.
2. Students will then find a new peer and share their explanations once again.

After students have finished the sharing protocol, hold a whole-class discussion for students to share what they found. Facilitate the conversation such that students agree on the following key ideas from the article:

- The body uses multiple sources of fuel for energy, including glucose and fatty acids. Glucose is used for the first 90-120 minutes of exercise. Fatty acids can be used for many hours.
- Some fuels are stored for later use, and some are used right away.
- During exercise, stored fat in the body (in the form of triglycerides within adipose or fat tissue) is broken down into fatty acids. These fatty acids are transported through the blood to muscles for fuel.

CCSS SUPPORT

RST 9-10.2 Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

If students are struggling, offer them Summarization Frames. These frames are sentence starters that guide students in constructing concise summaries. For example, "In this passage, the main idea is…" or "The author supports their argument by…"

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

Share with students that they will now create an explanation for the questions they set out to investigate: *How does someone exercising for a long time get the energy their body needs to keep moving?* Students can record their explanation in Lesson 23 Part 5: Constructing an Explanation of How Energy Keeps the Body Moving Over Longer Duration Exercise. As students work, circulate the room to informally assess their explanations and provide feedback by asking questions about their work.

Hold a whole-class share out for students to share their explanations with each other. Facilitate the conversation such that students agree that:

- 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

Ask students to reorient to the Driving Question for the unit, ***How can milk help athletes recover from physical exercise?*** Share with students that they will now update the class Effects of Exercise and Recovery Models. Share with students that they can take the explanations they wrote in Part 5: Constructing an Explanation of How Energy Keeps the Body Moving Over Longer Duration Exercise to help inform how to build these models.

TEACHER SUPPORT
Here students should be adding onto the Class Consensus Models from Lessons 20 and 22, which should be displayed as large murals on a class wall or saved digitally for projection for the entire class.

Hold a whole-class discussion in which the class adds to the two existing Class Consensus Models. Students can write their initial ideas for additions on their Lesson 23 Student Guide Part 6: Revising the Effects of Exercise and Recovery Models. Walk students through the class consensus discussion steps below so they can create the Class Consensus Models.

1. Each group should select one or more reporters to share one part of their explanations to add to the models. Have the first group share one idea to add to the consensus models. This can be one component, arrow, relationship, or any other feature the group wants to select.
2. The next reporters can agree with, disagree with, or revise parts of the model that have already been added or can add new parts. Continue this process until both of the full Class Consensus Models for Exercise Effects and Recovery are built.
3. As students share, some strategies you can use to help the class build the consensus model are:
    a. Helpful sentence starters such as:
    b. We agree with _____'s group, and we also want to add _____.
    c. We disagree with _____'s group because _____
    d. We would like to change _____ because (evidence).
4. Use discussion prompts such as asking the class:
    a. Is there anything else that needs to be added to this component before we move on?
    b. How does this idea fit with what is on the model currently?
    c. What new body systems are we introducing? Which organs are included in these systems?
    d. How are we showing the movement of matter in this model? The movement of energy? How are milk nutrients shown in this model?
    e. What specialized cells are a part of this organ, and what are their functions?

STUDENT SUPPORT

The data that students viewed in this lesson focused on how fatty acid levels increase in the bloodstream, enter muscles, and are used in beta oxidation during exercise. Students do not have direct evidence of where these fatty acids come from in the body, or how the fatty acids in recovery when drinking milk are used. Accordingly, as a part of this class discussion, you may need to support students with making the following inferences:

- In the Exercise Effects model, fatty acids enter the bloodstream from fat tissue, or adipose tissue, where fatty acids are stored for long-term use.
- In the Recovery model, fatty acids in the bloodstream that have come from milk being digested move into the adipose tissue to recover fat stores.

CCCS SUPPORT

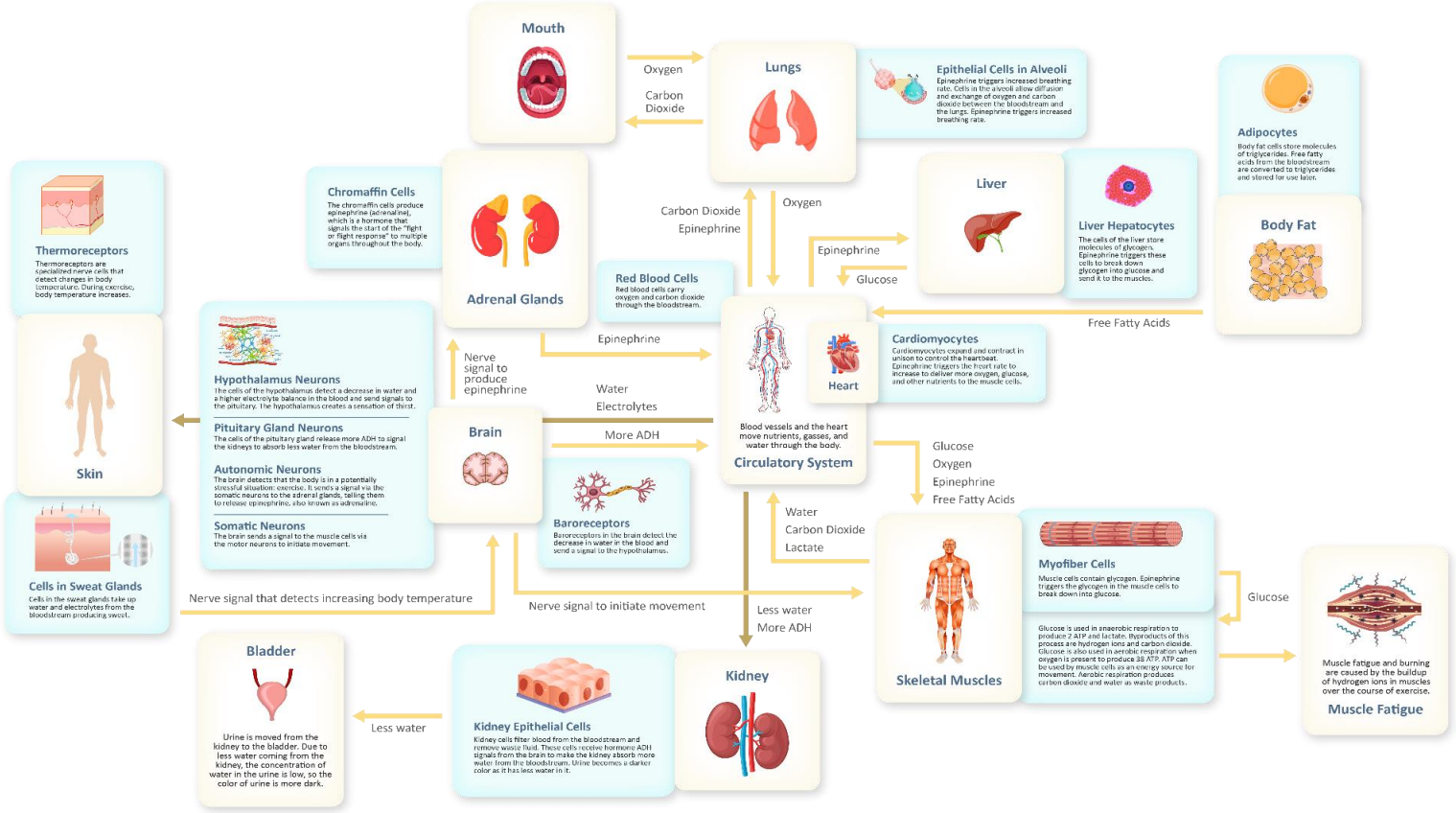
SL 9-10.1(d): Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted qualify or justify their own views and understanding and make new connections in light of the evidence and reasoning presented.

Because student explanations may differ, it is important to emphasize that the revisions to the model are being made based on evidence. You may want to ask students to discuss the difference between evidence vs. opinion when discussing what components to include in the Class Consensus Models.

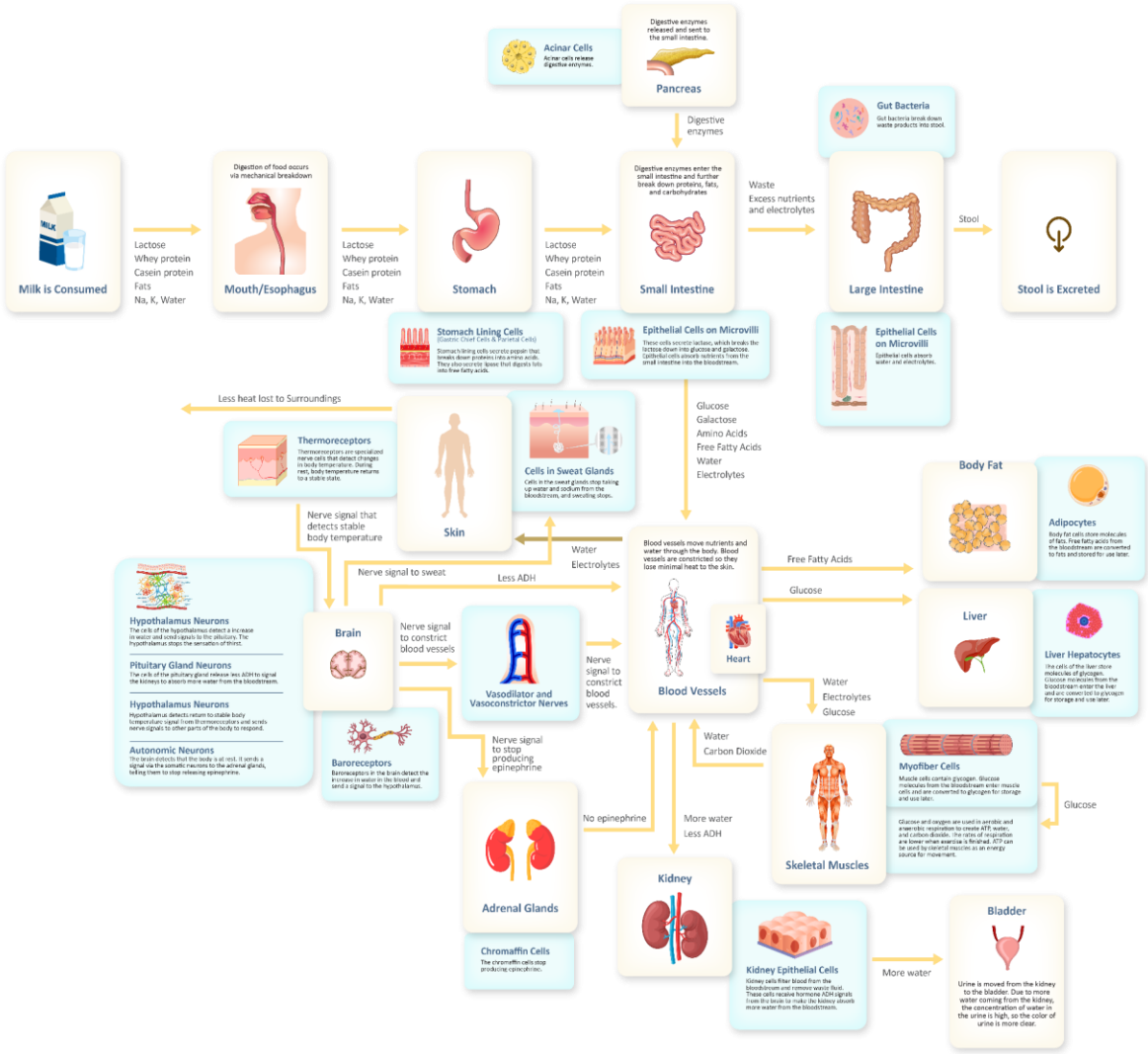
Below are examples of what a Class Consensus Model may look like, though you will want to follow the ideas of your class rather than drive them to this exact model.

Example Class Consensus Models

Exercise Effects Model



Recovery Model



Navigate to the next lesson by sharing that students will return to the Anchor Phenomenon and update their presentations on how milk helps athletes recover from intense exercise.