TEACHER GUIDE
EXPLORE 1D LESSON 19

Module Questions: *Why are there so many changes to my body during exercise? How does milk help with recovery from these changes?*		
What We Figure Out: We figure out that high-intensity exercise triggers many different things in the body related to producing energy for exercise. We learn that starting high-intensity exercise triggers anaerobic cellular respiration that uses the glucose molecules to produce 2 ATP molecules to be used by muscle cells for movement, carbon dioxide, lactate, and H^+ ions as byproducts. High-intensity exercise also triggers a response in the brain to signal the adrenal glands to release epinephrine into the bloodstream. This increases our heart rate and breathing rate and causes the liver and muscles to release more glucose (by breaking down glycogen into glucose). These changes allow more glucose and oxygen to be available for aerobic and anaerobic respiration in the muscle cells to produce ATP that can be used by the muscle fibers for movement. Excess carbon dioxide comes from both anaerobic respiration and aerobic respiration, which is exhaled by the body out of the lungs. The burning sensation and fatigue come from the buildup of lactate and H^+ accumulating in the muscles. There are pain receptors in muscle cells that sense the drop in pH, tell the brain, and the brain sends back a pain signal to those muscles to encourage them to slow down so that the lactate and H+ can be removed from the muscles.		
3D Learning Objective: Students use a model to explain how increased rates of aerobic and anaerobic respiration lead to changes in the body during exercise.	**Time estimate:** 150 minutes	**Materials:** Lesson 19 Student Guide Lesson 19 Student Handout Science Theater Cards Lesson 19 Teacher Resource Science Theater Directions
Targeted Elements		

SEP:	DCI:	CCC:
MOD-H5: **Use a model to provide mechanistic accounts of phenomena.**	**LS1.A-H1:** **Systems of specialized cells within organisms help them perform the essential functions of life.** **LS2.B-H1:** Photosynthesis and **cellular respiration (including anaerobic processes) provide most of the energy for life processes.**	**SC-H1:** **Much of science deals with constructing explanations of how things change and how they remain stable.**

Directions

Part 1: Our Motivation

USE OF PHENOMENA
Between Lessons 16-20, students will focus on the topic of exercise from the Module Phenomenon. In Lessons 21-22, they will focus on the topic of recovery from the Module Phenomenon. In Lesson 23, they will investigate a related phenomenon. They will return to the Anchor Phenomenon in Lesson 24 and revise their presentations to help their peers understand how milk can help them recover from exercise.

Have students revisit the explanations they constructed in Lesson 18 Part 4: Constructing Explanations. Invite a few students to share the explanation they constructed or one they heard. These might sound like:

- 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.
- When epinephrine levels increase, my heart feels like it is pounding.
- Decreasing muscle glycogen levels make muscles burn.

Remind students that based on their explanations, they added several new questions to the Driving Question Board. Return to it and focus on the questions specifically added to the board at the end of Lesson 18. Most of these questions likely ended up in the *Exercise, Milk & Energy* category. Examples of these questions include:

- Does epinephrine make my heart pound?
- Does epinephrine give me energy?
- Why do blood glucose levels go up? Isn't glucose being used to make ATP?
- How much glucose can the liver release? Is it unlimited?
- Can you eventually use up your blood glucose?
- Do my muscles get tired when muscle glycogen levels are low?
- Do my muscles burn when lactate levels go up?
- Does lactate make my muscles sore?
- Does low pH make my muscles hurt?

Build off student explanations and questions to point out that, in general, while the data sets students analyzed showed some of the measurable variables that change in the body during intense exercise, students are still not able to make sense of why we experience so many changes in our bodies during intense exercise. Students can record these current explanations and their questions on their Lesson 19 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.

Part 2: Using a Model of Increased Breathing Rate, Heart Rate, and Fatigued/Burning Muscles During Intense Exercise

Remind students that in the previous two modules, they've been able to use a Science Theater model to better understand different processes happening inside the body. Ask students, "How could we benefit from using Science Theater to model this process?" Example responses might include the following:

- Science Theater might help us understand how the variables we looked at in the different data sets are related.
- Science Theater might help us see the order of how things are changing during exercise or how one thing causes another.
- Science Theater might help us explain why our heart rate, breathing rate, and muscle fatigue increase during exercise.

Agree that using a Science Theater model of what is happening inside the body during intense exercise will be a useful next step in moving them toward explaining the Module Phenomenon. Share with students that to start figuring out what is going on inside the body to increase our breathing rate, heart rate, and to make our muscles tired/burn, students will use once again a Science Theater activity. Additionally, share that we can use the Science Theater model to help figure out how our muscles get energy for movement.

INTRODUCTION TO ROLES:

Introduce students to the different roles in Science Theater, each of which is a specialized cell within an organ that is involved in breathing the cardiorespiratory system:

- Lungs - Alveolar epithelial cells
- Skeletal muscles - Myocytes
- Blood Vessels - Red blood cells
- Heart - Pacemaker Cells & Myocytes
- Brain & Autonomic Nerves - Neurons
- Brain & Somatic Nerves - Neurons

SETUP:

Use the Lesson 19 Student Handout Science Theater Card Set and Lesson 19 Teacher Resource Science Theater Directions to set up the room. Show students the setup of the room, including where each of the tables are that represent each of the organs and the specialized cells in the organ. Ask students how the setup of this activity compares to the setup of Science Theater from Lesson 11. Student responses may vary, but be sure to emphasize that different organs and specialized cells are involved in this process. Share that once again, students will use a fishbowl method, where half of the class engages in the Science Theater activity, and the other half observes the overall model as it is carried out.

TEACHER SUPPORT

This is the fourth of five Science Theater activities in this unit. Before starting, you may want to remind students of the norms you established in Lessons 4, 9, and 11. Reflect on any successes and areas of improvement in how they previously engaged in Science Theater so that they can make improvements.

ROLE ASSIGNMENT:

Next, assign roles to students and instruct students to move their assigned positions. Alternatively, students may also choose roles.

TEACHER SUPPORT
Depending on the number of students in your classroom, you may choose to assign one student to each role, or each role can be completed by a pair or trio of students. You may also want to assign roles based on student ability or interest. The role of the Brain & Somatic Nerves is the least complex role to play, and the Skeletal Muscle is the most complex role in this Science Theater model.

PREPARATION:

Allow some time for students to:

- Summarize their role of the organ/specialized cells they played including the actions they took and the other organs/cells with whom they interacted.
- Summarize what they observed in the model in the graphic organizer provided.

STUDENT SUPPORT
If you think your students still need additional support to move from one scale to another when analyzing these models, you can ask students to refer back to their Lesson 3 Orders of Magnitude tool and/or to record several examples of the structures shown in these models on the tool.

MODEL ENACTMENT - ACT 1:

Begin the activity by saying what process students will be modeling. In this case, you can say something like, “We will model what happens in the body during high-intensity exercise.” Remind students that when they complete an action, they should verbalize what organ/cell is doing the action, what the action is, and show any tokens to the observers so that the observers will know what is happening at each step of the model. Allow time for students to carry out the model.

OBSERVATION AND REFLECTION:

As students work, circulate the room to support students in engaging in the model and in observing the model. Students can write responses on their Lesson 19 Student Guide Part 2: Using a Model of Increased Breathing Rate, Heart Rate, and Fatigued/Burning Muscles During Intense Exercise. You can use questions like:
Modelers:

- What is the responsibility of your organ? What other organs will you interact with?
- What function do specialized cells carry out in your organ?
- What changes or signals from other cells are you looking for to respond to?

- What does it say you do with the (molecules?) Where do you get them from? What happens to them while they are within you? Where do you hand them next?
- How is your organ responding to changes in the body? How does it help the body return to a stable state?

Observers:

- What are you seeing overall?
- What are (specific cell type) doing at (specific organ)?
- What changes are happening?
- How do breathing and heart rate seem to be linked?
- What are two ways the skeletal muscle can obtain glucose for cellular respiration?

MODEL ENACTMENT - ACTS 2-4:

When students have finished modeling Act 1, announce each subsequent act by stating the number of the act and what is being modeled. For example, for Act 2, state that "Now you will all model what happens in the body as exercise continues and the heart rate and breathing rate increase. After all four acts of the model are complete, give students a moment to finish collecting their notes, then have students switch roles between modelers and observers. Engage in all acts of the model a second time.

OBSERVATION AND REFLECTION:

After each implementation of the model, allow students time to summarize the role their cells or organ played in Science Theater on their Lesson 19 Student Guide Part 2: Using a Model of Increased Breathing Rate, Heart Rate, and Fatigued/Burning Muscles During Intense Exercise.

FORMATIVE ASSESSMENT OPPORTUNITY

Students use a model to explain how increased rates of aerobic and anaerobic respiration lead to changes in the body during exercise.

Assessment Artifacts:

- Students' use of the model to summarize what changes in the body occur to produce cellular energy for exercise and to increase breathing rate, heart rate, and muscle burning (Lesson 19 Student Guide Part 2: Using a Model of Increased Breathing Rate, Heart Rate, and Fatigued/Burning Muscles During Intense Exercise).
- Students' reflection on how the lens of stability and change was useful in figuring out how the specialized cells support the body to produce cellular energy for exercise (Lesson 19 Student Guide Part 2: Using a Model of Increased Breathing Rate, Heart Rate, and Fatigued/Burning Muscles During Intense Exercise).

Look Fors:

- Students use the Science Theater model to provide a mechanistic account of how increased rates of aerobic and anaerobic respiration during exercise lead to changes in the body, including increased heart and breathing rates and muscle burn and fatigue (MOD-H5, LS2.B-H1, SC-H1).
- Students use the Science Theater model to explain how intense exercise uses ATP from both aerobic and anaerobic respiration for energy for movement (SC-H1, LS2.B-H1).
- Students describe how specialized cells in each organ contribute to the function of the organ (LS1.A-H1).

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	How Changes in Heart Rate, Breathing Rate, Fatigue, and Production of Cellular Energy Occur: During exercise, breathing rate and heart rate increase because the body is working harder and needs to get more oxygen to the muscle cells. The muscle cells use oxygen to make energy. Muscles burn because there is a buildup of hydrogen ions. Reflection on Stability and Change: A lot of different changes happen in the body to produce energy for movement. Some changes are the increased heart rate, increased	How Changes in Heart Rate, Breathing Rate, Fatigue, and Production of Cellular Energy Occur: Electrical signals from the brain trigger the adrenal glands to release epinephrine. Epinephrine travels in the bloodstream to reach the lungs, heart, liver, and skeletal muscles. In the skeletal muscles and liver, epinephrine releases glucose. In the heart, epinephrine makes the heart beat faster. In the lungs, airways are opened, and the breathing rate increases. Contracting skeletal muscles utilize and require more ATP during intense exercise. They use aerobic and anaerobic respiration to generate the ATP. They get the resources (oxygen, glucose) for these	How Changes in Heart Rate, Breathing Rate, Fatigue, and Production of Cellular Energy Occur: Electrical signals from the brain trigger the chromaffin cells in the adrenal glands to release epinephrine. Epinephrine travels in the bloodstream to reach the lungs, heart, liver, and skeletal muscles. In the skeletal muscles and liver, epinephrine triggers myocytes and hepatocytes to break down their glycogen stores to glucose. In the heart, epinephrine triggers pacemaker cells, which make the heart beat faster and the cardiomyocytes to contract harder. In the lungs, airways are opened, and the breathing rate increases. Contracting skeletal muscles utilize and require more ATP during intense exercise. They use aerobic and anaerobic respiration to generate the ATP. They get the resources (oxygen, glucose) for these processes from the bloodstream. Anaerobic cellular respiration uses glucose to generate small amounts of ATP. Aerobic cellular

	breathing rate, and more blood flow.	processes from the bloodstream. The burning sensation in muscles during intense exercise can be a result of H+ ions that build up during anaerobic respiration and lower pH. Reflection on Stability and Change: We observed that the body undergoes numerous changes to produce cellular energy as exercise occurs. As the body begins exercising, the need for ATP to contract muscles rapidly increases, so there is more ATP generated by the muscle cells using anaerobic and aerobic respiration.	respiration uses glucose and oxygen to generate large amounts of ATP. The burning sensation in muscles during intense exercise can be a result of H+ ions that build up during anaerobic respiration and lower pH. The brain is alerted via nerve cells and sends a pain signal in response. Reflection on Stability and Change: We observed that the body undergoes numerous changes to produce cellular energy as exercise occurs. At the stable state at rest, the body does not have a large need for cellular energy (ATP). As the body begins exercising, the need for ATP to contract muscles rapidly increases. As a result, the body undergoes several changes to make this happen. It makes the cardiomyocytes and pacemaker cells in the heart beat faster and breathing rate increases. The alveolar epithelial cells can get more oxygen into the bloodstream and more carbon dioxide out of the bloodstream. Getting more oxygen to the muscles allows the myocytes to use oxygen for aerobic respiration. The muscles break down liver and muscle glycogen, so more glucose is available for aerobic and anaerobic respiration.
How to Achieve This Level	Student completes 0 out of 3 Look Fors	Student completes 1-2 out of 3 Look Fors	Student completes 3 out of 3 Look Fors

To Provide Additional Support for Students:
If students need additional support engaging with the model or in understanding what components, relationships, or processes the model is demonstrating, consider:

- Pausing the enactment of the model as needed and asking students to review the description of their organ's function or of their role.
- Building in intentional pauses in the model for students to record what they observe and what they are doing.

- Having students read their role cards as a group and rehearsing what they will do before enacting the model.

DISCUSSION AND ANALYSIS:

After students record their ideas, bring the class together to hold a whole-class discussion for students to share what they found. As students share, you may want to refer to the changes observed in the data sets from Lesson 18 that correspond to each process that students are sharing. This may help make connections between what students observed in Science Theater and the changes that they observed in the data. Facilitate the discussion, so students agree that:

- The heart pumps blood through the blood vessels, which transports oxygen, carbon dioxide, and glucose to skeletal muscles.
- Oxygen is inhaled and enters the mouth/nose, trachea, and lungs. Oxygen moves across the alveoli epithelial cells into the red blood cells, where they bind to hemoglobin.
- Carbon dioxide travels the opposite path to be released to the lungs by the alveolar epithelial cells so they can be exhaled.
- Contracting skeletal muscles utilize and require more ATP during intense exercise. They use aerobic and anaerobic respiration to generate the ATP.
  - Anaerobic cellular respiration uses glucose to generate ATP and byproducts, including carbon dioxide, lactate, and H+ ions.
    - H+ ions that build up during anaerobic respiration and lower pH. The brain is alerted via nerve cells and sends a pain signal in response.
  - Aerobic cellular respiration uses glucose and oxygen to generate ATP and produces water and carbon dioxide as byproducts.
- Specialized cells, including myocytes and hepatocytes, can store extra glucose molecules as glycogen, which can be converted back to glucose during intense exercise.
  - Myocytes use their glycogen stores to produce glucose directly in the muscle cells.
  - Hepatocytes release the glucose from their glycogen stores into the bloodstream to travel to muscle cells.
- Electrical signals from the brain trigger the chromaffin cells in the adrenal glands to release epinephrine.
  - Epinephrine travels in the bloodstream to reach the lungs, heart, liver, and skeletal muscles.
    - In the skeletal muscles and liver, epinephrine triggers myocytes and hepatocytes to break down their glycogen stores to glucose.
    - In the heart, epinephrine triggers pacemaker cells, which make the heart beat faster and the cardiomyocytes to contract harder.
    - In the lungs, airways are opened, and the breathing rate increases.
- The burning sensation in muscles during intense exercise can be a result of H+ ions that build up during anaerobic respiration and lower pH. The brain is alerted via nerve cells and sends a pain signal in response.

After the discussion, ask students to reflect on how the lens of stability and change was used in the Science Theater model to show how the body produces energy from exercise. Use a Think-Pair-Share for students to share their responses.

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:

- We observed that the body undergoes numerous changes to produce cellular energy as exercise occurs. In the stable state at rest, the body does not have a large need for cellular energy (ATP). As the body begins exercising, the need for ATP to contract muscles rapidly increases.
- As a result, the body undergoes several changes to make this happen. It makes the heart beat faster, and the breathing rate increases to get more oxygen to the muscles so that the muscles can use it for aerobic respiration. It breaks down liver and muscle glycogen so more glucose is available for aerobic and anaerobic respiration.

CCSS 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 ideas may differ, it is important to emphasize that how each student experienced that model may be different but what we are looking for are understandings based on evidence. You may want to ask students to discuss the difference between evidence vs. opinion when discussing during a class discussion and analysis.

CONCLUSION:

Remind students that in Lesson 18, they figured out that much of the science of studying how the human body responds to exercise involves studying changes that occur to various factors in the body. Ask students if they think this understanding still holds true based on what they observed in Science Theater. Acknowledge student responses and confirm that now students can see that there are numerous, interrelated changes that occur in the body to produce cellular energy for exercise. Scientists aim to study how each of these changes relates to each other to help the body exercise, just as students figured out in Lessons 18 and 19.