POSTGAME ANALYSIS

HOW CAN MILK HELP ATHLETES RECOVER FROM PHYSICAL EXERCISE?

Food and Agriculture Center for Science Education

Synopsis

In this unit, students investigate how milk helps athletes recover from intense exercise. Students begin by observing a series of professional athletes undergoing intense exercise and drinking milk after their exercise sessions. These athletes claim that drinking milk helps them recover from their workouts. This leads to the Driving Question for the unit: ***How can milk help athletes recover from physical exercise?***

Students set out to figure out how exercise impacts the body and how milk helps with recovery. In the first module of the unit, students figure out that milk is digested in a series of steps in the digestive system. Students carry out investigations and use models to figure out that organs of the digestive system are made of cells that are specialized in specific functions to digest food and that the multiple different organs and cells in the digestive system work together in digestion.

In the second module, students then explore why changes in body temperature and water balance occur during exercise. Students figure out that the body has a series of negative feedback loops that involve the function of various kinds of specialized cells, all of which work together to try to return the body's conditions to a stable state. They also figure out that the water content of milk can help the body replenish lost water and return to the stable state.

Then in the third module, students investigate why heart rate increases, breathing rate increases, and muscle fatigue and burn occur during exercise. They figure out that the body uses glucose in aerobic and anaerobic respiration to generate cellular energy that muscles use for rapid movement during exercise. They see that the sugar content of milk helps the body to recover glycogen that is lost during exercise, which can be used for later bouts of exercise. They also figure out that fats, both stored in the body and consumed from milk, can be used for extended exercise.

Next, in the fourth module, students observe that skeletal muscle soreness is common after exercise such as lifting weights and that drinking milk after the workout can help reduce the perception of muscle soreness. Students figure out that muscle soreness is caused by microtears in muscles, which bring the muscles out of a stable condition. The body responds with a negative feedback mechanism to help bring the muscles back to a stable state. Immune cells, protein synthesis, and muscle satellite cells all respond to help repair damage to muscle cells.

Throughout the unit, students work together in groups to create presentations about how milk helps in recovery from intense exercise. They choose a specific audience that they want to communicate this information to, develop a presentation in the format of their choosing, and deliver the presentation to their chosen audience. what happens in the body during exercise and how the milk that athletes consume after physical activity can help them recover.

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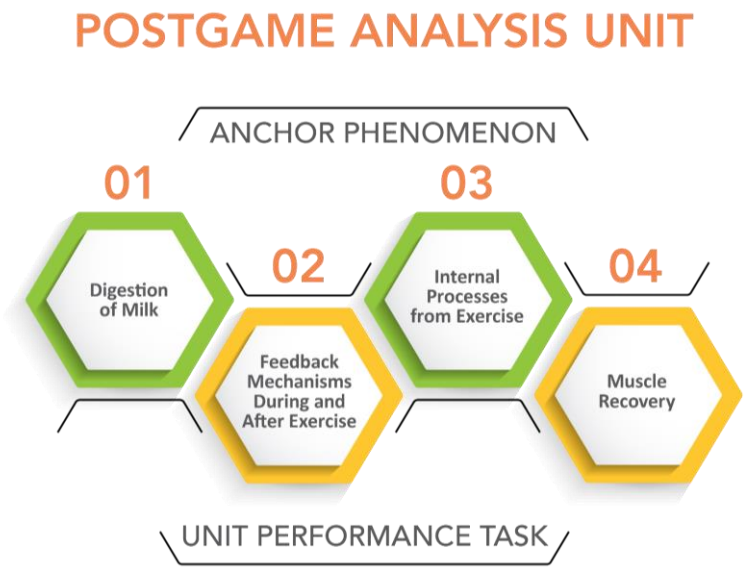
Unit Overview

In this high school 5E unit on cell specialization, body systems, and homeostasis, students figure out how intense exercise impacts the body and how milk helps the body recover from exercise. Students uncover how digestion and absorption of nutrients occurs, explore how negative feedback mechanisms help the body recover during and after exercise, discover how cellular energy for exercise is made, and figure out how muscle soreness occurs and goes away. Students also figure out how milk can aid in recovery from all of these effects of

exercise. Throughout the unit students create presentations to an audience of their choosing to communicate the information that they found.



Module Pacing & Summaries

Anchor Phenomenon

Anchor Phenomenon:
Students see various athletes choosing milk products for recovery through a series of videos and text anecdotes. This generates questions about recovery after exercise, nutrition for athletes, the body's use of energy, what happens in the body after exercise, and why milk products might be a good

Driving Question:
How can milk help athletes recover from physical exercise?

recovery choice. Students create initial explanations to show how the milk that athletes consume can help them recover after physical activity.

Lesson #s: 1

Time: 50 minutes
Approximately 1 class period

What Students Figure Out:
Students observe that milk can help athletes recover from intense exercise. Students share their initial ideas about how this happens and realize that they need to know more about how human bodies use what is in milk to help with exercise recovery.

What Students Do:
- Observe the Anchor Phenomenon through videos.
- Draft an initial presentation about how milk might help athletes recover from physical exercise.
- Share and record areas of agreement and disagreement

Navigation to the Next Module:
Students ask many questions about how milk helps with recovery from intense exercise. To help figure this out, students agree that it first makes sense to figure out what is in milk and what happens to milk in the body after it is first consumed.

Module 1: Digestion of Milk

Module Phenomenon:
Students observe a video that shows footage from a pill camera as it travels through the digestive system together with a meal. As students watch, they record what they observe about how food is digested, what they notice happens to food, and what organs are involved in the process.

Module Question:
How is milk digested after it is consumed?

Lesson #s: 2-7

Time: 600 minutes
Approximately 12 class periods

What Students Figure Out:
Students figure out that the digestive system is a system of specialized cells that work together to help break down the various molecules in milk and therefore help digest milk. Each organ of the digestive system contains specific kinds of specialized cells that

What Students Do:
- Observe the module phenomenon.
- Create initial models of how milk is digested.

carry out specific functions in digestion. Students see that the nutrient molecules in milk are broken down into smaller molecules. Lactose is broken down in the small intestine into glucose and galactose, proteins and fats are broken down in the stomach by stomach acid and digestive enzymes, and proteins are further broken down in the small intestine by additional digestive enzymes. Students then see that these nutrient molecules are absorbed into the bloodstream.	• Defend a claim about which organs most play a role in digestion and gather evidence via lab investigations. • Use a Science Theater model to demonstrate the mechanisms of digestion. • Revise their initial models of how milk is digested. • Revise their presentations about how milk might help athletes recover from physical exercise.	
Connection to Anchor Phenomenon: Students figure out that in order for milk to help in recovery, the molecules in milk first are broken down into smaller molecules via digestion. They are then absorbed into the bloodstream where they travel throughout the body.		

Navigation to the Next Module:
Students observed that the various molecular components of milk (amino acids, fatty acids, sugars, water, and electrolytes) get into the bloodstream, but they don't know what happens to them after that or what they do to help in recovery. Students use this as a motivation to further investigate what happens to these molecules. Students also return to the Driving Question Board and focus on questions that have to do with exercise and hydration.

Module 2: Feedback Mechanisms During and After Exercise

Module Phenomenon: Students observe a video of how an individual who is exercising experiences an increase in body temperature, sweat, and thirst. The athlete stops exercising and drinks milk, which she says makes her feel cooler, stop sweating, and less thirsty.	**Module Question:** *Why do we get sweaty and thirsty after exercise?*

What Students Figure Out: Students figure out that during exercise, a person experiences sweat, thirst, and urine color changes because of changes in the levels of water in the body. The body has a feedback mechanism that tries to maintain normal levels of water in the bloodstream. This mechanism occurs when exercising; the body produces a lot of sweat that pulls water out of the bloodstream in an effort to reduce temperature. The osmoreceptors in the brain sense the reduced amount of water in the bloodstream. These signals are detected by the hypothalamus region of the brain to create a sensation of thirst. The pituitary region of the brain sends 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 because it contains less water. The amount of water in the blood begins to return to its stable state. This response is an example of how the body tries to maintain homeostasis. Milk contains water, so athletes that drink milk to recover from a workout are able to replenish water. Water passes from the digestive system into the bloodstream, which further helps the body return to its stable state.	**What Students Do:** ● Observe the module phenomenon. ● Create an initial explanation of why athletes get sweaty, thirsty, hot, and have urine color change during exercise. ● Analyze data on how an athlete's temperature changes during exercise ● Use a Science Theater model to demonstrate how production of sweat and vasodilation are feedback mechanisms. ● Develop an explanation of sweat and temperature changes during exercise ● Create class models of the Effects of Exercise on the Body and How Milk Helps Recovery from Exercise. ● Analyze data on changes to blood volume and urine color during exercise ● Use a Science Theater model to demonstrate the mechanism by which thirst, urine color changes, and blood volume changes during exercise are connected. ● Observe new phenomena about athletes who died from overhydration and dehydration. ● Use a hands-on model to visualize how overhydration and underhydration change levels of water in cells. ● Obtain information from text describing the effects of overhydration and underhydration on the function of cells	*Why does the color of our urine change?* *How does milk help us recover from these effects?* **Lesson #s:** 8-14 **Time:** 550 minutes Approximately 11 class periods

	• Revise their initial explanation of how thirst, urine color change, and sweat occur during exercise and how milk helps in recovery • Revise their presentations about how milk might help athletes recover from physical exercise.	
Connection to Anchor Phenomenon: Students figure out that milk contains water, so athletes that drink milk to recover from a workout are able to replenish water. Water passes from the digestive system into the bloodstream, which restores levels of water in the bloodstream. This would allow the athlete to feel less thirsty and to sweat more if the workout continued.		

Navigation to the Next Module:
Students reflect on what next steps would be helpful to continue to make progress on the unit Driving Question. They see that they can still figure out more about what happens to the amino acids, fatty acids, and sugars from milk once they go into the bloodstream and how they help recovery from exercise. Students also return to the Driving Question Board and focus on questions that have to do with getting enough energy for exercise.

Module 3: Internal Processes from Exercise

Module Phenomenon: Students will complete a high-intensity workout to observe what happens to their bodies during exercise, including increases in heart rate and breathing rate and muscle burn and fatigue.		**Module Question:** *Why are there so many changes to my body during exercise? How does milk help with recovery from these changes?* **Lesson #s:** 15-24
What Students Figure Out: Students figure out that increased heart rate, breathing rate, and muscle fatigue during exercise all have to do with how the body produces cellular energy	**What Students Do:** • Complete an intense exercise session and observe the effects on their body.	

to be used by muscle cells during exercise. Starting high-intensity exercise triggers anaerobic cellular respiration to produce ATP molecules to be used by muscle cells for movement. Heart rate and breathing rate because epinephrine increases the heart and breathing rates in order to begin to increase the exchange of oxygen and carbon dioxide in the lungs and bloodstream. It also stimulates the breakdown of stored glycogen in the muscles and liver to produce glucose, which can be used in anaerobic respiration (and later aerobic respiration). As exercise continues, more oxygen is needed by the muscle cells so that they can undergo aerobic respiration, which produces more ATP molecules to be used by muscle cells for movement. Carbon dioxide is produced as a result of both aerobic and anaerobic respiration, which can be removed from the bloodstream by an increased heart rate to pump more blood through the body and an increased breathing rate to facilitate more exhalation of carbon dioxide. The burning sensation and fatigue come from the buildup of lactate and H^+ accumulating in the muscles as a result of anaerobic respiration. 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.	• Create an initial explanation of why heart rate and breathing rate increase and muscle burn and fatigue occur during exercise. • Plan and carry out an investigation into how the amount of carbon dioxide in breath changes with exercise. • Analyze data on how the amount of oxygen inhaled changes during exercise. • Analyze multiple sets of data to determine how various molecular factors in the body change during exercise. • Use a Science Theater model to demonstrate the mechanism by which increases in heart rate and breathing rate and muscle fatigue and burn occur. • Revise their initial explanation of how increases in heart rate and breathing rate and muscle fatigue and burn occur. • Obtain information from text describing how different molecules in food are used as energy sources in different durations of exercise. • Revise their presentations about how milk might help athletes recover from physical exercise.	**Time:** 900 minutes Approximately 18 class periods

Connection to Anchor Phenomenon:
Students figure out that milk helps their bodies recover from exercise by refilling the glycogen stores in skeletal muscle myocytes, and likely in the liver hepatocytes.

Navigation to the Next Module:
Students reflect on what next steps would be helpful to continue to make progress on the unit Driving Question. They see that they can still figure out more about how the proteins and amino acids in milk help recovery from exercise. Students also return to the Driving Question Board and focus on questions that have to do with protein and muscle recovery in exercise.

Module 4: Muscle Recovery

Module Phenomenon:
Students observe a video of how an individual who is exercising experiences less soreness after lifting weights and recovering with milk afterwards than without drinking milk afterwards.

What Students Figure Out:
We observe that skeletal muscle soreness is common after exercise such as lifting weights. We figure out that skeletal muscle soreness is the result of microtears that occur in the structure of the muscle cells as a person is exercising. We figure out that satellite cells, immune cells, and protein synthesis are responses that the body must use to help repair the muscle fibers and bring skeletal muscles back to a stable state. We figure out that a workout can also result in adaptation of the muscle fiber cells in which they increase their ability to lift more weight or lift the weight faster in the future.

What Students Do:
- Observe an individual lifting weights and recovering with and without milk and describing his experiences.
- Create an initial explanation of why muscles get sore in exercise and how milk can help them recover.
- Sort cards and watch a video that shows how muscle cells expand and contract in the process of lifting a weight.
- Analyze data that demonstrates how muscles experience microtears during intense exercise.
- Analyze data on the changes that occur in various molecular factors to help muscles recover from exercise.

Module Question:
How does milk help in muscle recovery from soreness induced by intense exercise?

Lesson #s: 25-31

Time: 450 minutes
Approximately 9 class periods

	• Use a Science Theater model to demonstrate the mechanism by which muscle soreness occurs and how the body responds to bring muscles back to a stable state. • Revise their initial explanation of why muscles get sore in exercise and how milk can help them recover. • Obtain information from text describing how muscles can undergo adaptations to improve future performance. • Revise their presentations about how milk might help athletes recover from physical exercise.	

Connection to Anchor Phenomenon:
Students figure out that protein in milk is digested into amino acids, moves into the bloodstream, and there they are taken up by muscle cells in the process of protein synthesis to help muscle cells form new proteins to recover from the microtears caused by intense exercise.

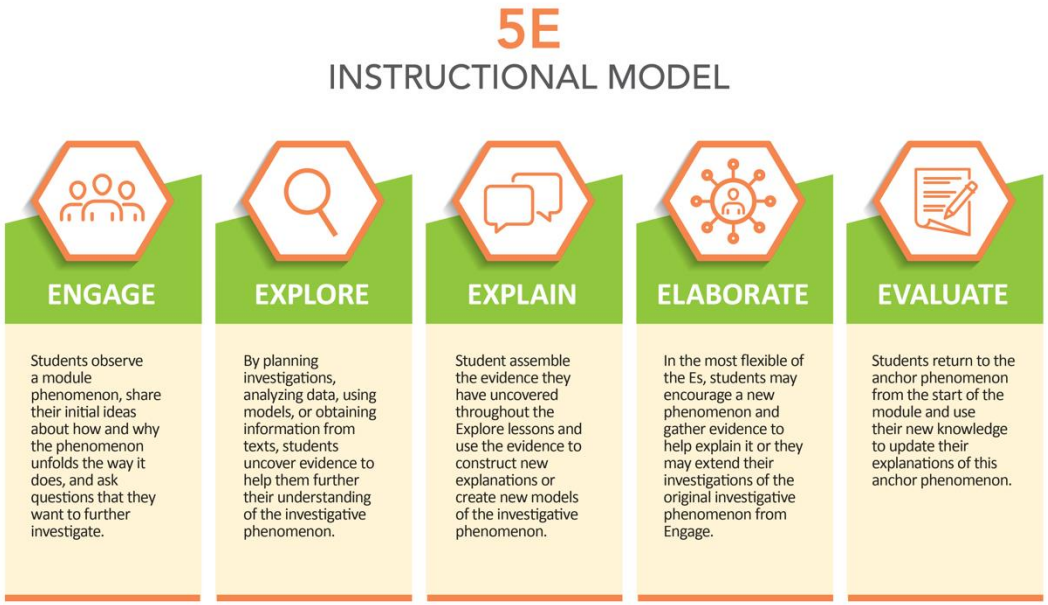
Performance Task

Return to Anchor Phenomenon: Throughout the unit, students create presentations to an audience of their choosing to describe how milk helps recovery from exercise. In the final Performance Task, students have the opportunity to revise these presentations and present them to the audience of their choosing.		**Driving Question:** *How can milk help athletes recover from physical exercise?* **Lesson #:** 32 **Time:** 100 minutes Approximately 2 class periods
What Students Figure Out: Students work together in groups to create final presentations demonstrating the scientific knowledge and presentation skills they learned in the unit. Their presentations offer a comprehensive, summary explanation of what happens in the body during	**What Students Do:** • Edit and prepare final presentations. • Communicate scientific information about the effects of exercise on the body and how milk can be used to recover from exercise. • (Optional) Provide feedback to peers.	

exercise and how the milk that athletes consume after physical activity can help them recover.		

Unit Structure & 5E Instructional Model

This unit is designed using the BSCS 5E Instructional Model. This instructional model has five lesson types: Engage, Explore, Explain, Elaborate, and Evaluate. The purpose of each lesson type is shown in the graphic below. Each module of the unit contains a 5E sequence.



In each module, students first observe a module phenomenon in the Engage lesson, which drives their learning within each individual module. Throughout the module, students will drive instruction by investigating different parts of the module phenomenon in the Explore

lessons. Students make sense of the module phenomenon through a variety of investigation types, such as developing and using models, analyzing data, and obtaining information from texts. Students have multiple opportunities to share their new understanding (content, vocabulary, ideas) with the teacher and their peer group. Students use their own questions to navigate from one lesson to another. This gives students the opportunity to decide what to figure out next based on their questions about the phenomenon. Students then use the new evidence they have gathered to better help explain the module phenomenon in Explain Lessons. In Elaborate lessons, students extend what they know about the module phenomenon or investigate new phenomena. At the end of each module in Evaluate lessons, students take their knowledge and use it to update their understanding of the unit anchoring phenomenon.

There are a variety of informal opportunities for assessment when using the 5E model of instruction. These opportunities are specifically called out for a teacher during each of the lessons. There are also formal summative assessment opportunities throughout each of the modules in the Evaluate lesson of each module. In these lessons, students demonstrate evidence of their learning from each module.

Supporting NGSS Implementation

Teacher supports in the form of activity type icons, SEP action icons, and callout boxes are provided throughout the unit to aid in the implementation of these three-dimensional, phenomenon-based learning.

Activity Type Icons

	Anchor Phenomena		Investigation
	Editing		Initial Ideas
	Consensus Building		Building Understanding

SEP Action Icons

	Analyzing and Interpreting Data		Asking Questions and Identifying Problems
	Constructing Explanations/Defining Solutions		Developing and Using Models

 Engaging in Argument from Evidence	 Obtaining Evaluating Communicating Info
 Planning and Carrying Out Investigations	 Using Math Computational Thinking

Callout Boxes

SEP SUPPORT
This box explains how to best support students in engaging with the associated SEP. It is also used to call attention to progressions of the SEP from prior grade bands or across the unit.

DCI SUPPORT
This box explains how to best support students in engaging with the associated DCI. It is also used to call attention to progressions of the DCI from prior grade bands or across the unit.

CCC SUPPORT
This box explains how to support students in engaging with the associated CCC. It is also used to call attention to progressions of the CCC to from prior grade bands or across the unit.

FORMATIVE ASSESSMENT OPPORTUNITY
This box is used to identify the student artifact that gives evidence of students' current performance of the three-dimensional learning objective(s) for the lesson. These artifacts can be used as formative assessments throughout the unit. In this box, you'll find a description of which artifacts to assess, what to look for, sample student responses, and action items to take for students' who may need additional support.

USE OF PHENOMENA
This box is intended to clarify how the multiple phenomena in the unit are used and how connections can be made by students across the phenomena.

CCSS Support
This box identifies selected Common Core State Standards that students are engaging with at key moments in a lesson.

LOOK FOR

This box is used to provide specific and direct guidance to the teacher to explain what they should be looking for in student work or responses.

TEACHER SUPPORT
This box provides guidance to a teacher on additional context for the design rationale for a portion of a lesson or how to implement or facilitate an action or direction. For example, this may include tips on how to engage with students in conversation, facilitate group discussion, engage participation, or provide directions on how to complete a task. This box is also used to explain how to best implement a particular teaching strategy that a teacher might not be familiar with.

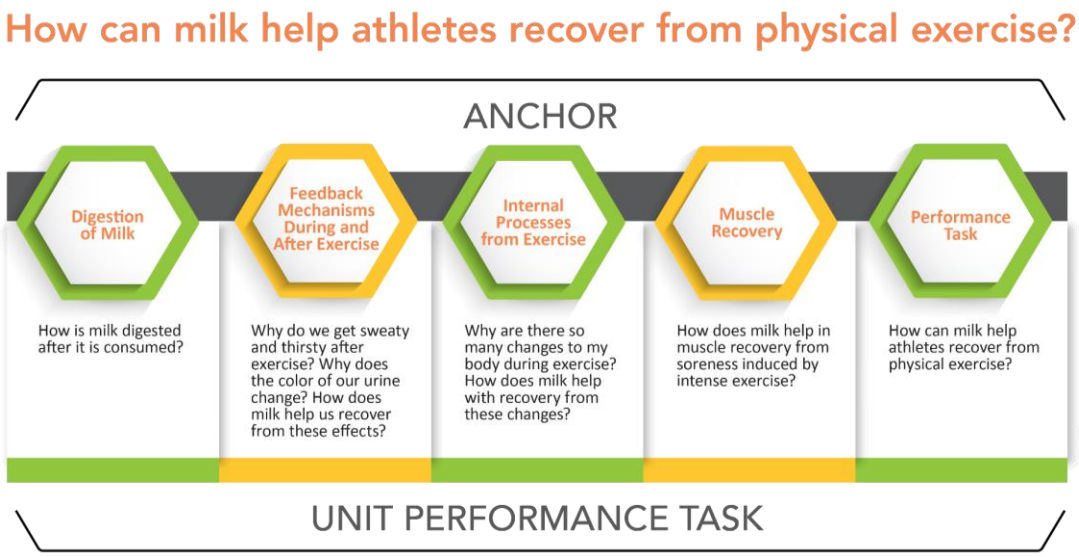
STUDENT SUPPORT
This box is meant to provide additional suggestions for how to support all learners in the classroom via differentiation strategies or other tips. For example, this box may provide an explanation of a strategy, a new series of questions, an additional prompt, or sentence starters.

DEFINE TERMS
This box is used when a teacher formalizes the definition of key terminology for all students to be familiar with throughout the remainder of the lesson(s).

Use of Anchor and Module Phenomena

Because the Next Generation Science Standards (NGSS) require students to make sense of phenomena and be able to explain them, supported by the DCIs, SEPs, and CCCs that are selected to frame instruction, they are central to student learning experiences. Phenomena are "observable events that occur in the universe and that we can use our science knowledge to explain or predict" (n.a. 2005). Throughout this unit, we use two types of phenomena to drive student learning – an anchor phenomenon and several module phenomena.

The anchoring phenomenon is used as the focus for the unit. In each learning module, students return to this phenomenon and revise their explanations about how it works by presenting evidence they gathered throughout each of the lessons. The anchor phenomenon is used across the whole unit. In addition, a module phenomenon is used within each module in the unit. Students will make sense of and be able to provide an explanation for the module phenomenon prior to the end of the module. Students can use what they figure out about the module phenomenon to help make sense of the anchor phenomenon. The descriptions of the anchoring and module phenomenon are outlined in the Module Summaries section of this document.



Assessment System Overview

Unit Assessment Structure

This unit contains a variety of both formative and summative assessment opportunities. All lessons include multiple formative assessment opportunities to assess students progressions toward achieving the three-dimensional learning objective for the lesson. Each lesson also designates specific student artifacts that can be used as either formative or summative assessments of student learning in that lesson. Each module ends with a summative assessment task for students to demonstrate their proficiency in selected NGSS elements.

Across the unit, assessments build on each other to aid in students reaching proficiency in the focal elements of the unit by the end of the unit. Teachers can use the assessments in this unit to both inform adjustments to instruction and to assign grades. Your choice on which assessments to use to assign grades is up to the needs of your classroom, school, or district.

Summative Assessment

Each module ends with a summative assessment opportunity in an Evaluate lesson. Students are evaluated on a three-dimensional combination of the unit focal elements in one or more tasks. The unit ends with a final performance task in which students demonstrate their proficiency of selected focal elements for the unit.

Each summative assessment task comes with a rubric that can be used to assess students' progress towards proficiency in three dimensions and a set of Look-Fors that students can use to guide their performance on the task and that teachers can use to score the task.

Formative Assessment

This unit contains multiple opportunities for formative assessment, including both embedded formal formative assessment opportunities and informal formative assessment opportunities.

Formal Formative Assessment Opportunities
In each lesson, one or more Formative Assessment Opportunity boxes call out a moment in the lesson in which students produce an artifact that shows their performance of the targeted three-dimensional learning objective for that lesson. The teacher can use these artifacts to assess students' understanding of the lesson goal by providing formative feedback and/or a grade or by having students give each other feedback on their artifacts.

Rubrics are provided that the teacher and/or other students can use to evaluate student performance on a lesson's three-dimensional learning target. Rubrics are built around 2-4 Look Fors that identify features of student performance that align with the targeted NGSS elements for a lesson. The 'Proficient' level of performance on each rubric corresponds to a proficient response within that lesson, and the expectations required to reach 'Proficient' gradually build in complexity across the unit. In other words, a 'Proficient' in Lesson 1 does not come with the same expectations and Look-Fors as a 'Proficient' in Lesson 20, even if some or all of the targeted NGSS elements in the lesson are the same.

The formative assessments and corresponding rubrics can be used in a variety of ways by the teacher and/or students and their peers:

As students complete a formative assessment:

- The teacher can provide the Look Fors to students as they complete the assessment artifact, so that students know the expectations of them.
- Students can use the Look Fors to provide feedback to one another.

- The teacher can use the "To Provide Additional Support for Students" tips to press students to higher levels of performance on the rubric.

After students complete a formative assessment:

- The teacher can collect the student artifact, score it, and provide feedback on which look for students accomplished and which they can improve on.
- The teacher can give students an opportunity to revise their artifacts based on feedback from their peers or from the teacher.

Informal Formative Assessment Opportunities

Each lesson also includes multiple informal formative assessment opportunities for students and the teacher to monitor and respond to student performance in three dimensions. Through discourse and writing, students are consistently able to share their thinking with peers and with the teacher and respond to the ideas of their peers. These provide opportunities for the teacher to assess and adjust their teaching approaches to better meet and respond to the current thinking of their students.

Self-Assessment

At the end of each Evaluate lesson in each module, students are provided with an opportunity to self-evaluate their progress in working with one or more of the focal SEP elements for the module. This gives students an opportunity to share how they think they are doing and how the classroom experience is going for them. This also provides the teacher an opportunity to check on how students are perceiving their classroom experience.

Students are also provided with Look Fors on each Summative Assessment task that they can use to self-assess the artifact that they have produced on the assessment task.

Pre-Assessment

In the Anchor Phenomenon lesson and in the Engage lessons in this unit, students create initial models or explanations of various phenomena. In these lessons, students share the knowledge they have about the phenomenon from their own background experience. Accordingly, the NGSS elements addressed in these lessons are tagged "Pre-Assessment". These elements are not meant to be developed in the given lesson and instead are meant to be used by students for the first time such that the teacher can obtain a formative assessment on what prior knowledge students have of using these elements.

Supporting Classroom Discourse

Productive discourse in the science classroom can be a challenge for students from a variety of backgrounds. While we want to see students pressing each other for evidence, critiquing each other's claims, evidence, and reasoning, and collaboratively making sense of data, often these are new forms of talk for students compared to their everyday discourse. Further complicating the matter is the challenge to build a culture in which students respect, value, and build on the ideas of all students in their group or in the whole class rather than a select few students. Given these challenges, we have compiled a set of tools intended to support students with discourse with each other. Please see the Science Classroom Discourse Supports and the Teacher Talk Compilation for more details.

NGSS Performance Expectations & DCI, SEP, and CCC Elements

According to the Framework for K-12 Science Education, performance expectations are essential to the standards. The term performance expectation "refers to statements that describe activities and outcomes that students are expected to achieve in order to demonstrate their ability to understand and apply the knowledge described in the disciplinary core ideas….[they] specify what students should know, understand and be able to do" (Framework, pg. 218). We formed the following conceptual bundle of the NGSS PEs to help guide our initial unit planning. We used the DCIs in this PE bundle as the focal DCIs in our unit. The SEPs and CCCs from these PEs are not necessarily those chosen as focal SEPs and CCCs for the unit.

Performance Expectations That Informed Design

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.

[*Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.*]

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.]
[*Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.*]

HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomata response to moisture and temperature, and root development in response to water levels.]

[Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]

HS-LS2-3: Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

[Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.]

[*Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.*]

Use of NGSS Elements

In each lesson teacher guide, we show the DCI, CCC, and SEP elements of the NGSS that are targeted in that particular lesson. We use bolding in these elements to demonstrate what parts of the elements students have and have not yet built proficiency within each lesson. As the unit progresses, students will become more proficient in the targeted elements and more of the element will gain bolded language. This allows the teacher to build student proficiency of an element across the unit instead of all in one lesson.

In our design, we chose specific focal DCI, SEP, and CCC elements that students would develop proficiency in across the unit. These elements are listed below. This unit was designed to support teachers in building student proficiency in these targeted elements across the entire unit, not for mastery within individual lessons. Accordingly, the unit is designed such that students should be supported in developing proficiency in the unit-level targeted DCIs, SEPs, and CCCs, listed below. While a wide variety of additional SEPs and CCCs may also be utilized across the unit as supporting elements, student proficiency in these elements will not be fully built nor assessed.

Unit Focal NGSS Elements

SEP:	DCI:	CCC:
CEDS-H2:	**LS1.A-H1:**	**SC-H1:**

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. **DATA-H4:** **Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.** **INFO-H5:** **Communicate scientific** and/or technical **information or ideas (e.g. about phenomena** and/or the process of development and the design and performance of a proposed process or system) **in multiple formats (including orally, graphically, textually, and mathematically).** **MOD-H5:** **Use a model to provide mechanistic accounts of phenomena.**	**Systems of specialized cells within organisms help them perform the essential functions of life.** **LS1.A-H3:** **Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.** **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.** **LS2.B-H1:** Photosynthesis and **cellular respiration (including anaerobic processes) provide most of the energy for life processes.**	**Much of science deals with constructing explanations of how things change and how they remain stable.** **SC-H3:** **Feedback (negative or positive) can stabilize or destabilize a system.** **SPQ-H4:** **Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.**

Focal Element Progression and Use Map

Corresponding Middle School SEP Element	Unit Focal High School SEP Element
CEDS-M3: Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.	**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.
DATA-M7: Analyze and interpret data to determine similarities and differences in findings.	**DATA-H4:** Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
INFO-M5: Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.	**INFO-H5:** Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).
MOD-M5: Develop and/or use a model to predict and/or describe phenomena.	**MOD-H5:** Use a model to provide mechanistic accounts of phenomena.

Building on Prior Middle School SEP Learning

This unit builds on students' middle school-level knowledge of Constructing Explanations and Designing Solutions, Analyzing and Interpreting Data, Obtaining, Evaluating and Communicating Information, and Developing and Using Models. This unit builds on students' middle school SEP proficiencies as follows:

- In middle school, students construct explanations based on valid and reliable evidence from their own experiments to explain how theories and laws describing the natural world operate the same as they have in the past. In this unit, students build on this middle school understanding to construct explanations now using evidence from a variety of sources. For example, in Module 4, students

construct an explanation about how milk helps muscle recovery from soreness induced by intense exercise. They are able to draw from evidence from scientific data, from class models, from Science Theater models, and from scientific literature.

- In middle school, students analyze and interpret data to identify similarities and differences in findings. In this unit, students build on this middle school understanding to compare the findings from two different studies to determine the consistency of measurements (methods) and outcomes (data). For example, in Module 3, students analyze and interpret the data from two studies. They are provided with the methods and data and are asked to compare the two studies to determine if their methods and findings are consistent.
- In middle school, students communicate scientific and/or technical information in writing and/or through oral presentations. In this unit, students build on this middle school understanding to communicate scientific information in multiple formats, including text, visuals, verbally, and graphically. Throughout the unit, students develop a presentation that they will present to the class in a format that best suits a targeted audience. Students begin developing these presentations in Lesson 1 and add on to and revise their presentations throughout Modules 1-4 and the Performance Task.
- 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. For example, in Module 2, students engage in a Science Theater activity to help figure out what causes changes in the amount of water in the blood, volume and color of urine, and the production of sweat during and after exercise. Students are given roles to engage in modeling the biological processes the body experiences during a workout. 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.

Corresponding Middle School DCI Element	**Unit Focal High School DCI Element**
LS1.A-M3: In multicellular organisms the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.	**LS1.A-H1:** Systems of specialized cells within organisms help them perform the essential functions of life.
LS1.A-M3: In multicellular organisms the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.	**LS1.A-H3:** Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.

LS1.D-M1: Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.	**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.
PS3.D-M2: Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.	**LS2.B-H1:** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.

Building on Prior Middle School DCI Learning

This unit builds on students' middle school-level knowledge of Structure and Function and Cycles of Matter and Energy Transfer in Ecosystems.

This unit builds on students' middle school DCI proficiencies as follows:

- 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 unit, students build on this middle school understanding to explain how the function of organs depends on cell specialization. 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. For example, in Module 3, students investigate the specialized cells of the heart (cardiomyocytes), lungs (alveolar epithelial cells), nervous system (motor neurons), liver (hepatic cells), and blood vessels (red blood cells). They learn about how specialized cells help an organ to properly function during exercise and exercise recovery.
- In middle school, students learned that the body is made up of interacting subsystems that contain groups of cells called tissues and that tissues form organs that have specialization for particular body functions. In this unit, students build on this middle school understanding to explain the hierarchical structural organization of the body and body systems. For example, in Module 1, students learn about the individual components of the digestive system and also develop an understanding of how various kinds of specialized cells within different organs contribute to the function of the whole system.

- In middle school, students learned that the brain processes different inputs (electromagnetic, mechanical, chemical) and uses sense receptors and nerves to transmit these signals and respond accordingly. In this unit, students build on this middle school understanding to explore how these sensory systems are used by the body to maintain homeostasis and to respond to changes in external conditions. For example, in Module 2, students figure out that the body has feedback mechanisms that are used to respond to internal changes caused by external factors, such as an increase in internal body temperature due to exercise or the sweat response due to blood vessel dilation. Each of these mechanisms involves receptors that inform the brain and consequently other body systems and cells as to how to respond to different internal and external inputs.
- In middle school, students learned that cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. In this unit, students build on this middle school understanding to figure out that cellular energy comes not only from aerobic respiration, but also from anaerobic respiration. Students also figure out that cellular energy is tied to the availability of stores of glucose in the body, which can change when exercising or when recovering from exercise. For example, in Module 3, students explore the measurable indicators of metabolic responses because of exercise, such as changes in the amounts of glucose in the bloodstream, glucose and glycogen in muscle and liver, and the way that muscle cells produce energy in aerobic and anaerobic conditions.

Corresponding Middle School CCC Element	**Unit Focal High School CCC Element**
SC-M1: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.	**SC-H1:** Much of science deals with constructing explanations of how things change and how they remain stable.
SC-M4: Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.	**SC-H3:** Feedback (negative or positive) can stabilize or destabilize a system.
SPQ-M1: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.	**SPQ-H4:** Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Building on Prior Middle School CCC Learning

This unit builds on students' middle school-level knowledge of Stability and Change and Scale, Proportion, and Quantity. This unit builds on students' middle school CCC proficiencies as follows:

- In middle school, students explain stability and change in natural or designed systems by examining changes over time and processes and different scales. In this unit, students build on this idea by figuring out that much of science deals with constructing explanations of how things change over time For example, in Modules 3 and 4, students analyze data and use models that show that many molecular markers in the body change when an individual exercises and return to a stable state in recovery. Students conclude that much of the science of studying the human body is based on studying changes that occur to various molecular factors during exercise or other events.
- 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 develop two models that demonstrate how feedback mechanisms in the body respond to temperature and water balance changes in the body during physical activity. They see that the body uses negative feedback mechanisms to help it return to a stable state in response to an external or internal change in temperature or water availability due to exercise.
- In middle school, students learn that time, space, and energy phenomena can be observed at small or large scales using models. In this unit, students build on this idea by using orders of magnitude to explain relationships at various scales on a model. For example, in Module 1, students are introduced to the Orders of Magnitude Tool to help them use orders of magnitude to understand how models at one size scale (eg, organs on the centimeter scale) relate to models at another scale (eg, cells on the micrometer scale).

Focal Element Use Map

Students are given multiple opportunities to build their proficiency with the focal elements for this unit. The lessons in which students build their proficiency for each focal element are shown below.

CEDS-H2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
				▯		▯		▯	▯				▯			▯

DATA-H4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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INFO-H5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
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MOD-H5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
				☐					☐		☐					
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			☐									☐				☐

LS1.A-H1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
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LS1.A-H3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

LS1.A-H4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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LS1.A-H4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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	☐	☐	☐	☐	☐	☐	☐	☐								

SC-H1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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	☐	☐	☐	☐	☐	☐	☐	☐						☐	☐	☐

SC-H3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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SPQ-H4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		☐	☐	☐	☐	☐	☐									
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

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