TEACHER GUIDE
Lesson 3: Homeostasis Lab

Time Estimate: Three 45-minute class periods

Driving Question: Why might someone who exercises consume whey protein?

Items needed:

- Homeostasis Lab Student Guide
- Homeostasis Lab Reading Handout
- Homeostasis Lab Models Handout
- Homeostasis Lab Case Study Handout
- Homeostasis Lab Expectations Handout
- Homeostasis Lab Experimental Design Tips Handout
- Homeostasis Lab Additional Resources Handout
- Homeostasis Lab Student Guide - KEY

NGSS:

DCI Connections

LS1.A: Structure and Function

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.

SEP Connections

CEDS-H2: Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

CCC Connections

CE-H2: Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller-scale mechanisms within the system.

PAT-H1: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Goals

- Students will conduct an experiment to determine what pre-workout containing whey protein does to the body during and after exercise. Students will measure different homeostatic mechanisms in the body and compare their results to determine if using a pre-workout substance has any effect on the values of those measurements.
- Students will generate an explanation that incorporates their experimental data to support their claims related to the unit driving question and the phenomenon of why an athlete might consume whey protein.

Instructional Approach

Introduction

1. Distribute the Homeostasis Lab Student Guide to students. Reintroduce students to the Driving Question for the unit - Why might someone who exercises consume whey protein?
2. Ask them to revisit the Driving Question Board they created in the Anchor Phenomenon and look through questions and/or categories that drive curiosity about what whey protein is, the effects that it might have on the body, and how those effects might impact exercise performance. Have them write any new questions in the Introduction section of their Homeostasis Lab Student Guide.
3. Let students know that they will be exploring various homeostatic mechanisms after consuming a pre-workout supplement to determine what impact these supplements might have on the body during and after exercise. Students should be instructed to design their lab by choosing what type of exercise to complete and also what homeostatic mechanisms to measure for evaluation of impact.
    - An example exercise circuit is shown below (work at a moderate intensity):
        - 1 minute of jumping jacks
        - 1 minute of squats
        - 1 minute of push-ups
        - 1 minute of mountain climbers
        - 1 minute of high knees
        - Rest for 2 minutes, then repeat the circuit 2-3 times
    - Possible homeostatic mechanism measures include:
        - Heart Rate
        - Blood Pressure
        - Body Temperature
        - Blood Glucose Levels
        - Respiratory Rate
        - Electrolyte Levels
        - pH Levels
        - Oxygen Saturation
        - Fluid Balance
        - Hormone Levels

Part 1: Reading about Homeostasis

1. To begin, distribute the Homeostasis Lab Reading to students. You can have students read together as a class or read independently in small groups.

2. A potential reading strategy to implement for independent reading is a modification of the Collaborative Strategic Reading Approach.
    - The first requirement is to allow students time to preview the reading. They should look at the title, any headings or subtitles, keywords that might be bolded or italicized in the reading, and any charts, graphs, or images that are included. From those key elements, ask students what they expect to learn. They can figure this out from the context clues in the text. This can help you to get a sense of what content they think the reading is about and what they think might potentially be important as they begin.
    - After facilitating a whole-class discussion about their predictions, provide students with an opportunity to begin reading in sections. To do this, choose a line break for students and ask them to read up to that point only. They can give you thumbs up when they have gotten to that point. An idea to help students feel comfortable is to identify a line break that might contain some tricky vocabulary or content language, using this as a "timeout" so that students do not start to feel overwhelmed.
    - Provide students time to share the "gist" of the content of that section with an elbow partner. Encourage them to share the important details and things that were mentioned and summarize the content in their own words. You might consider practicing this strategy as a class before having students complete this on their own.
    - Repeat this process until students have read the entirety of the reading. After students have completed the reading, provide them with an opportunity to share with one another. Consider using the following prompts:
        - What did you discover from this reading?
        - What information did you know previously about this topic?
        - How do you think this reading relates to the phenomenon we are exploring?
    - Students should be given an opportunity to reassess what they learned from the reading and ask new questions that they might have about the content as it relates to the Driving Question. They can record their new understandings in Part 1: Reading about Homeostasis in their Homeostasis Lab Student Guide.

Part 2: Interpreting Homeostasis Models

1. Present students with the Homeostasis Lab Models handout for students to make sense of the vocabulary they read about by using a different visual or graphic organizer. While there is a model presented in the reading, to truly test whether or not students understand homeostasis mechanisms (particularly negative feedback), showing them new types of models to make sense of can help them determine what terms, content, and ideas they are still struggling with prior to beginning their experimentation.
    - For students who are still struggling to make sense of the new models, consider providing them with a few alternate examples, such as thyroid regulation, calcium

homeostasis, and photosynthetic response (in plants) due to increased presence of carbon dioxide.

- Additionally, you could discuss the differences between negative feedback and positive feedback. Homeostatic mechanisms that use positive feedback include uterine contractions, milk production, blood clotting, and fever production. THIS WEBPAGE (from Carnegie Mellon Open Learning Initiative) has negative and positive feedback loop models and examples to consider presenting to students.

TEACHER SUPPORT
To reuse in the future, it is suggested to print and laminate the Homeostasis Lab Models handout.

2. Ask students to return to the Driving Question. Give them an opportunity to write their new understandings in Part 2: Interpreting Homeostasis Models in their Homeostasis Lab Student Guide.
3. Facilitate whole-class discussion to the norm on the content of both the reading and the models on the importance of and processes associated with homeostatic mechanisms in the body.
4. Ask them to briefly share with an elbow partner about the ways in which homeostasis might show up in a lab where students take pre-workout supplements followed by engagement in exercise.

Part 3: Case Study of Homeostasis in Action

1. Direct students to the Homeostasis Case Study. This is an excerpt from a case study called "*Too Hot To Trot? The Role of Exercise in Homeostasis*" from the National Center for Case Study Teaching in Science. Give students time to make a small group of 3-4 students. Ask them to read through the case study as a group.
2. As a group, students will discuss how to fill in the information for the figure and apply their knowledge of homeostasis to the question in their student guide. Individually, students will record their new understandings in Part 3: Case Study of Homeostasis in Action.
3. Facilitate whole-class discussion about the Thermoregulatory Homeostatic Loop figure from the case study. Listen for responses like:
    - As body temperature increases, sensing organs in the skin, called thermoreceptors, sense the change from the acceptable range. They send signals (action potentials) to the hypothalamus in the brain.
    - The hypothalamus, located in the brain, interprets the signals and initiates efferent signals through nerves to cause the skin and lungs to increase blood flow to the surface in an effort to cool the body.
    - The effector organs (blood vessels) are stimulated by nerves to cause dilation of the arteries to get more blood to flow to the skin, causing body temperature to go down.

- Once body temperature is returning to the acceptable range, the effector activation is decreased and dilation of arteries is reduced.

4. As a class, come to agreement on the following before moving students forward in the lab experience:
    - The loop starts in the lower left corner with "A."
    - Thermoreceptors are located in the periphery, in the core of the body and also in the hypothalamus itself and are continuously sending information via afferent neurons to the hypothalamus about body temperature. If the hypothalamus detects that body temperature is above the normal range, it will initiate a series of efferent action potentials to effector organs.
    - First, it will cause a decrease in heat-generating mechanisms. Next, signals will be sent along efferent nerves, which cause vasodilation of arteries leading to the surface of the body, specifically within the skin and lungs.
    - As a result, more heat is carried to the surface, where it can be given off to the atmosphere. More heat to the surface also creates a larger concentration gradient of heat between the surface and the external environment, which should result in faster movement of heat as long as the external environment isn't too near or above body temperature.

Part 4: Homeostasis Lab

1. Students will now begin to design their experiments. To do so, provide student groups time to read through the Homeostasis Lab Expectations. This handout includes the materials provided and basic directions for students to conduct their experiments. These directions are purposefully vague, and students will need time to discuss the details of the tests they plan to conduct. As they plan, students should write this information in Part 4: Homeostasis Lab.
    - To assist students in knowing what physiological parameters can be measured and what the potential impacts of common pre-workout supplements have on the body, direct students to the Homeostasis Lab Additional Resources handout. This document has helpful information that students may not be aware of prior to planning their experiment. The content might help them better make decisions about the design elements of their experiment.
    - It is important that before students begin, this section is checked by the teacher to ensure all safety protocols necessary are in place. Equally important is that they have determined an appropriate way to record their data. If students are struggling with how to capture this information, consider providing them with an example or asking them to visit with another group that has an appropriate data table for data collection before they begin. An example of data is shown below:

Measurement (time taken)	Control Group (no supplement)	Experimental Group (pre-workout supplement)
Heart rate		
Blood pressure		
Body temperature		
RPE (Rating of Perceived Exertion)		

2. Prior to students starting the experiment, remind them that they will need to get baseline measurements for the physiological parameters of their choice and also collect their data accurately for the best results.
3. Give students time to complete their experiments. As students conduct their testing, they should be keeping track of their results in Part 4: Homeostasis Lab on their Homeostasis Lab Student Guide.
4. Give students time to discuss their results as a group and complete the summary of the data. This will help them to organize their data, make sense of it, and begin to connect it to the Driving Question by providing a reasonable, data-driven assessment of the data they obtained. To do so, they should respond to the prompt at the end of Part 4: Homeostasis Lab on their Homeostasis Lab Student Guide.
5. Before moving on to Part 5, consider holding a whole-class discussion to address the different types of data that student groups collected during their experimentation. Give students an opportunity to share their thoughts and understanding with one another to help them make sense of the phenomenon and Driving Question. Sharing with an elbow partner can help students:
    - clarify their understanding by exchanging ideas
    - connect their learning to what they currently know
    - reflect on new perspectives based on the topic
    - more fully engage in the learning experience
    - share their ideas in casual conversation with peers and the teacher
6. Direct students to Part 5: Constructing an Explanation about the Impact of Pre-Workout and Protein Supplements on Homeostasis During and After Exercise. Give them time to generate their explanations. Consider providing an opportunity for students to share out upon completion (in small groups or with the class) as a final reflection in this learning experience.

Scientific Background

Homeostasis refers to the body's ability to regulate its internal environment, ensuring stable conditions despite external changes, such as those induced by physical labor or exercise. Maintaining homeostasis during exercise is critical for preventing fatigue, optimizing performance, and avoiding injury or illness. Pre-workout supplements can assist in this by supporting energy levels, electrolyte balance, and blood flow.

In this lab, we will explore how key physiological parameters can be impacted by exercise. These include body temperature regulation, blood glucose levels, electrolyte and fluid balance, pH balance, as well as oxygen and blood flow. Students will take a pre-workout supplement of their choice and safely complete a workout to measure the ways in which the supplement impacts their homeostatic measurements. This analysis will help us understand the composition of pre-workout supplements and the potential health benefits of their use and consumption.

However, improper or excessive use of pre-workout supplements can disrupt homeostasis in the body, potentially leading to adverse effects such as dehydration, hyperthermia, or cardiovascular strain. It's essential to make informed decisions about the products used to enhance exercise performance, and it is crucial to understand the components of a supplement and know the ways in which they might interact with the body during exercise. Through this experiment, you will gain hands-on experience with techniques used to measure physiological data changes in the body and develop useful knowledge related to the impacts of biological molecules on the body during and after exercise.

General Setup

The start of experimentation requires students to plan an investigation that explores the impacts of pre-workout and protein supplements on physiological parameters related to homeostasis. In middle school, students should have planned investigations in which they identified independent and dependent variables, controls, and methods for recording data. If students are not familiar with how to design elements of an experiment, you might need to have some whole-class conversation around important design features, reminding them of their previous knowledge related to experimental design. These include but are not limited to generating an investigation question, establishing a clear and logical testing protocol and procedure, including high-quality design elements, like appropriate experimental and control variables, establishing a method to collect and record student data, and making a reasonable hypothesis. Prior to starting Part 4: Homeostasis Lab, distribute the Experimental Design Tips handout. Read this table together with the class and elaborate on any items you think are needed by your students based on their prior knowledge.

TEACHER SUPPORT

As students are designing their investigation, circulate the room to support students by asking pressing questions, such as:

- What did you plan to do at this step? Why?
- Can you tell me about how this plan ensures that confounding variables are eliminated?
- What confounding variables may be present in this investigation plan?

Before students move forward with their experimentation, make sure that all groups have a safe and reliable testing method established.

Below is an outline of materials, set-up suggestions, and expected outcomes.

Materials

Pre-workout supplement (e.g., containing caffeine, amino acids, and vitamins)
Various protein supplements (e.g., whey protein, soy protein, casein protein)
Water
Blender or shaker bottle
Water bottles
Timer
Exercise equipment (e.g., jump rope, step platform, or space for running in place, exercise mats)
Heart rate monitor or manual pulse counting
Digital thermometers
Rating of Perceived Exertion (RPE) chart
Blood pressure monitor

Physiological Parameters

Students should be exploring one or more of the following physiological parameters related to homeostasis. If they need help with knowing how these test variables might be measured, direct them to the Homeostasis Lab Additional Resources handout.

- Heart rate
- Blood pressure
- Body temperature
- Blood glucose levels
- Respiratory rate
- Electrolyte levels
- pH levels
- Oxygen saturation
- Fluid balance
- Hormone levels

It should be noted that most of these factors are associated with one another during exercise. As the heart rate goes up, so does blood pressure, body temperature, and respiration rate. For that reason, students should consider testing multiple variables if possible. However, more factors to take data on increases the complexity of the experiment. For struggling students, consider variables that are generally easier to identify and are likely more familiar to them in prior research at younger grade levels, such as heart rate, blood pressure, and body temperature. More complicated variables are those that require specific tests or observations of changes in body weight.

Expected Outcomes

Shown below are just examples of possible lab outcomes when conducting an experiment to identify the impacts of pre-workout and protein supplements on homeostasis mechanisms in the body. It should be noted that students completed the following exercise session (at moderate intensity) to obtain the sample student experimental data shown.

- 1 minute of jumping jacks
- 1 minute of squats
- 1 minute of push-ups
- 1 minute of mountain climbers
- 1 minute of high knees
- Rest for 2 minutes, then repeat the circuit 2-3 times

Baseline Measurements Pre-Workout	**Control Group (no supplement)**	**Experimental Group (pre-workout supplement)**
Heart Rate	72 BPM	75 BPM
Blood Pressure	118/76 mmHg	120/78 mmHg
Body Temperature	98.1°F	98.2°F
RPE (Rating of Perceived Exertion)	1	1

Post-Workout Measurements Immediately After Exercise	**Control Group (no supplement)**	**Experimental Group (pre-workout supplement)**
Heart Rate	142 BPM	155 BPM
Blood Pressure	136/85 mmHg	145/90 mmHg
Body Temperature	99.4°F	99.6°F
RPE (Rating of Perceived Exertion)	7	8

Post-Workout Measurements During Cool Down (10 minutes after exercise)	**Control Group (no supplement)**	**Experimental Group (pre-workout supplement)**
Heart Rate	88 BPM	95 BPM
Blood Pressure	125/80 mmHg	130/82 mmHg

Body Temperature	98.6°F	98.8°F
RPE (Rating of Perceived Exertion)	3	4

A pre-workout supplement (with ingredients like caffeine, beta-alanine, and citrulline) would be the primary driver behind the elevated heart rate, blood pressure, and increased perceived exertion observed in the experimental group. A typical product on the market that contains these ingredients would be something like C4 Pre-Workout or Optimum Nutrition Gold Standard Pre-Workout.

To obtain these example results, students would consume the following pre-workout supplement ingredients:

- Caffeine (100-300 mg)
- Beta-Alanine (2-4g)
- L-Citrulline or Citrulline Malate (6-8g)
- Creatine Monohydrate (3-5g)
- Taurine (500-1000mg)
- Whey Protein (20-30g)
    - The fast absorption helps with muscle recovery after the workout, but it doesn't significantly affect physiological parameters during the exercise.