TEACHER GUIDE
EXPLORE 1 LESSON 9

Food and Agriculture Center for Science Education

Module Questions: ***Why do we get sweaty and thirsty after exercise? Why does the color of our urine change? How does milk help us recover from these effects?***

What We Figure Out:

We figure out that body temperature rises while working out and eventually returns to normal after exercise. Body temperature goes up due to exercise, and thermoreceptors detect the temperature rise and send a signal to the brain. The brain sends nerve signals to sweat glands, which produce sweat to lower the body temperature. At the same time, muscle cells detect the need for additional nutrients to use in movement, and they send signals like nitric oxide to nearby blood vessels, causing them to dilate. This widening of blood vessels, known as vasodilation, allows warm blood to go to the surface of the body to be cooled by the surrounding environment.

3D Learning Objective:	**Time estimate:**	**Materials:**
Students obtain information from a scientific journal article to describe how a negative feedback mechanism can help stabilize body temperature after exercise. Students use a model to provide an explanation of how the body uses a negative feedback mechanism to stabilize body temperature after exercise.	100 minutes	Lesson 9 Student Guide Lesson 9 Student Handout Science Theater Card Set Lesson 9 Teacher Resource Science Theater Directions

Targeted Elements

SEP:	DCI:	CCC:
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.** **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.** **LS1.A-H4:** **Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.**	**SC-H3:** **Feedback** (negative or positive) **can stabilize or destabilize a system.**

Directions

Part 1: Our Motivation

USE OF PHENOMENA
Between Lessons 9-12, students will focus on the Module Phenomenon. In Lesson 14, they will return to the Anchor Phenomenon to create presentations on how milk can help athletes recover from exercise.

Remind students that they concluded the last lesson by identifying gaps in their explanations describing how they think we get sweaty, thirsty, and experience changes in urine color after exercise and how milk helps them recover from these changes. Ask students to share what some of those gaps were. In student responses, listen for the following ideas:

- We don't know why body temperature goes up during exercise.
- We aren't sure why body temperature goes back down after exercise.
- We don't understand how sweat helps the body cool down.
- We still aren't sure of how we get thirsty during exercise.
- We still don't know how milk can help an athlete recover from exercise.
- We are still unsure of why our urine changes from a lighter to a darker color during exercise.
- We don't know how/if all these changes have to do with changes to water in the body.

Build off student responses to share that we will now gather evidence on how body temperature change during and after exercise plays a role in producing sweat. Hold a class discussion with students to determine what Driving Question Board questions and category they want to explore next. Facilitate the conversation to get students to focus on questions related to temperature changes during/after exercise. Share a few selected questions from the Driving Question Board that align with what students will investigate in the upcoming lesson.

Example student questions or ideas could include:

- Why does body temperature elevate during a workout?
- Why does your body temperature return to normal after it elevates?
- How long does it take body temperature to return to normal after working out?

Students can record these questions on their Lesson 9 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 Anchor and Module Phenomena.

Part 2: Analyzing Body Temperature Data

Share with students that we will first look at new data in this lesson to figure out more closely how the body temperature changes during exercise. Direct students to Lesson 9 Student Guide Part 2: Analyzing Body Temperature Data. Share that this data set provides some new information about how body temperature changes during and after exercise. Allow students time in groups or pairs to analyze and paraphrase the experiment design and to analyze the data. As students work, ask them pressing questions to help with their interpretation of the experiment design and the data and provide feedback. Questions and feedback might include:

- What was the goal of the study? How was this study designed? What were the scientists measuring?

- What trends do you see in the data?
- How can you use a lens of stability and change to analyze this data?
- Where in the data did you specifically observe the information you cited as evidence in your interpretation?
- Does the data you observed match what you were expecting based on the experimental design?

FORMATIVE ASSESSMENT OPPORTUNITY

Students obtain information from a scientific journal article to describe how a negative feedback mechanism can help stabilize body temperature after exercise.

Assessment Artifacts:

- Students' analysis of the experimental methods and data from the scientific journal article (Lesson 9 Student Guide Part 2: Analyzing Body Temperature Data).
- Students' analysis of the data using the lens of stability and change (Lesson 9 Student Guide Part 2: Analyzing Body Temperature Data).

Look Fors:

- Students accurately paraphrase the experimental design of the experiment from scientific literature (INFO-H1).
- Students use evidence from the data to support their response (INFO-H1).
- Students describe the stable state and changes that occur in body temperature before, during, and after exercise (LS1.A-H4, SC-H3).

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	Experimental design summary: The experiment was designed to measure the changes in body temperature before, during, and after exercise. Trends observed:	Experimental design summary: The experiment was designed to measure the changes in body temperature before, during, and after exercise. Trends observed:	Experimental design summary: The experiment was designed to measure the changes in body temperature from before, during, and after exercise in two different conditions: room temperature and at 4° C. Exercisers rode on a stationary bike for 30 minutes and had their internal ear temperature taken in 15-minute intervals (before exercise), 4-minute intervals (during

	The core body temperature went up, then went down again. Stability and change: The core body temperature changed during exercise.	The core body temperature in both conditions at first at rest did not change much, but then it increased. Both body temperatures returned to approximately their starting temperatures during the recovery period after exercise. Stability and change: Prior to exercise, the body temperature is stable. When the person is exercising, this makes the body temperature change and increase. When the person is done exercising, this also makes the body temperature change and decrease back to its original stable state.	exercise), and 10-minute intervals (after exercise). Trends observed: The core body temperature in both conditions at first at rest did not change much, then it increased by about 0.8° C at room temperature and by about 0.6 ° C in the 4 ° C condition. Both body temperatures returned to approximately their starting temperatures during the recovery period after exercise. Stability and change: Prior to exercise, the body temperature is stable. When the person is exercising, this makes the body temperature change and increase. When the person is done exercising, this also makes the body temperature change and decrease back to its original stable state.
How to Achieve This Level	Student completes 0-1 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 analyzing the experiment design or the data, consider:

- Providing students with a graphic organizer that helps them identify the goal of the study, the independent variable, the dependent variable, the controlled variables, and the way data is being gathered.
- Providing students with a data analysis strategy, such as breaking the graphs into approximately four parts and annotating what changes they see in each part of the graph.
- Providing sentence stems for data analysis, such as:
    - As _____ increases/decreases, we see _____ increasing/decreasing.
    - This graph shows that, over time, _____ was increasing/decreasing.
    - One major trend I saw in this graph was…
- Provide access to this "How to read line graphs" video starting at the 5:00 mark to offer extra support.

SEP SUPPORT
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.

Here, students are analyzing the experiment design and outcome from one scientific research article. They will repeat the use of this SEP in Lesson 11. Later, in Modules 3 and 4, they will progress to comparing the design and outcomes from two or more scientific research studies when using SEP DATA-H4. Accordingly, in this lesson, monitor for students who need support in analyzing the design and outcomes of an experiment and support students as needed so they are ready to progress to the more complex analysis in Modules 3 and 4.

CCSS SUPPORT ELA-LITERACY RST.9-10.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

To support students in achieving this standard, consider modeling and providing examples of how to extract relevant details from the text to enhance students' understanding and analysis. Additionally, support students in developing skills to articulate their interpretations and insights based on the evidence gathered from the text.

When ready, use a Think-Pair-Share to have students share their summaries of the experiment design and the trends they found in the data set. Facilitate the conversation so that students agree that:

- The experiment was designed to measure the changes in body temperature from before, during, and after exercise in two different conditions: room temperature and at 4° C. Exercisers rode on a stationary bike for 30 minutes and had their internal ear temperature taken in 15-minute intervals (before exercise), 4-minute intervals (during exercise), and 10-minute intervals (after exercise).
- The core body temperature in both conditions at first at rest did not change much, then it increased by about 0.8° C at room temperature and by about 0.6 ° C in the 4 ° C condition. Both body temperatures returned to approximately their starting temperatures during the recovery period after exercise.

Next, ask students how they can use the lens of stability and change to analyze the results of this experiment. Use a Think-Pair-Share to build off student observations to name features of the pattern that students described. Share that the core body temperature has a **stable**

state temperature at which it operates during rest – approximately 36-37° C. Then, the temperature changes in response to exercise. Then, eventually, when resting again, the core body temperature returns to its stable state.

DCI SUPPORT
LS1.A-H4: Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

Observing this pattern in temperature change of the body before, during, and after exercise is meant to support students in beginning to develop an understanding of how the body has feedback mechanisms that stabilize internal conditions as external conditions change. Here, students see that from the perspective of a measurable quantity, such as temperature, it has a stable state and can change when exercising but, upon rest, will return to a stable state. In Part 3 of this lesson, students will go further into this observed change to explain the physiological mechanisms responsible for the observed changes in temperature.

CCC SUPPORT
SC-H3: Feedback (negative or positive) **can stabilize or destabilize a system.**

In this prompt, students are asked to use the concept of stability and change to explain their thinking. This is an initial support for students to begin using this lens as a way for them to see that the body has a stable state in its internal temperature, which then can change as exercise occurs or rest occurs. In Part 3, they will continue to figure out the exact feedback mechanisms responsible for returning the body's temperature to its stable state.

Transition to the next activity by sharing that students will figure out more about **how** the body is able to respond to exercise to both increase and decrease its core body temperature.

Part 3: Using a Model of Temperature Change During Exercise

Next, students will use a model of the physiological processes that regulate temperature change in the body in response to exercise. Students will once again use a Science Theater activity to do so. Share with students that they left off the previous activity wondering how

body temperature changes during exercise and how it returns to its stable state after exercise. To help figure this out, students will engage in a Science Theater activity.

INTRODUCTION TO ROLES:

Introduce students to the different roles in the Science Theater, each of which is a specialized cell within an organ that is involved in the way the body maintains its core temperature and responds to changes in temperature:

- Brain (hypothalamus) - Neurons
- Nerves: Thermoreceptor Neurons
- Skeletal muscles - Myocytes
- Blood vessels
- Sweat glands - Myoepithelial cells

SETUP:

Use the Lesson 9 Student Handout Science Theater Card Set and Lesson 9 Teacher Resource Science Theater Directions to set up the room. Show students the setup of the room, including the location of each table representing each of the organs and the stations at each table representing the different types of cells in the organ. Ask students how the setup of this activity compares to the setup of Science Theater from Lesson 4. Student responses may vary, but be sure to emphasize that there are different organs and different specialized cells 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.

TEACHER SUPPORT

This is the second of five Science Theater activities in this unit. Before starting, you may want to remind students of the norms you established the first time in Lesson 4 and 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 (or let them choose roles) and instruct students to move their assigned positions.

TEACHER SUPPORT

Depending on the number of students in your classroom, you may assign one student to each role, or a pair or trio of students can complete each role. You may also want to assign roles based on student ability or interest. The Blood Vessels are likely the least complex

when it comes to the actions modeled during the activity.

PREPARATION:

Allow some time for students to review the summary of their organ and cells, the actions their role will take, and to organize the different tokens at their station. Students can record a summary of the role their cells or organ will play in Science Theater in their Lesson 9 Student Guide Part 3: Using a Model of Temperature Change During Exercise. Remind students that when they complete an action, they should verbalize what organ/cell is doing the action, verbalize 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.

DCI SUPPORT

LS1.A-H1: Systems of specialized cells within organisms help them perform the essential functions of life. In middle school, students learned that the body is made up of interacting subsystems that contain organs, tissues, and cells and that tissues form organs that have specialization for particular body functions. In this lesson, students build on this middle school understanding to explain the function of organs during exercise. In all modules of the unit, students develop and/or revise explanations and use models that include the ways in which specialized cells carry out various biological processes associated with exercise recovery.

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, “Now we will model what happens in the body when a person is exercising.” Allow time for students to carry out the first act of the model.

TEACHER SUPPORT

At any time during the Science Theater, you can call a “time-out” to reiterate directions, allow students time to process actions that have occurred or next steps, or highlight a certain action. You can also give the students the autonomy to call a student “time-out” to clarify their role or point out a certain action.

SEP SUPPORT

MOD-H5: Use a model to provide mechanistic accounts of phenomena. In middle school, students develop models to predict and/or describe phenomena. In this unit, students build on this middle school understanding to use models to provide mechanistic explanations of phenomena. In this module, students engage in a Science Theater activity to help figure out why temperature changes during exercise. Students are given roles to engage in modeling the biological processes the body experiences during exercise. They use this model to demonstrate the mechanism by which these changes to the body occur. A similar mechanistic modeling activity occurs in all other unit modules as well.

OBSERVATION AND REFLECTION:

As students work, circulate the room to support students in engaging in the model and in observing the model. Students should write their observations on their Lesson 9 Student Guide Part 3: Using a Model of Temperature Change During Exercise. You can use questions like:

Modelers:

- What is the responsibility of your organ and cells? What other organs and cells will you interact with?
- What function do specialized cells carry out in your organ?
- What does it say you do with the (token/signal)? Where do you get them from? What happens to them while they are within you? Where do you hand them next?
- What changes or signals from other cells are you looking for to respond to?
- How do you think the responses of these cells and organs are helping the body return to its stable state for body temperature?

Observers:

- What are you seeing overall?
- What is happening to [molecule] at [organ]?
- What changes are happening in the body to help it return to its stable state?

MODEL ENACTMENT - ACT 2:

When students have finished modeling the exercise portion of the model (Act 1), have them return to their original positions and announce that they will model what happens when the person stops exercising and is at rest (Act 2).

After the model is complete, give students a moment to finish collecting their notes, then have students switch roles between modelers and observers. Engage in both scenarios of the model a second time.

After the second implementation of the model, allow students time to summarize what they observed in the model in the graphic organizer provided. Share with students that they will use the lens of stability and change to reflect on the processes that the body used to respond to changes that were occurring in body temperature and the processes the body used to try to bring its temperature back to the stable state. Students should record this in the graphic organizer at the end of Lesson 9 Student Guide Part 3: Using a Model of Temperature Change During Exercise.

FORMATIVE ASSESSMENT OPPORTUNITY

Students use a model to provide an explanation of how a living system's internal conditions change due to an outside factor and how the living system responds to stabilize the system to keep conditions within a normal range.

Assessment Artifacts:

- Students' explanations of how the body responds to changes in temperature due to exercise, located in the graphic organizer (Lesson 9 Student Guide Part 3: Using a Model of Temperature Change During Exercise).

Look Fors:

- Students use the Science Theater model to provide a mechanistic account explaining in writing how multiple body systems and cells interact to regulate body temperature (MOD-H5).
- Students describe how the organ and its specialized cells contribute to a negative feedback mechanism (though students do not yet use this term) to respond to body temperature change and bring body temperature back to a stable state (LS1.A-H4, SC-H3).
- Students describe how specialized cells in each organ contribute to the function of the system or organ (LS1.A-H1).

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	The body has different ways to help make the temperature go down when exercising. When exercising, the body sweats to cool it and bring the temperature down. It also makes more blood flow to the skin to release heat.	When exercising, the muscles and skin sense the temperature increase that occurs during exercise. They send nerve signals to the brain. The hypothalamus in the brain detects the signal from the nerves. The hypothalamus sends signals to sweat glands to release sweat and cool the body. The hypothalamus also	When exercising, thermoreceptors (specialized nerve cells) in the muscles and skin sense and report the temperature increase that occurs during exercise. The thermoreceptors send nerve signals to the brain. The hypothalamus in the brain detects the signal from the nerves. The hypothalamus sends signals via nerves to sweat glands to release sweat and cool the body. Sweat cools the body to decrease body temperature back to its

		sends signals to blood vessels to increase blood flow from the body's core to the body's surface. At rest, the skin and muscles sense the temperature decrease that occurs after stopping exercise. They send signals to the brain. The hypothalamus in the brain detects the signal and sends a signal to the sweat glands to stop producing sweat. The hypothalamus also sends signals to the blood vessels to decrease blood flow from the body's core to the body's surface.	stable state. The hypothalamus also sends signals via nerves to the vasodilatory nerves to increase blood flow from the body's core to the body's surface. Blood flow to the body's surface makes heat move from the body to the body's surroundings, cooling the body to bring body temperature back to its stable state. At rest, thermoreceptors (specialized nerve cells) in the skin and muscles sense and report the temperature decrease that occurs after stopping exercise. The thermoreceptors send nerve signals to the brain. The hypothalamus in the brain detects the signal from the nerves and sends a signal to the sweat glands to stop producing sweat. The body sweats less, helping to maintain the decreased body temperature at its stable state. The hypothalamus also sends signals via nerves to the vasoconstricting nerves to decrease blood flow from the body's core to the body's surface. Less blood flow to the body's surface maintains heat in the body's internal core, helping to maintain body temperature.
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 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 parts of the graph in Part 2 that correspond to each process that is occurring. Record the class consensus on the front board in a graphic organizer that is similar to the one on the student handout.

Facilitate the discussion so that students agree that:

- During exercise, the muscle cells use cellular energy to contract and expand to move the body. This process generates heat that increases the body's temperature.
- During exercise, thermoreceptors (specialized nerve cells) in the skin and muscles sense and report the temperature increase that occurs during exercise via nerve signals to the brain. The hypothalamus in the brain detects the signal from the nerves. The hypothalamus sends signals via nerves to sweat glands in the skin to release sweat and cool the body.
- During exercise, the blood vessels throughout the body dilate to increase blood flow and bring warm blood from the body's core to the surface of the body so that its heat can be transferred to the surroundings.
- When resting, muscle cells generate less heat due to fewer contractions occurring. This process maintains but does not increase body temperature.
- When resting, thermoreceptors (specialized nerve cells) in the skin, muscles, and internal organs sense and report the temperature decrease that occurs after stopping exercise. The thermoreceptors send nerve signals to the brain. The hypothalamus in the brain detects the signal from the nerves and sends a signal to the sweat glands to stop sweating. This helps return and maintain body temperature to the stable state.
- When resting, the blood vessels throughout the body constrict, which lowers the rate of heat transfer from the blood to the surrounding environment. This returns and helps maintain the body's temperature at its stable state.
- The responses of the body during and after exercise related to sweat and body temperature are based on negative feedback mechanisms that help regulate the body and help it return to its stable state of conditions.

CONCLUSION:

Build off student responses to introduce the term **homeostasis** as the processes used by the body to maintain stable internal conditions, and body temperature is one measure that the body tries to maintain homeostasis. Further state that the body has **negative feedback mechanisms** that help the body return to its stable state of conditions when conditions, such as body temperature, move outside of a normal range. In this lesson, students figured out two feedback mechanisms the body uses to respond to an increase in temperature to bring the temperature back down to normal: the sweat response and the blood vessel dilation response.

DCI SUPPORT

LS1.C-H4: As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. **Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.**

While this is not a focal element for this unit, students are partially engaging with the bolded part of this DCI element in this lesson. Students figure out that muscle cells generate heat for the body both at rest and during exercise.