# TEACHER GUIDE
## EXPLORE 2 LESSON 11

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 the sensation of thirst during and after exercise and a change in urine color comes from a change in the amount of water in the body. When we sweat, we lose water in sweat, which both comes from the bloodstream. The water balance in the bloodstream decreases while someone is working out because water is lost to sweat. This brings the body out of its stable state. Osmoreceptors in the brain detect the decrease in water in the bloodstream and send a signal via the nerves to the hypothalamus. The hypothalamus detects this lack of water in the bloodstream and signals a perception of thirst. The pituitary also sends a hormone signal called ADH through the bloodstream to kidney epithelial cells, which causes the kidneys to absorb less water from the bloodstream and pass it to the bladder to make urine. Because less water is present in urine, the color of urine becomes darker, and the volume of urine decreases. The person then drinks a drink like milk to help recover water, which moves through the digestive system and into the bloodstream, restoring the stable condition.

| **3D Learning Objectives:** | **Time estimate:** | **Materials:** |
|---|---|---|
| Students obtain information from a scientific journal article to describe how a negative feedback mechanism can help stabilize blood water volume after exercise.<br><br>Students use a model to provide an explanation of how a living system's water balance changes due to exercise and how the living system responds to stabilize the water balance in the system. | 150 minutes | Lesson 11 Student Guide<br>Lesson 11 Student Handout Urinalysis<br>Lesson 11 Student Handout Science Theater Card Set<br>Lesson 11 Teacher Resource Science Theater Directions<br>2 Beakers or clear cups<br>Water<br>Yellow food coloring |

## Targeted Elements

| SEP: | DCI: | CCC: |
|---|---|---|
| **INFO-H1:**<br>**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.**<br><br>**MOD-H5:**<br>**Use a model to provide mechanistic accounts of phenomena.** | **LS1.A-H1:**<br>**Systems of specialized cells within organisms help them perform the essential functions of life.**<br><br>**LS1.A-H4:**<br>**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:**<br>**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 developing Class Consensus Effects of Exercise and Recovery Models that show the impacts of exercise on the body and the ways in which milk helps the body recover from these impacts. Ask students to review these models and determine if they fully answer the 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?* Use a Think-Pair-Share to invite a few students to share what some of those gaps are.

In student responses, listen for the following ideas:

- 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.

Build off student responses to share that we will now gather evidence on how body temperature during and after exercise plays a role in producing sweat. 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 do we get thirsty during a workout?
- Why does the color of our urine change after exercise?
- What role do milk nutrients have in exercise recovery?

Students can record these questions on their Lesson 11 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 Data About Urine Color

Share with students that we will start by looking at new data in this lesson to figure out why urine color changes after exercise.

First, ask students what their experiences are with when their urine color changes. Invite a few students to share their experiences. Listen for responses that share that urine color changes have something to do with drinking more or less water and when getting dehydrated or overhydrated. Share with students to record these observations on their Lesson 11 Student Guide Part 2: Analyzing Data About Urine Color, and keep these experiences in mind as we continue to figure out why urine color changes.

**STUDENT SUPPORT**

Students may have differing experiences and levels of comfort in sharing about bodily functions. If no student is willing to share, move along with the lesson to honor their privacy.

Direct students to their Lesson 11 Student Guide Part 2: Analyzing Data About Urine Color, and the Lesson 11 Student Handout Urinalysis. Provide students with time to review the data and record their interpretations. Hold a whole-class discussion for students to share their interpretations. Build off student contributions to confirm that the average urine color of these 16 athletes changed by about 1 point from before to after exercise – their urine color got darker, just like the urine of the woman in the Module Phenomenon.

Share with students that they will now build off the experiences they shared earlier to start to try to explain why urine color changes. Share that students thought urine color change had something to do with drinking more or less water. Build off this idea to introduce the demonstration. Show students two beakers with a few drops of yellow food coloring in each and explain that these beakers are a model that represents urine before exercise and after. Add 150 mL of water to the first sample and 50 mL of water to the second sample. Ask students to observe the two samples and record what they think this model can help them understand about why urine color changes after exercise on their Lesson 11 Student Guide Part 2: Analyzing Data About Urine Color.

Use a Think-Pair-Share to have students share what they notice and what they think the model represents.

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 for students to agree that:

- When more water is added to the yellow food coloring, the simulated urine is lighter in color. When less water is added, the simulated urine is darker in color. Urine color changes during exercise because the urine has less water in it. When you drink milk after exercising, it adds water because that is one of its components, so the urine color is a clearer color.

Follow the conversation by asking students what they think happened during exercise to make the urine have less water in it. Facilitate the conversation such that students agree that the body loses water in sweat during exercise, which means there is less water in the body to be present in urine, so the urine color gets darker.

Ask students how they think less water is in urine – where in the body did the water go? Build off student responses to agree that it was lost in sweat, and press students further to ask how the water went from where it is stored for urine, in the bladder, to get all around the body to be lost in sweat. Allow students to share ideas. Students may speculate that it has something to do with the skin and/or

circulation/bloodstream because these organs move molecules all throughout the body. Build off of these responses to share that we will now look at how the water blood to see if water is indeed lost from the blood during exercise.

## Part 3: Analyzing Data on Changes to the Water Content of Blood During Exercise

Introduce the experiment that students will analyze how the amount of water in the blood changes over time during exercise and during recovery from exercise. Share that while this study did not use milk as a recovery beverage, it used a beverage with some similar nutrients as in milk, such as carbohydrates and electrolytes. Allow students time in groups or pairs to analyze and paraphrase the experiment design and to analyze the data. Students can record their interpretations on their Lesson 11 Student Guide Part 3: Analyzing Data on Changes to the Water Content of Blood During Exercise. As students work, ask them pressing questions to help with their interpretation of the experiment design and the data. Questions 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?

**FORMATIVE ASSESSMENT OPPORTUNITY**

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

**Assessment Artifacts:**

- Students' analysis of the experimental methods and data from the scientific journal article (Lesson 11 Student Guide Part 3: Analyzing Data About the Water Content of Blood During Exercise).
- Students' analysis of the data using the lens of stability and change (Lesson 11 Student Guide Part 3: Analyzing Data About the Water Content of Blood During Exercise).

**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 blood volume before, during, and after exercise, using evidence from the data (LS1.A-H4, SC-H3).

**Assessment Rubric:**

| | Emerging | Developing | Proficient |
|---|---|---|---|
| **Sample Student Response** | Experimental design summary:<br>The experiment was designed to measure the changes in water in the blood before, during, and after exercise.<br><br>Trends observed:<br>Water in the blood went down, then up, then down again.<br><br>Stability and change:<br>The amount of water in the blood changed during exercise. | Experimental design summary:<br>The experiment was designed to measure the changes in body temperature before, during, and after exercise.<br><br>Trends observed:<br>As the person starts to exercise, the blood volume decreases, indicating less water in the blood. After exercising and drinking a beverage, blood volume increased back to its original state and even gained some. During the max effort workout, blood volume decreased again.<br><br>Stability and change:<br>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. | Experimental design summary:<br>The experiment was designed to measure how two different recovery beverages could help restore water in the blood after exercise. The researchers had participants undergo an exercise session, and then they drank one of the two beverages, then they did a max effort exercise session. They collected blood samples along the way to measure how the amount of water in the blood changed.<br><br>Trends observed:<br><br>As the person starts to exercise, the blood volume decreases by about 10%, indicating less water in the blood. After exercise and drinking a beverage, blood volume increased back to its original state and even gained about 10% more volume. During the max effort workout, blood volume decreased again by about 20% this time.<br><br>Stability and change:<br>Prior to exercise, the amount of water in the blood is at its stable state. Exercise results in a change in the amount of water in the blood as it decreased. But then, at rest and in the rehydration period, the water in the blood returned to its stable state and even increased. Then, it changed again in the max effort workout. There might be a feedback mechanism that occurs here, similar to how the body controls its temperature during exercise. |
| **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, similar to the practice they used in Lesson 9. 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, continue to 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.9-10.7** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
To support students in achieving this standard, consider modeling and providing examples of how to analyze and paraphrase relevant details from the text to enhance students' understanding and analysis. Additionally, this standard will support students in developing skills to articulate their interpretations and insights based on the evidence gathered from the text.

Hold a whole-class discussion for students to share their interpretations. Build off student contributions to agree that:

- The experiment was designed to measure how two different recovery beverages could help restore water in the blood after exercise. The researchers had participants undergo an exercise session, and then they drank one of the two beverages. Then, they did a max-effort exercise session. They collected blood samples along the way to measure how the amount of water in the blood changed.
- As the person starts to exercise, the blood volume decreases, indicating less water is in the blood. After exercise and drinking a recovery beverage, blood volume increases back to its original state. As the person starts the max-effort exercise, blood volume decreases again.
- The body has a stable state for the amount of water in the blood, and drinking a recovery beverage can help the amount of water in the blood return to that stable state.

Ask students to take stock of the changes they have observed so far in this lesson to help try to figure out why urine color changes after exercise and why you get thirsty. Start a class list to record each of the different ideas students have figured out, including:

- The color of urine becomes darker during exercise, indicating there is less water in the urine.
- The volume of the blood decreases during exercise, indicating there is less water in the blood.
- The person loses water via sweating.

From this list, ask students what each of these science ideas has in common. Build off student responses to confirm that each of them has to do with the amount of water in different parts of the body changing during exercise. Share that water loss in the body can somehow result in each of these different changes in the body, but that students aren't quite sure yet how all these different changes are connected in the body. Share that we will continue to investigate how changes to the amount of water in the body might have something to do with sweat, thirst, and urine color change. To do so, we will use a Science Theater Model.

## Part 4: Using a Model of Sweat, Thirst, and Urine Color Change

Next, students will use a model of the physiological processes that regulate water changes in the body in response to exercise. Share with students that they left off the previous activity wondering what ways in which changes to the amount of water in blood, urine, and sweat seemed to be connected to the experiences of thirst, sweat, and urine color change. To help figure this out, students will engage in a Science Theater activity.

**INTRODUCTION TO ROLES:**

Introduce students to the different roles in this version of Science Theater, each of which is an organ that is involved in controlling the amount of water in the body and the way the body responds to changes in the amount of water in the body.

- Brain: Hypothalamus neurons, Pituitary gland neurons
- Brain: Osmoreceptors
- Kidney: Kidney epithelial cells
- Bladder: Urothelial cells
- Blood Vessels

**SETUP:**

Use the Lesson 11 Student Handout Science Theater Card Set and Lesson 11 Teacher Resource Science Theater Directions to set up the room. Show students the setup of the room, including each of the tables that represent each of the organs. Ask students how the setup of this activity compares to the setup of Science Theater from Lessons 4 and 9. Student responses may vary, but be sure to emphasize that there are different organs 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 third of five Science Theater activities in this unit. Before starting, you may want to remind students of the norms you established in Lessons 4 and 9 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 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 11 Student

Guide Part 2: Using a Model of Sweat, Thirst, and Urine Color Change. After students have summarized their actions, 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.

**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 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.

**OBSERVATION AND REFLECTION:**

As students work, circulate the room to support them in engaging in the model and observing it. Students should write their observations on their Lesson 11 Student Guide Part 4: Using a Model of Sweat, Thirst, and Urine Color Change. You can use probing 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 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?
- 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 the amount of water in the bloodstream?

Observers:

- What are you seeing overall?
- What is happening to [molecule] at [organ]?
- What changes are happening to the molecules?

**MODEL ENACTMENT-ACT 2:**

When students have finished modeling the exercise portion of the model (Act 1), announce that they will next model what happens when the person stops exercising and drinks milk to recover (Act 2). Here, you may first want to draw students' attention to the Class Consensus Recovery Model from Lesson 10 and ask students to describe what they recall about what happens to the water molecules from milk after milk is consumed. Build off student responses to confirm that the water molecules eventually make their way to the bloodstream after going through the digestive system. Students can use this information to help orient their thinking about what happens when more water is added to the bloodstream in the second act of Science Theater.

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 Acts of the model a second time.

**OBSERVATION AND REFLECTION:**

After the second implementation of the model, allow students time to summarize what they observed in the model in the graphic organizer provided.

**CCC SUPPORT**

**SC-H3: Feedback (negative or positive) can stabilize or destabilize a system.** In middle school, students learn that system stability is due to a balance of inputs and outputs that maintain dynamic equilibrium. This unit builds on this middle school knowledge by focusing on how feedback can stabilize or destabilize a system. For example, in Module 2, students come to consensus on two models that demonstrate their understanding of the feedback mechanisms associated with temperature and water balance in the body as a response to physical activity.

**FORMATIVE ASSESSMENT OPPORTUNITY**

Students use a model to provide a mechanistic account 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' use of the model to make observations and describe how feedback loops operate to maintain water balance in the bloodstream (Lesson 11 Student Guide Part 4: Using a Model of Sweat, Thirst, and Urine Color Change).

**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 water levels in the blood (MOD-H5).
- Students describe how the organ and its specialized cells contribute to a negative feedback mechanism to respond to water level changes in the blood and bring them 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** | There is not enough water in the body so the kidneys prevent more water from going to urine.<br><br>When there is enough water in the body, the kidneys let more water into the urine. | The osmoreceptors in the brain sense the reduced amount of water in the bloodstream. The brain creates a sensation of thirst and sends more signals via a hormone called ADH to the kidney to absorb less water from the blood, leading to the urine color becoming darker.<br><br>The osmoreceptors in the brain sense a normal amount of water in the bloodstream. The brain signals the sensation of thirst and signals to the kidney to absorb more water from the blood, resulting in urine color becoming clearer. | The osmoreceptors in the brain sense the reduced amount of water in the bloodstream. The brain signals to the hypothalamus region of the brain to create a sensation of thirst. The pituitary region of the brain sends more signals via a hormone called ADH to the kidney to absorb less water from the blood, leading to less water moving to the bladder, where it is stored as urine. The urine color becomes darker. This process is a negative feedback loop and is how the body prevents additional water loss.<br><br>The osmoreceptors in the brain sense a normal amount of water in the bloodstream. The brain signals to the hypothalamus region of the brain to reduce the sensation of thirst. The pituitary region of the brain sends fewer signals via a hormone called ADH to the kidney to absorb more water from the blood, resulting in more water accumulating in the bladder as urine and urine color become clearer. This is a feedback loop that helps pull |

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|---|---|---|---|
| | | | extra water out of the blood. |
| **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 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. 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 students agree that:

- Water Loss During Exercise: 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 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.
- Water Replenished With Milk: The osmoreceptors in the brain sense a normal amount of water in the bloodstream. The brain signals to the hypothalamus region of the brain to reduce the sensation of thirst. The pituitary region of the brain sends fewer signals via a hormone called ADH to the kidney to absorb more water from the blood, resulting in more water accumulating in the bladder as urine and urine color become clearer. This is a feedback loop that helps pull extra water out of the blood.

**CONCLUSION:**

After the discussion, ask students to consider if they think the mechanisms that they figured out are similar to that of how the body responds to changes in its temperature. Build off of student responses to confirm that the body has negative feedback mechanisms that try to bring the levels of water in the bloodstream to a stable state when those levels decrease, just like the body has negative feedback mechanisms that try to bring body temperature back to a stable state when the body temperature increases. Both are examples of the body trying to maintain homeostasis and maintain a normal amount of water in the bloodstream and a normal body temperature.