NGSS Sample Bundles

Volume B:

6-12

NEXT GENERATION SCIENCE STANDARDS

For States, By States

Example Bundles Guide

The Next Generation Science Standards (NGSS) identify what students should know and be able to do in science in order to be ready for college and careers. Because the NGSS are academic standards, they do not describe curriculum or the lessons and activities in which students engage during a course or year of instruction. Curriculum designed for the NGSS, including lesson plans, activities, scope and sequence documents, and assessments, is needed for classroom instruction.

The NGSS PEs are not intended to be taught or assessed one-at-a-time, or in isolation. Therefore, one helpful approach to beginning the translation of the NGSS into curriculum and instruction is to “bundle” standards together, arranging them in groups for instruction. Bundles of standards can be helpful to show connections between ideas, facilitate phenomenon-driven instruction, and promote efficient use of instructional time. They can form end goals for instruction at a similar scale to that of traditional curricular units. Several bundles can be assembled such that they coherently address all of the standards found within a grade level of instruction; when this process is done strategically, the bundles can form the outline of an entire course.

This Example Bundles Guide explains, in detail, considerations related to bundling. The Guide accompanies a set of concrete examples within each grade level K–12 of what it can look like when several related standards are bundled together. They are by no means the only way that standards could be bundled together, but they are designed to be illustrative of the process of bundling and the types of thinking necessary in building bundles that capitalize on the connections between standards. Curriculum developers can use these example bundles in thinking about how they will create and arrange bundles in a way that coherently builds student proficiency in all three dimensions of the standards.

This Guide is intended to enable a user to read and navigate the Example Bundles documents. Another focus is to explain how to use the principle of “bundling.” These two ideas overlap a great deal. Users that are working to gain a deep understanding of bundling should review these documents following this sequence: First, ensure you are very familiar with the NGSS and the National Research Council’s (NRC) *Framework for K–12 Science Education*, on which the NGSS were based. Then, read through this Guide and at least one Example Bundle course (a model for one instructional year) for an introduction to bundling.

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Key Definitions of This Guide

A number of terms have a technical significance in this Guide that goes beyond their typical use in the education community. Please review this section before moving on to other parts of the Guide.

Bundle - A bundle is a group of performance expectations that have been brought together to organize instruction. A bundle in this document is intended to match the scale of the instructional "unit," as it is commonly thought of in many education settings. Additionally, within the Example Bundles, a bundle document identifies an underlying rationale and assumptions about the relationships between the performance expectations that have been grouped together.

Bundling - The iterative process of developing a bundle of performance expectations for purposes of both instruction and assessment.

CCC - Crosscutting Concept**.** There are seven crosscutting concepts in the NGSS, described in the *Framework for K-12 Science Education*. The progression for each crosscutting concept across the grade bands is outlined in NGSS Appendix G, with the associated elements identified in the foundation box of each performance expectation.

Course - A course is a group of bundles that collectively address all of the performance expectations in a grade level.

Course set - A course set is a set of courses that collectively address all of the performance expectations in the middle school (6–8) or high school (9–12) grade bands.

DCI - Disciplinary Core Idea. The DCIs are defined by the *Framework for K-12 Science Education*, outlined in NGSS Appendix E, with the associated elements identified in the foundation box of each performance expectation.

ED - Engineering Design. This is the title of one of the Engineering, Technology, and Applications of Science Disciplinary Core Ideas from the *Framework for K-12 Science Education*.

ETS - Engineering, Technology, and Applications of Science. This is one of the four content categories of the Disciplinary Core Ideas in the NRC Framework and the NGSS.

Grade band - In the NRC *Framework* and the NGSS, a grade band is a set of grades for elementary grades (K–2 and 3–5), middle school (6–8) or high school (9–12). The middle and high school grade bands do not indicate a sequence within the band, but they do organize all of the performance expectations that should be addressed for that band. In the elementary grades, however, the NGSS describes which performance expectations are at each grade level.

NGSS Element - An NGSS element is a grade band-specific part of a Disciplinary Core Idea, Crosscutting Concept, or Science and Engineering Practices[1]. NGSS elements are often formatted with bullets and are identified by the title of a DCI, SEP, CCC, in the foundation box of a performance expectation.

NOS - Nature of Science Statement. There are eight categories of understandings about the nature of science that are outlined in NGSS Appendix H, and identified in the foundation boxes of select performance expectations. Four of the eight categories are integrated within Science and Engineering Practices and four are associated within Crosscutting Concepts.

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[1] Anyone unfamiliar with the components of the NGSS is encouraged to review "How to Read the Standards" resources and videos on www.nextgenscience.org, and to become deeply familiar with the NGSS and the NRC Framework before using the Example Bundle documents.

NRC *Framework* - *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012)

PE - Performance Expectations. These are the form in which the NGSS is written – as student performance expectations.

Phenomenon - Something observable that happens in the real world, whether natural or man-made. Student inquiry about phenomena—together with student-driven designing of solutions to problems—should drive instruction.

SEP - Science and Engineering Practice. There are eight practices, described by the *Framework for K-12 Science Education*. The progression for each SEP across the grade bands is outlined in NGSS Appendix F, with the associated elements identified in the foundation box of each performance expectation.

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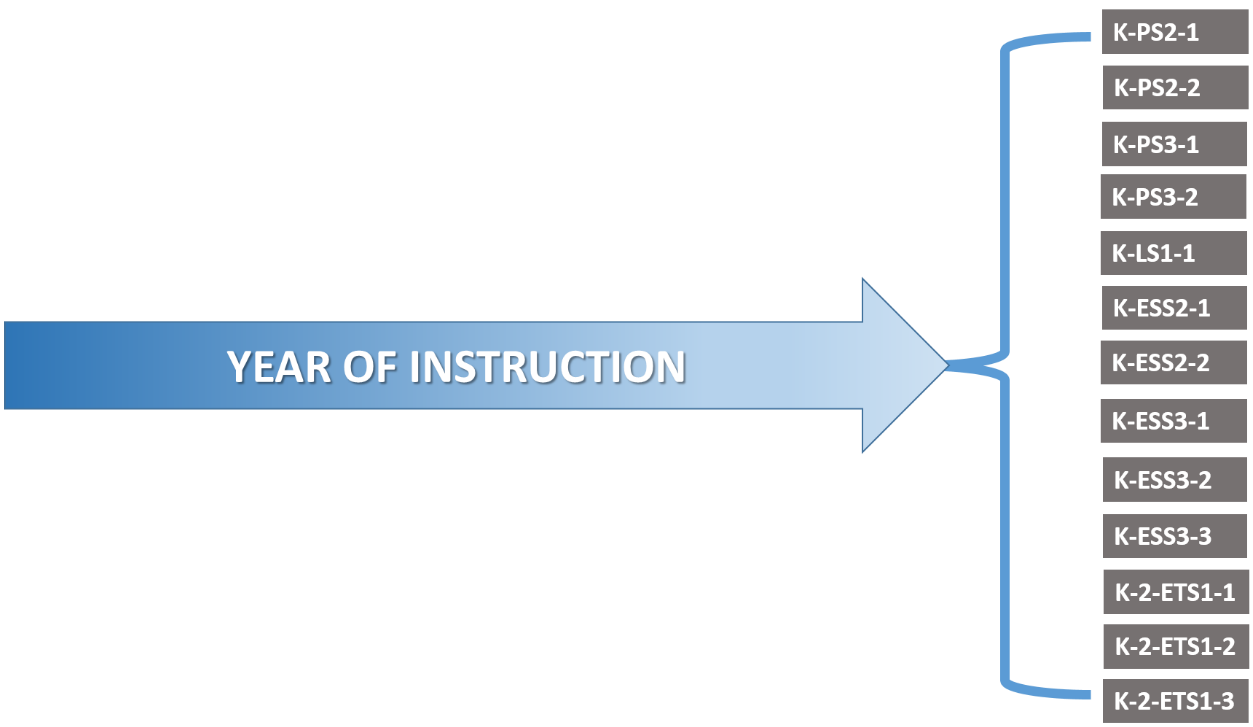
Why is Bundling Important?

The Need

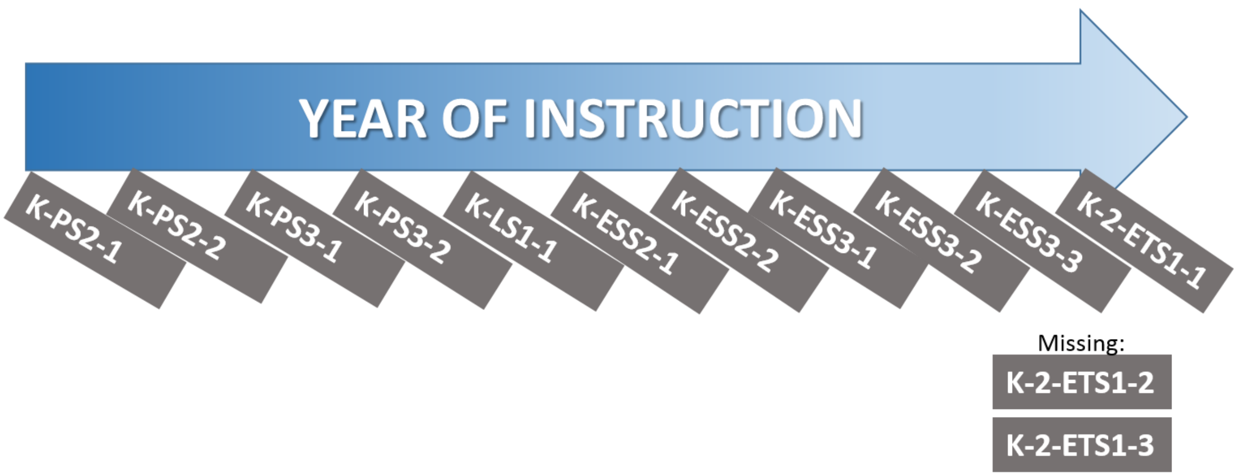
As states, districts, and educators implement the Next Generation Science Standards (NGSS), a critical step in their effort is translating the grade level (or grade band) endpoint standards into units of instruction that build all three dimensions of the NGSS over the course of a year or over multiple years. In the NGSS, the standards are often called performance expectations (PEs), and instruction can be organized in many different ways throughout a year to help prepare students to meet or exceed these expectations *by the end of the year*. Figures 1, 2, and 3 below represent what this could mean for the Kindergarten PEs of the NGSS.

Figure 1: *The NGSS Kindergarten PEs are all written as expectations of what students should be ready to perform* by the end *of their Kindergarten experience.*



The year or years of instruction leading to PEs is typically organized into units and lessons. One way to begin to organize instruction might be to target the PEs individually, sequencing them one at a time. However, this approach often leads to instruction taught without a cohesive storyline, and leads teachers and students to rush through content and entirely miss instruction on PEs sequenced toward the end of the year.

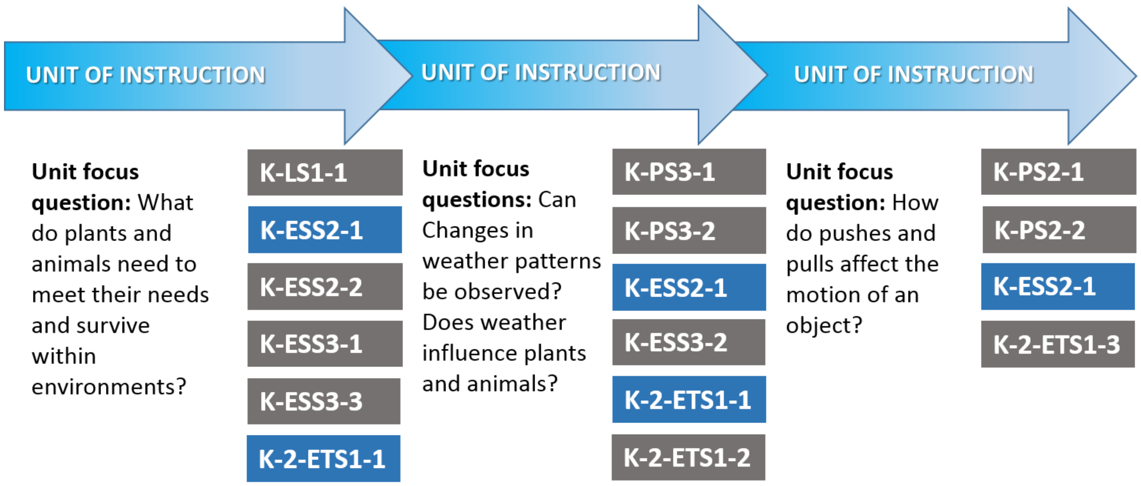
Figure 2: *What a Kindergarten lesson sequence might look like if instruction is organized for one PE at a time.*



The NGSS PEs are not intended to be taught or assessed one-at-a-time, or in isolation. Therefore, bundling PEs can be a useful step in organizing instruction. Curriculum developers can group PEs together in manageable arrangements to help students and teachers look for the connections between ideas that naturally exist in the sciences. Instruction that builds toward a bundle of related PEs simultaneously will also help students develop a more complete explanation of phenomena. Once these arrangements—or bundles—are developed, they may be used as the unit endpoints from which to design instruction and classroom assessment[2].

[2] Classroom assessment involves both summative and formative assessment. However the Example Bundles provide information about the end goals of instruction as opposed to interim steps. Comments on the development of formative classroom assessment and other aspects of assessment, including the design of implementation of assessment systems, are topics that exist outside of the scope of these documents.

Figure 3: *What a Kindergarten unit sequence might look like with a series of PE bundles over the course of a year. PEs in blue represent PEs that are only partially met in a particular unit.*



The Example Bundles were written to demonstrate some of the many ways PEs can be grouped together to support the development of a cohesive instructional unit. Additional examples of NGSS bundles are already available in the arrangements of the NGSS; the PEs were published in two different types of arrangements: by topic and by Disciplinary Core Idea (DCI). There is no one right way to bundle PEs, so the Example Bundles are just that—examples. Curriculum developers and others designing instructional units can be creative in their approach. The inclusion of multiple instructional-year models for each grade level in K–5 and each grade band in the secondary levels emphasizes the diverse possibilities available to teachers.

The Example Bundles also do not emphasize or include all of the aspects of developing three-dimensional instruction and curriculum. After standards are bundled, additional work must be done to develop lessons, activities, and assessments. Other resources are available that address important aspects of curriculum development and should be consulted before developing curriculum.[3]

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Who Can Use the Example Bundles?

The Example Bundles were created for curriculum designers and educators who develop curriculum, who have prior knowledge of the NGSS and the NRC *Framework*, and who are looking for a resource that will help them in the development of curricula for any grade level. A Suggestions for Use of the Example Bundles section is provided later in this Guide.

[3] See Appendix 2: Further Reading on Three-Dimensional Instruction

Getting Around the Documents

The Example Bundles documents are organized by courses, which are groups of bundles that collectively address all of the PEs in a grade level[4]. Each Example Bundle Course contains:

1. A Course Summary – a document that introduces a user to the themes of the year-long course, and briefly describes the way those themes are derived from the arrangement of the PEs within the bundles of the course.
2. A Course Flow Chart – a visual example of how the writers connected DCIs across bundles in a course.
3. Several Bundle Documents (one for each bundle of PEs) – each document includes a narrative about the connections between bundle PEs, example phenomena for the bundle, and additional science and engineering practices (SEPs), crosscutting concepts (CCCs), and nature of science (NOS) components that can be used in instruction toward the bundle.

Course Summary

Course Summaries begin with a narrative and rationale that explains the content overview for the year, the rationale for how the PEs were bundled throughout the year, and, for middle and high school courses, the source[4] of the year end-points for middle and high school.

The second part of the Course Summary includes one column for each bundle, indicating the number of example bundles in the course, the PEs grouped within those bundles, and a rough estimate of instructional duration (in weeks) for each bundle.

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[4] In grades K–5, the NGSS were written as grade-level PEs, so the Example Bundles writers started with the PEs as the year endpoints. In grades 6–12, the NGSS were written as grade-banded PEs, so the Example Bundles writers started with various arrangements of the middle and high school PEs listed in or modified from NGSS Appendix K. For example, some of the middle school Example Bundles used the California Conceptual Progressions Course Map (page 20–21 of NGSS Appendix K) as the guide for grade level endpoints, because it was the first state-specific course map to be developed. Each Course Summary document describes the origin of its end-of-year endpoints.

Figure 4: *A Course Summary for Kindergarten*

<table>
<tr><td colspan="3">Kindergarten Topic Model
Narrative and Rationale: The three bundles in this Kindergarten model are characterized by the overarching ideas that weather, sunlight, and the needs of living things affect us daily—ideas that apply to the physical, life, and Earth and space sciences, as well as engineering.

Bundle 1 centers on a guiding question about pushes and pulls on objects and their effects. Bundle 2 centers on a guiding question about the needs of plants and animals for food, water, and sunlight to survive. Bundle 3 centers on a guiding question about patterns and the effects of sunlight. While this framework is arranged by topic, the study of weather occurs throughout the year, over time.

In Kindergarten, students begin to build their understanding of the Crosscutting Concepts (CCCs) of patterns and the relationship between cause and effect in a logical progression over time. This model also introduces students to the Science and Engineering Practices (SEPs). It places special emphasis on planning and carrying out investigations, analyzing and interpreting data, engaging in argument from evidence, and constructing explanations and designing solutions. However, additional SEPs should be used throughout instruction. The SEPs contribute to students' understanding of both the CCCs and the Disciplinary Core Ideas (DCIs) they explore in Kindergarten. Students become familiar with SEPs over the course of the year, and the level of sophistication at which they are able to engage in the SEPs increases over time.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Bundle 1: How do objects move and what happens when they interact?

~4 weeks</td><td>Bundle 2: What is the relationship between the needs of different plants and animals and the places they live?

~18 weeks</td><td>Bundle 3: What can we observe about sunlight?

~14 weeks</td></tr>
<tr><td>K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

K-PS2-2. Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.*

K-ESS2-1. Use and share observations of local weather conditions to describe patterns over time. [1]

K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.</td><td>K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive.

K-ESS2-1. Use and share observations of local weather conditions to describe patterns over time. [1]

K-ESS2-2. Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.

K-ESS3-1. Use a model to represent the relationship between the needs of different plants and animals (including humans) and the places they live.

K-ESS3-2. Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to severe weather.

K-ESS3-3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.*

K-2-ETS1-1. Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.[1]</td><td>K-PS3-1. Make observations to determine the effect of sunlight on Earth's surface.

K-PS3-2. Use tools and materials provided to design and build a structure that will reduce the warming effect of sunlight on Earth's surface.*

K-ESS2-1. Use and share observations of local weather conditions to describe patterns over time.

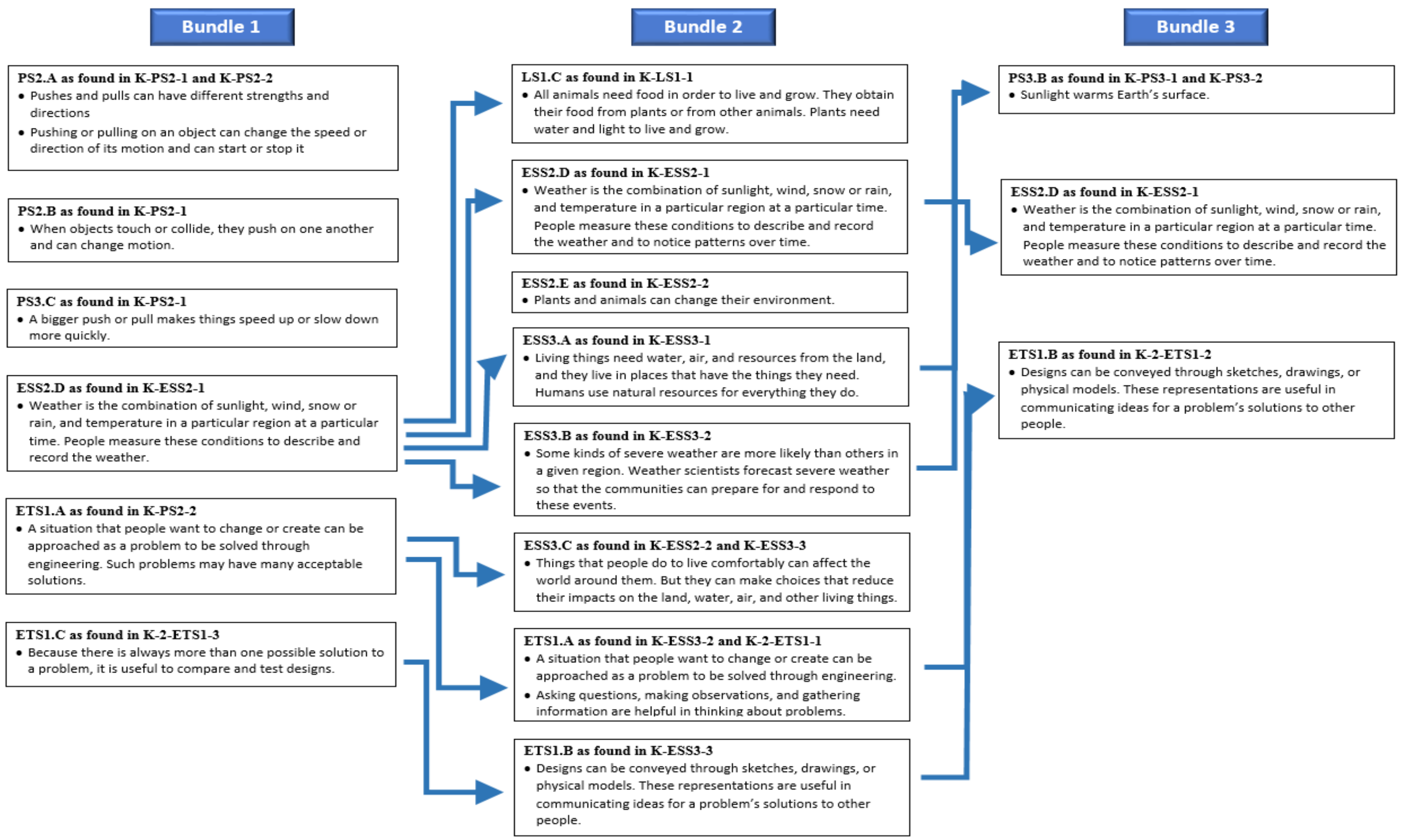
K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.</td></tr>
</table>

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

Course Flowchart

The Course Flow Chart shows the DCIs in each bundle of the course, indicates connections *between* the bundles, and provides a one-page overview of the progression of DCIs over the year. When the writers created and ordered the bundles throughout each year, these conceptual progressions were one of their main areas of focus. Therefore DCIs are emphasized in the flowchart because they were the dimension primarily used for the bundling and ordering process. However, SEPs and CCCs are also essential learning goals and components of instruction throughout the year, and are discussed in each bundle document. The DCI connections shown via the arrows in the flowchart are also not exhaustive; many more connections could be made. The arrows show opportunities for conceptual flow—not a sequence of instruction.

Figure 5: *An example of a Course Flowchart for Kindergarten*



Bundle Document

To demonstrate the rationale behind each PE bundle, each individual bundle document identifies some of the DCI-level connections within the bundle. Also, the Example Bundles make suggestions for using SEPs, CCCs, and NOS elements during instruction. These inclusions show how multiple SEPs and CCCs can be interwoven with DCIs while building students' understandings toward the PEs.

Each Example Bundle Document contains the following components[5]:

Summary - A narrative describing the connections between the DCIs, SEPs, and CCCs in the bundle.

Performance Expectation Chart - A list of each PE in the bundle.

Phenomena – Example engaging phenomena that could be used in instruction.

Additional Practices Building to the PEs – Suggestions for additional SEPs that could be used in instruction toward the bundle PEs. .

Additional Crosscutting Concepts Building to the PEs – Suggestion for additional CCCs that could be used in instruction toward the bundle PEs.

Additional Connections to Nature of Science (NOS) – Suggestion for additional NOS elements that could be used in instruction toward the bundle PEs.

Evidence Statements - Evidence Statements support summative assessment of a given PE or part of a PE, but can be used to inform instruction and formative assessment.

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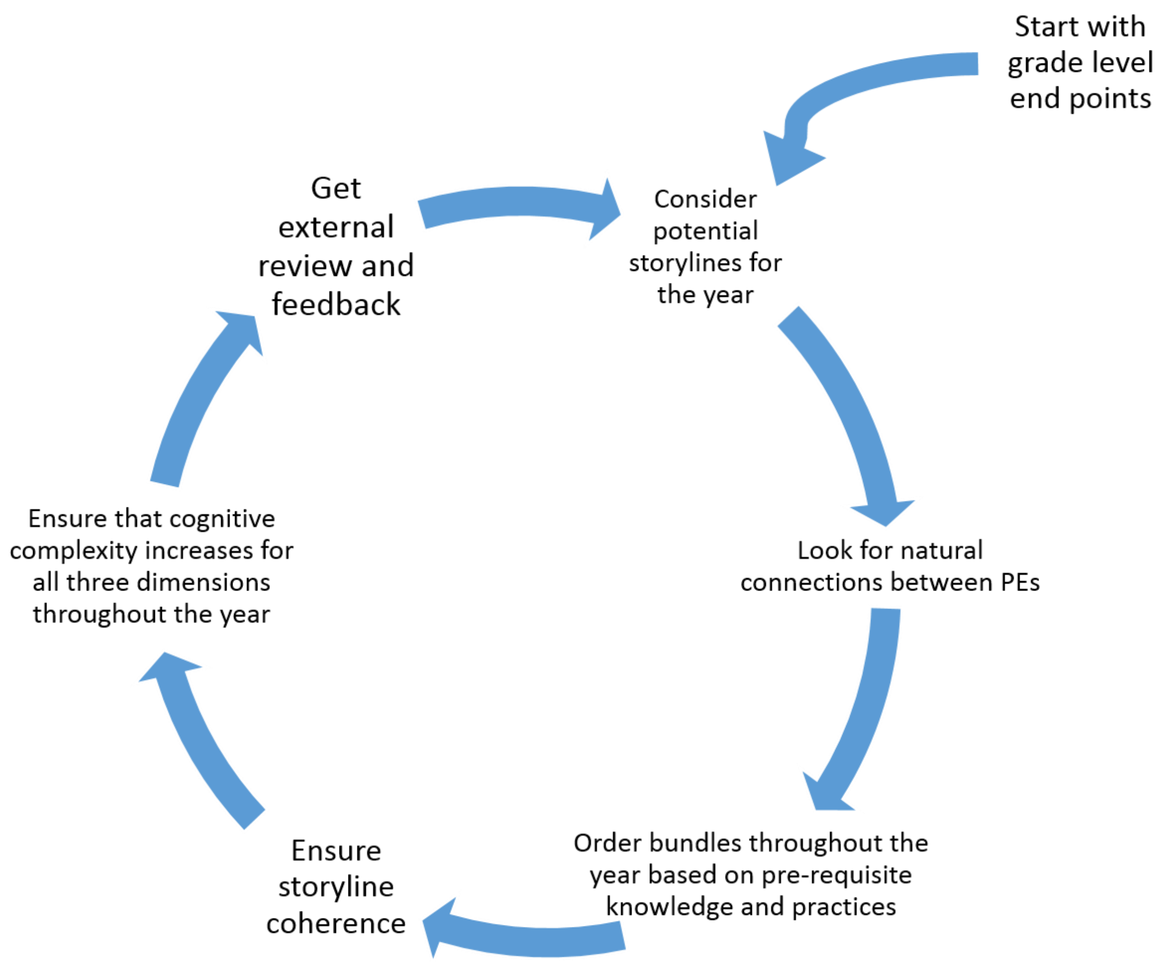
[5] A full explanation of the styles used in the Example Bundle Documents may found in Appendix 1: Example Bundle Styles and Explanations

Creating Bundles, Courses, and Course Sets

The Iterative Process of Creating the Example Bundles

In a process facilitated by Achieve, the Example Bundles were developed by teams of experts, including many of the NGSS writers and other educators and scientists[6], to demonstrate the design principles curriculum developers need to understand. For this reason, the idea of presenting multiple examples of course models and bundles was made a key feature of the Example Bundles from the outset.

Figure 6: *A summary of the iterative Example Bundles development process*



As described in the figure above, the Example Bundles were developed in an iterative process, where the writers began by looking at all the PEs in a grade level[4] and considering potential storylines that could help students build toward proficiency on those PEs by the end of the year. They then considered any natural connections between concepts of the different PEs in order to create potential bundles. The Evidence Statements for each PE were often used to help find natural connections between different

[6] A full list of the Example Bundle writers who contributed to this project may be found in the Acknowledgements section.

PEs. For example, Figure 7 on the next page shows some possible connections between MS-LS1-7 and MS-PS1-5.

Figure 7: *The evidence statements for MS-LS1-7 and MS-PS1-5 are highlighted in purple to show potential connections.*

Evidence Statements for **MS-LS1-7**:

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a phenomenon, students develop a model in which they identify the relevant components for describing how food molecules are rearranged as matter moves through an organism, including:	
		i.	Molecules of food, which are complex carbon-containing molecules.
		ii.	Oxygen.
		iii.	Energy that is released or absorbed during chemical reactions between food and oxygen.
		iv.	New types of molecules produced through chemical reactions involving food.
2	Relationships		
	a	In the model, students identify and describe the relationships between components, including:	
		i.	During cellular respiration, molecules of food undergo chemical reactions with oxygen, releasing stored energy.
		ii.	The atoms in food are rearranged through chemical reactions to form new molecules.
3	Connections		
	a	Students use the model to describe:	
		i.	The number of each type of atom being the same before and after chemical reactions, indicating that the matter ingested as food is conserved as it moves through an organism to support growth.
		ii.	That all matter (atoms) used by the organism for growth comes from the products of the chemical reactions involving the matter taken in by the organism.
		iii.	Food molecules taken in by the organism are broken down and can then be rearranged to become the molecules that comprise the organism (e.g., the proteins and other molecules in a hamburger can be broken down and used to make a variety of tissues in humans).
		iv.	As food molecules are rearranged, energy is released and can be used to support other processes within the organism.

Evidence Statements for **MS-PS1-5**:

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a given phenomenon, students develop a model in which they identify the relevant components for a given chemical reaction, including:	
		i.	The types and number of molecules that make up the reactants.
		ii.	The types and number of molecules that make up the products.
2	Relationships		
	a	In the model, students describe relationships between the components, including:	
		i.	Each molecule in each of the reactants is made up of the same type(s) and number of atoms.
		ii.	When a chemical reaction occurs, the atoms that make up the molecules of reactants rearrange and form new molecules (i.e., products).
		iii.	The number and types of atoms that make up the products are equal to the number and types of atoms that make up the reactants.
		iv.	Each type of atom has a specific mass, which is the same for all atoms of that type.
3	Connections		
	a	Students use the model to describe that the atoms that make up the reactants rearrange and come together in different arrangements to form the products of a reaction.	
	b	Students use the model to provide a causal account that mass is conserved during chemical reactions because the number and types of atoms that are in the reactants equal the number and types of atoms that are in the products, and all atoms of the same type have the same mass regardless of the molecule in which they are found.	

Because they were developing multiple models, the writers considered different approaches[7] to connecting PEs, including looking at CCC themes and answering a driving question. Overall, the writers discovered that *bundles that were based on helping students make sense of a particular phenomenon worked the best in the models,* and this is an approach they would recommend for future bundles.

The writers then developed a sequence for the bundles within the instructional year by taking into account prerequisite concepts, storyline coherence, and cognitive complexity of each of the three dimensions. They focused on avoiding the "black box"—when students are asked to memorize content during one instructional unit but only begin to understand it in a later instructional unit. The writers then sought external feedback for the bundles and prototype courses in relation to the shifts of the NGSS and the vision of the NRC *Framework*. After revising the bundles in response to the feedback, the bundles were again externally reviewed and that feedback was incorporated. As schools and districts develop their own bundles, courses, and course sets, a similar iterative process should be employed.

[7] The approach taken to bundle PEs in a specific course model is described in the course summary and is used in the name of the course model (e.g., Kindergarten Thematic Model).

Creating Your Own Bundles

There are many important considerations for anyone working to create NGSS bundles, courses, and course sets. The assumptions and rationale that guide the formation of a bundle require careful consideration of the needs and characteristics of students in the classroom. The same reflective and collaborative thought process is required for organizing instruction and designing curriculum at every scale, from bundles, to courses, to course sets. Once curriculum developers have created bundles, they can begin to design lesson plans that collectively build toward the bundle—i.e., the instructional unit goals.

The following section outlines some questions to consider when you begin developing your own bundles. These considerations may be encountered in a variety of ways, and at different times in the development process, so they are identified without a specific sequence.

Considerations for Creating Your Own Bundles:

Scale

What is the scale of the curriculum that is being developed—is it a lesson, unit, year, or set of courses across multiple years? Is an individual bundle being created? Are a set of bundles being designed or redesigned to fit within other established curriculum?

Coherence

How are the SEPs, CCCs, and DCIs developed across each grade level and grade band? What do possible storylines suggest about the ways the PEs might be bundled and about the way bundles should be sequenced?

Phenomena

What phenomena might drive engaging lines of inquiry for the students served by this instruction? Will instruction focus on helping students explain a single phenomenon, or will different parts of instruction need to address different phenomena?

Connections

In what ways can CCCs and DCIs be used to explicitly make connections across bundles and between scientific disciplines? Are there other relevant connections between concepts? What about interdisciplinary connections to mathematics or English/language arts (ELA)? At what point in the school year will students be learning the associated mathematics and ELA concepts?

Implementation

What resources are available to support instruction? In what stage is the school or district in its transition to full NGSS implementation? Are the students ready for these DCIs, CCCs, and SEPs?

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Suggestions for Use of the Example Bundles

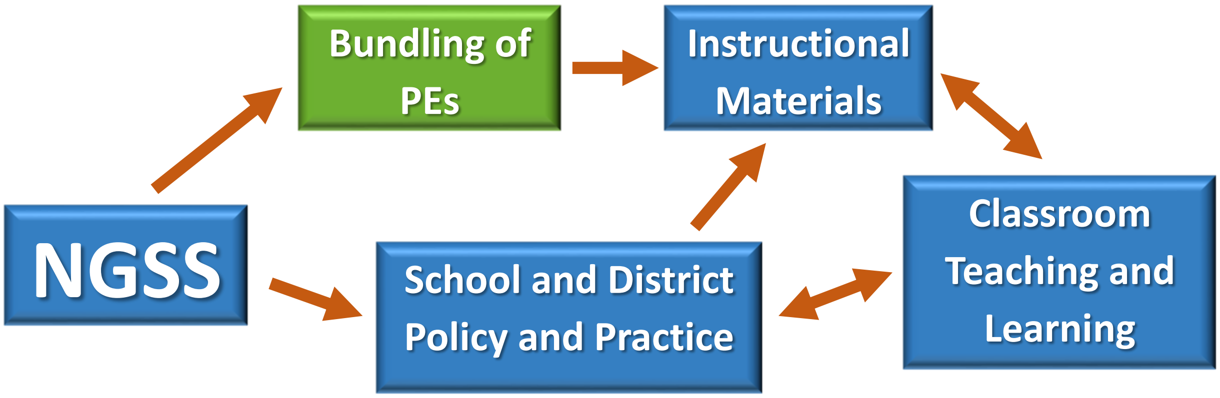

Figure 8: *Bundling is shown as an intermediary step in the instructional materials development process between the NGSS and the use of aligned instructional materials during instruction. Classroom teachers and school and district administrations are also shown as having large influences on the instructional materials that are used. This diagram does not show all the components and relationships in an education system.*

Teachers and School-based Curriculum Developers

Since teachers are ultimately responsible for the instruction in their classrooms, sometimes they are the developers of school- or classroom-based curriculum and instructional materials, or are engaged in the selection of pre-made materials that can serve the needs of their classrooms. In either case, school-based curriculum developers can use the Example Bundles and descriptions of the bundling process as examples of how other teachers have thought about bundling PEs, as a tool for reflecting on their own instructional units, and as a source of ideas for the things to consider when beginning the process of curriculum development. By engaging with the Example Bundles, teachers will also be better prepared to evaluate instructional materials.

School and District Leaders

Bundling is a first step in translating the vision of the NGSS into curriculum and then into instruction. To support the development of NGSS-aligned curriculum, school and district leaders need to be aware of the implications of the NGSS and the process of bundling, even if they are not directly involved in the development process. Though not always directly engaged in curriculum development, school and district leaders enable the development work through their common understanding of the complexity of and time required for the process. District curriculum coordinators and others involved in district curriculum development can use the Example Bundles and descriptions of the bundling process as inspiration for developing their own bundles. Administrators can also use the Example Bundles in other ways, such as for helping teachers better understand the NGSS, or as a tool to help jump start school or district professional learning communities.

Publishers and Commercial Instructional Material Developers

Since the release of the NGSS in 2013, high-quality instructional materials designed for the NGSS have been a critical need in the science education community. Choosing from commercial products is one way that schools fill this need. The Example Bundles may hold much of the same value for publishers that they offer to schools and districts by presenting examples of ways to organize the NGSS. Additionally, by illustrating some of the early steps related to developing NGSS-designed curriculum, the Example Bundles can provide publishers with a common language to use with educators.

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Acknowledgements: Example Bundle Authors and Contributors

In a process coordinated by Achieve, the following scientists and education professionals worked together to develop the Example Bundles. The titles below indicate their positions at the time of development.

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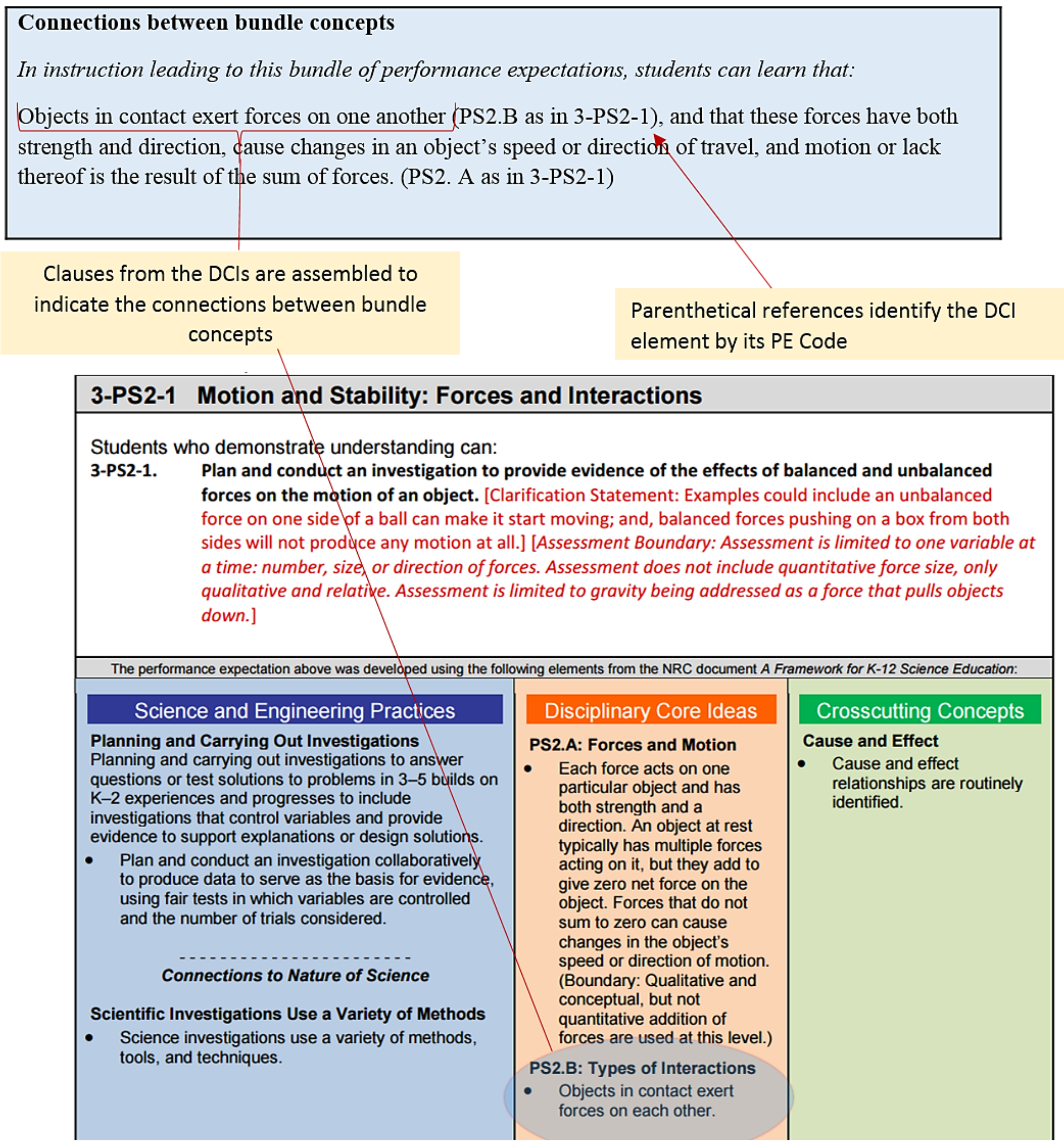
Appendix 1: Example Bundle Styles and Explanations

A Note about the Style of the Example Bundle Document

Fidelity to the language of the NGSS is a driving design principle of the Example Bundles. Wherever possible, direct quotes of NGSS language, such as clauses of the PEs or DCI, CCC, and SEP elements are used in identifying connections between the PEs. This language is identified with specific type styles, such as italics when using SEP language in the additional SEPs section, and with parenthetical references that identify the relevant PE code. Non-NGSS or paraphrased language is used as sparingly as possible; only where absolutely necessary to demonstrate connections between PEs or to offer suggestions for instruction.

Figure 9: *An excerpt from a 3rd grade bundle is shown along with its source material in 3-PS2-1.*



Connections between bundle concepts

In instruction leading to this bundle of performance expectations, students can learn that:

Objects in contact exert forces on one another (PS2.B as in 3-PS2-1), and that these forces have both strength and direction, cause changes in an object's speed or direction of travel, and motion or lack thereof is the result of the sum of forces. (PS2. A as in 3-PS2-1)

3-PS2-1 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

3-PS2-1. **Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.** [Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.] [*Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.

Connections to Nature of Science

Scientific Investigations Use a Variety of Methods

- Science investigations use a variety of methods, tools, and techniques.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.)

PS2.B: Types of Interactions

- Objects in contact exert forces on each other.

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships are routinely identified.

Bundle Summary

***Figure 10:** An image from the Bundle Summary of a Kindergarten bundle document*

Bundle 1 Question: This bundles is assembled to address the questions of "How do objects move and what happens when they interact?"

Summary
The bundle organizes performance expectations around the topic of *pushes and pulls.* Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it (PS2.A as in K-PS2-1 and K-PS2-2). This concept of motion connects to the idea that a bigger push or pull makes things speed up or slow down more quickly (PS3.C as in K-PS2-1).

The concept of pushing or pulling on an object (PS2.A as in K-PS2-1 and K-PS2-2) also connects to the idea that when objects touch, or collide, they push on one another and can change motion. (PS2.B as in K-PS2-1)

The idea that a bigger push or pull makes things speed up or slow down more quickly (PS3.C as in K-PS2-1) connects to the concept that pushes and pulls can have different strengths and directions (PS2.A as in K-PS2-1 and K-PS2-2).

The concept that people measure weather conditions to describe and record the weather and to notice patterns over time (ESS2.D as in K-ESS2-1) connects to the idea that it is useful to compare and test designs (ETS1.C as in K-2-ETS1-3) through data analysis.

The ideas that a situation that people want to change or create can be approached as a problem to be solved through engineering (ETS1.A as in K-PS2-2) and that, because there is always more than one possible solution to a problem, it is useful to compare and test designs (ETS1.C as in K-2-ETS1-3) could connect to multiple physical science concepts in this bundle. For example, these concepts could connect to the idea that when objects touch or collide, they push on one another and can change motion (PS2.B as in K-PS2-1) through a task in which students are challenged to work in groups to change the direction or speed of a ball with another object and then test and compare each group's solution. Alternatively, these engineering concepts could connect to the idea that a bigger push or pull makes things speed up or slow down more quickly (PS3.C as in K-PS2-1) through a different task in which students are asked to pull or push an object in a certain amount of time and then challenged to do it faster. Students could then compare their solutions and reflect on how their pull or push needed to change in order to move the object faster.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of planning and carrying out investigations (K-PS2-1); and analyzing and interpreting data (K-PS2-2, K-ESS2-1, and K-2-ETS1-3). Many other practice elements can be used in instruction.

Engineering, Technology, and Applications of Science (ETS) DCIs Paired with Science DCIs

The integration of engineering design with science is a goal of the NGSS. When an Engineering, Technology, and Applications of Science (ETS) DCI is part of an example bundle, it is paired with some of the science concepts of the bundle. For example:

> *"...the concept that tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved (ETS1.B as in 3-5-ETS1-3) could connect to several concepts such as objects in contact exert forces on one another (PS2.B as in 3-PS2-1), or the idea that forces from electric and magnetic forces (PS2.B as in 3-PS2-3 and 3-PS2-4) come from objects. These connections could be made through an engineering design task such as designing a mechanical or a magnetic door latch to prevent a door from swinging open. Alternatively, students could be challenged with a different design task involving tests (ETS1.B as in 3-5-ETS1-3) that use patterns in motion to predict future motion (PS2.A as in 3-PS2-2) such as creating and testing a set of ramps designed to stop toy car rolling down a slope, modeling the challenges faced by vehicles whose brakes have failed as they descended a steep grade."*

Additionally, several examples are provided to indicate what the ETS DCI might look like during instruction.

Bundle Science and Engineering Practices and Bundle Crosscutting Concepts

To emphasize that the SEP and CCC elements of the bundle PEs are part of instruction, the summary section concludes with a listing of their titles and accompanying PE codes. Note that these are the student goals for *the end of instruction*—these are NOT the only SEPs and CCCs that could or should be used *during* instruction. An educator should not be limited by the SEP and CCC elements listed here, but rather should incorporate other SEP and CCC elements throughout instruction to ensure that all instruction is three-dimensional.

Bundle Performance Expectation Chart

The PE chart for a given bundle of PEs identifies the PE code, PE text, Assessment Boundary, and Clarification Statement associated with a given PE.

Figure 11: *A Performance Expectation chart from a Kindergarten Example Bundle*

Performance Expectations	K-PS2-1 **Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. [Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.] [*Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.*]** K-PS2-2 **Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.* [Clarification Statement: Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.] [*Assessment Boundary: Assessment does not include friction as a mechanism for change in speed.*]** K-ESS2-1 **Use and share observations of local weather conditions to describe patterns over time. [Clarification Statement: Examples of qualitative observations could include descriptions of the weather (such as sunny, cloudy, rainy, and warm); examples of quantitative observations could include numbers of sunny, windy, and rainy days in a month. Examples of patterns could include that it is usually cooler in the morning than in the afternoon and the number of sunny days versus cloudy days in different months.] [*Assessment Boundary:***

	***Assessment of quantitative observations limited to whole numbers and relative measures such as warmer/cooler.*]** K-2-ETS1-3 **Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.**

Example phenomena

The example phenomena shown in this section are sample engaging phenomena that could be used in instruction, whether as an anchor for a unit or a driver for a lesson. Lines of student inquiry about these phenomena could drive instruction toward the bundle of PEs. However, these are not the only phenomena that could be used.

Figure 12: *An Example Phenomena chart from a Kindergarten Example Bundle*

Example Phenomena	A swing moves as it is pushed. A box pushed across a floor moves quickly with a strong push and slows down as when the pushing becomes weaker.

Additional Science and Engineering Practices Building to the PEs

This section demonstrates how additional SEPs—other than those already included in the bundle PEs—can support instruction. These additional SEPs are only examples and are not intended to be summatively assessed.

Figure 13: *An excerpt from the chart of Additional Practices Building to the PEs from a Kindergarten Example Bundle*

Additional Practices Building to the PEs	**Asking questions and defining problems** ● Ask and/or identify questions that can be answered by an investigation. Students could *identify questions about* **pushing or pulling on an object** *[to]* **change the speed or direction of its motion and can start or stop it** *that can be answered by an investigation.* K-PS2-1 and K-PS2-2

In this section, an SEP element is included from each of the eight SEP categories. Below the SEP element, a statement is included that shows a possible connection between the element and a DCI from one of the bundle PEs. The statement uses italics to identify SEP language and bold italics to identify DCI language. Additional phrases, included to increase the readability of the resulting statement, but not found in either the original DCI or SEP language, are set off with brackets, [].[8]

Additional Crosscutting Concepts Building to the PEs

Additional CCCs—other than those already included in the bundle PEs—are offered to help demonstrate the large number of options available to teachers to help students identify connections between ideas and engage in sense-making. These additional CCCs are only examples and are not intended to be summatively assessed.

Figure 14: *An excerpt from the chart of Additional Crosscutting Concepts Building to the PEs*

Additional Crosscutting Concepts Building to the PEs	**Patterns** ● Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. Students could *observe patterns* ***of motion*** *and use these patterns as evidence* ***[of how] pushing or pulling on an object can change the speed or direction of its motion and can start or stop it***. K-PS2-1 and K-PS2-2

In this section, a CCC element is included for at least three of the seven CCCs. Below the CCC element, a statement shows a possible connection between the element and a DCI from one of the bundle PEs. The statement uses italics to identify CCC language and bold italics to identify DCI language. Plain text is used to show the suggested student action. Additional phrases, included to increase the readability of the resulting statement, but not found in either the original DCI or CCC language, are set off with brackets, [].[9]

[8] As stated in the NGSS Appendix F, "[I]t is too much to expect each performance to reflect all components of a given practice. The most appropriate aspect of the practice is identified for each performance expectation (in the NGSS foundation boxes for each PE)." (NGSS Appendices p. 50) Therefore, there are slight wording differences between some SEP elements in Appendix F of the NGSS and the appearance of those same elements when placed in context with PEs in the foundation boxes.

[9] As stated in the NGSS Appendix G, "Most performance expectations reflect only some aspects of a crosscutting concept. These aspects are indicated in the right-hand foundation box in each standard. All aspects of each core idea considered by the writing team can be found in the matrix [at the end of Appendix G]." (NGSS Appendices p. 80) Therefore, there are slight differences between some CCC elements in Appendix G of the NGSS and the appearance of those same elements when placed in context with PEs in the displays of the standards.

Additional Connections to Nature of Science

Additional NOS connections—other than those that may already be present in the bundle PEs—are offered to help demonstrate the large number of options available to teachers. These additional NOS connections are examples only and are not intended to be summatively assessed.

Figure 15: *An excerpt from the chart of Additional Connections to Nature of Science*

Additional Connections to Nature of Science	**Scientific investigations use a variety of materials** ● Scientific investigations begin with a question. Students could *begin a scientific investigation with a question* ***[about how] pushing or pulling on an object can change the speed or direction of its motion and can start or stop it*** and then reflect on the fact that their *investigation began with a question.* K-PS2-1 and K-PS2-2.

Below the NOS connection is a statement that shows a possible connection between the NOS idea, and a DCI and SEP from the bundle PEs. The statement uses italics to identify NOS language and bold italics to identify DCI language. Plain text shows the suggested student action. The PE code associated with the DCI is included to provide easier identification of the DCI within NGSS documents. Additional phrases, included to increase the readability of the resulting statement, but not found in either the original bundle PE, DCI, CCC, or suggested NOS language, are set off with brackets, [].

Evidence Statements

Evidence statements shown in the bundles always describe summative assessment of a given PE or part of a PE. *PEs may be broken up across several bundles* or even between courses in middle and high school, with instruction focusing on different components of a PE in different bundles. In such cases, different observable components of the evidence statements are highlighted in each bundle. Across the scope of the grade level or grade band of PEs, all of the observable components are addressed.

Figure 16: *The Evidence Statement for HS-PS2-4. The black text show the goals for one bundle and the grayed-out sections are goals for a later bundle (in this case, in the following year of instruction).*

Observable features of the student performance by the end of the course:		
1	Representation	
	a	Students clearly define the system of the interacting objects that is mathematically represented.
	b	Using the given mathematical representations, students identify and describe* the gravitational attraction between two objects as the product of their masses divided by the separation distance squared $\left(F_g = -G\frac{m_1 m_2}{d^2}\right)$, where a negative force is understood to be attractive.
	c	Using the given mathematical representations, students identify and describe* the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared $\left(F_e = k\frac{q_1 q_2}{d^2}\right)$, where a negative force is understood to be attractive.
2	Mathematical modeling	
	a	Students correctly use the given mathematical formulas to predict the gravitational force between objects or predict the electrostatic force between charged objects.
3	Analysis	
	a	Based on the given mathematical models, students describe* that the ratio between gravitational and electric forces between objects with a given charge and mass is a pattern that is independent of distance.
	b	Students describe* that the mathematical representation of the gravitational field $\left(F_g = -G\frac{m_1 m_2}{d^2}\right)$ only predicts an attractive force because mass is always positive.
	c	Students describe* that the mathematical representation of the electric field $\left(F_e = k\frac{q_1 q_2}{d^2}\right)$ predicts both attraction and repulsion because electric charge can be either positive or negative.
	d	Students use the given formulas for the forces as evidence to describe* that the change in the energy of objects interacting through electric or gravitational forces depends on the distance between the objects.

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Appendix 2: Further Reading on Three-Dimensional Instruction

Bundling standards is only one part of the work needed to develop three-dimensional curriculum, lesson plans, and instructional strategies. For further reading on these topics, the resources listed below might be helpful. Many states also develop their own guidance about these issues.

Research and Visioning Documents

- A *Framework* for K-12 Science Education: www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts
- Next Generation Science Standards: www.nextgenscience.org
- Taking Science To School: http://www.nap.edu/catalog/11625/taking-science-to-school-learning-and-teaching-science-in-grades. Includes much of the research underlying the NRC Framework and the NGSS, as well as descriptions of students' commonly held ideas.
- Ready, Set, SCIENCE: http://www.nap.edu/catalog/11882/ready-set-science-putting-research-to-work-in-k-8. The practitioners guide to Taking Science To School

Sources of a Wide-Range of Implementation Support and Resources

- Guide to Implementing the NGSS: http://www.nap.edu/catalog/18802/guide-to-implementing-the-next-generation-science-standards. A document from the National Research Council
- NGSS website resource library: http://nextgenscience.org/resource-library
- NGSS@NSTA website: ngss.nsta.org
- STEM Teaching Tools: http://stemteachingtools.org/

Unpacking the NGSS

- NGSS Evidence Statements: http://nextgenscience.org/evidence-statements

Resources for Equitable Instructional Strategies

- NGSS Appendix D and its accompanying case studies: http://nextgenscience.org/appendix-d-case-studies
- NGSS for All Students: www.nsta.org/store/product_detail.aspx?id=10.2505/9781938946295. Case studies of research- and standards-based classroom strategies for engaging diverse student groups.

Criteria for NGSS-aligned Instructional Materials

- EQuIP Rubric: www.nextgenscience.org/equip. Provides criteria for measuring quality and NGSS-design of lessons and units
- PEEC tool: www.nextgenscience.org/peec. NGSS Publishers Criteria, providing criteria for measuring NGSS design of year-long or multi-year instructional materials

Resources for Developing Instructional Materials Designed for the NGSS

- www.nextgenstorylines.org
- Paper on Designing Coherent Storylines Aligned with NGSS for the K–12 Classroom: hwww.academia.edu/6884962/Designing_Coherent_Storylines_Aligned_with_NGSS_for_the_K-12_Classroom
- Paper on Planning Instruction to Meet the Intent of the Next Generation Science Standards: http://link.springer.com/article/10.1007/s10972-014-9383-2

Information about Middle and High School Course Models

- NGSS Appendix K: http://nextgenscience.org/sites/default/files/Appendix K_Revised 8.30.13.pdf

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Middle School Phenomenon Model Course 1 - Bundle 1
Natural Resources

This is the first bundle of the Middle School Phenomenon Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 1 Question: This bundle is assembled to address the questions of "How important are our natural resources?"

Summary

The bundle organizes performance expectations around helping students understand how resource availability is partially the result of geoscience processes. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

The concept that resources are distributed unevenly around the planet as a result of past geologic processes (ESS3.A as in MS-ESS3-1) connects to the idea that maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart (ESS2.B as in MS-ESS2-3).

The idea of geologic processes also connects to the ideas that tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches (ESS1.C as in MS-ESS2-3) and that water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations (ESS2.C as in MS-ESS2-2). These concepts connect to the idea that the planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future (ESS2.A as in MS-ESS2-2).

The distribution of resources also connects to the idea that organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources (LS2.A as in MS-LS2-1). This concept also connects to the idea that humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes (ESS3.A as in MS-ESS3-1).

The idea that population increases are limited by access to resources also connects to the concept that predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared (LS2.A as in MS-LS2-2).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of analyzing and interpreting data (MS-LS2-1, MS-ESS2-3, and MS-ESS3-1) and constructing explanations and designing solutions (MS-LS2-2 and MS-ESS2-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-LS2-2 and MS-ESS2-3), Cause and Effect (MS-LS2-1 and MS-ESS3-1), and Scale, Proportion, and Quantity (MS-ESS2-2). Many other crosscutting concepts elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations MS-ESS2-2 is partially assessable	MS-LS2-1. **Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.** [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.] MS-LS2-2. **Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.** [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.] MS-ESS2-2. **Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.] MS-ESS2-3. **Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.** [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [*Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.*] MS-ESS3-1. **Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.** [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]
Example Phenomena	The coastlines of South America and Africa appear as though they could fit together. The native Inuit people of the Arctic live on a high-meat diet while other cultures eat little to no meat. Nearly identical fossils, rock strata, and geologic formations occur in widely separated portions of the globe.
Suggested Practices Building to the PEs	**Asking Questions** ● Ask questions that require sufficient and appropriate empirical evidence to answer. Students could *ask questions that require sufficient and appropriate empirical evidence to answer* **about the distribution of resources around the planet**. MS-ESS3-1

Suggested Practices Building to the PEs (Continued)	**Developing and Using Models** ● Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. Students could *modify a model based on evidence* [about] **organisms' dependence on their environmental interactions both with other living things and with nonliving factors** *to match what happens if a variable or component of a system is changed*. MS-LS2-1 **Planning and Carrying Out Investigations** ● Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. Students could *plan an investigation* [to identify] **organisms' dependence on environmental interactions both with other living things and with nonliving factors**. MS-LS2-1 **Analyzing and Interpreting Data** ● Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. Students could *use graphical displays* (i.e., **maps of ancient land and water patterns**) *of large data sets* [of] **rocks and fossils** *to identify temporal and spatial relationships* [such as] **how Earth's plates have moved great distances, collided, and spread apart**. MS-ESS2-3 **Using Math and Computational Thinking** ● Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. Students could *apply mathematical concepts to answer scientific questions* [about the] **generation of new ocean sea floor at ridges** and the **movement of Earth's plates.** MS-ESS2-3 **Constructing Explanations** ● Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. Students could *construct an explanation that includes qualitative relationships between variables to describe* **how Earth's plates have moved great distances, collided, and spread apart**. MS-ESS2-3 **Engaging in Argument from Evidence** ● Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support of refute an explanation or a model for a phenomenon. Students could *present an oral argument supported by empirical evidence and scientific reasoning to support a model* [of] **organisms' dependence on their environmental interactions both with other living things and with nonliving factors.** MS-LS2-1

Suggested Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** ● Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural world. Students could *critically read scientific texts adapted for classroom use to obtain scientific information to describe patterns in* **weathering and erosion**. MS-ESS2-2
Suggested Crosscutting Concepts Building to the PEs	**Patterns** ● Graphs, charts, and images can be used to identify patterns in data. Students could use *images to identify patterns in data* [about] **water's movements, weathering, and erosion**. MS-ESS2-2 **Cause and Effect** ● Cause and effect relationships may be used to predict phenomena in natural or designed systems. Students could use *cause and effect relationships to predict* **competitive, predatory, and mutually beneficial interactions** [of organisms] *in natural systems.* MS-LS2-2 **Scale, Proportion, and Quantity** ● Phenomena that can be observed at one scale may not be observable at another scale. Students could identify *phenomena* [related to] **weathering and erosion** *that can be observed at one scale* [but are] *not observable at another scale.* MS-ESS2-2
Additional Connections to Nature of Science **Additional Connections to Nature of Science (Continued)**	**Scientific Investigations Use a Variety of Methods** ● Science investigations are guided by a set of values to ensure accuracy of measurements, observations, and objectivity of findings. Students could report on their efforts *to ensure accuracy of measurements, observations, and objectivity of findings* [when they conduct] *investigations* [regarding] **organisms dependence on environmental interactions both with other living things and with nonliving factors**. MS-LS2-1 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ● Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. Students could [identify how their conclusions about the effects of] **water's movements on the land's surface features and underground formations** [are based on the] *assumption that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.* MS-ESS2-2

Middle School Phenomenon Model Course 1 - Bundle 2
Thermal Energy

This is the second bundle of the Middle School Phenomenon Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 1 Question: This bundle is assembled to address the question of "How does a change in thermal energy effect matter?"

Summary

The bundle organizes performance expectations around helping students understand the relationship between matter and thermal energy. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

The concept that substances are made from different types of atoms, which combine with one another in various ways (PS1.A as in MS-PS1-1), connects to the ideas that gases and liquids are made of molecules or inert atoms that are moving about relative to each other, and in a solid, atoms may vibrate in position but do not change relative locations (PS1.A as in MS-PS1-4).

In science, heat refers to the energy transferred due to the temperature difference between two objects (PS3.A as in MS-PS1-4); this connects to the idea that temperature is a measure of the average kinetic energy of particles of matter (PS3.A as in MS-PS3-3). These ideas also connect to the concept that the amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment (PS3.A as in MS-PS3-4).

These concepts of energy transfer connect to the idea that the ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents (ESS2.D as in MS-ESS2-6), which in turn connects to the idea that global movements of water and its changes in form are propelled by sunlight and gravity (ESS2.C as in MS-ESS2-4). These concepts also connect to the idea that complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns (ESS2.C as in MS-ESS2-5).

The idea that the iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution (ETS1.C as in MS-ETS1-4) could connect to several concepts, such as energy is spontaneously transferred out of hotter regions or objects and into colder ones (PS3.A as in MS-PS3-3) and weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things, and these interactions vary with latitude, altitude, and local and regional geography (ESS2.D as in MS-ESS2-6). These connections could be made through tasks such as designing a solar cooker or a device designed for a specific location and is used to harness energy for conversion to practical energy for human consumption such as electricity. For example, a wind-powered electrical generator would be effective and practical in some locations but not in others. In both tasks, students need an opportunity to test solutions to identify the most promising and then modify those to optimize their solutions.

Bundle Science and Engineering Practices Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of planning and carrying out investigations (MS-PS3-4 and MS-ESS2-5), developing and using models (MS-PS1-1, MS-PS1-4, MS-ESS2-4, MS-ESS2-6, and MS-ETS1-4), and constructing explanations and designing solutions (MS-PS3-3). Many other practice elements can be used in instruction. **Bundle Crosscutting Concepts** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (MS-PS1-4 and MS-ESS2-5), Scale, Proportion, and Quantity (MS-PS1-1 and MS-PS3-4), Energy and Matter (MS-PS3-3 and MS-ESS2-4), and Systems and System Model (MS-ESS2-6). Many other crosscutting concepts elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations MS-ESS2-5 and MS-ESS2-6 are partially assessable.	MS-PS1-1. **Develop models to describe the atomic composition of simple molecules and extended structures.** [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [*Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or extended structure is not required.*] MS-PS1-4. **Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.** [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawing and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.] MS-PS3-3. **Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*** [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*] MS-PS3-4. **Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*] MS-ESS2-4. **Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.** [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.] [*Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.*]

Performance Expectations (Continued)	MS-ESS2-5. **Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.** [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*] MS-ESS2-6. **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine global climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*] MS-ETS1-4. **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.**
Example Phenomena	Water boils when heat is added. Precipitation only occurs when there are clouds in the sky. Some parts of the world get lots of precipitation; others get almost none at all. Climates near the equator tend to be warmer than climates near the poles.
Suggested Practices Building to the PEs	**Asking Questions and Defining Problems** ● Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. Students could *define a design problem* [related to] **interactions involving sunlight, the ocean, and ice** *that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints*. MS-ESS2-6 **Developing and Using Models** ● Develop a model to describe unobservable mechanisms. Students could *develop a model to describe* [how] **water continually cycles among land, ocean, and atmosphere,** [including] *unobservable mechanisms* [of the processes of] **transpiration and evaporation**. MS-ESS2-4 **Planning and Carrying Out Investigations** ● Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *conduct an investigation* [of how] **the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present**. MS-PS3-3

Suggested Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** ● Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. Students could *use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify spatial relationships* [related to] **weather and climate** [as they are] **influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things**. MS-ESS2-6 **Using Mathematics and Computational Thinking** ● Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. Students could *apply mathematical concepts to scientific questions* [about how] **the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present**. MS-PS3-4 **Constructing Explanations and Designing Solutions** ● Construct an explanation using models or representations. Students could *construct an explanation* [about] **the changes of state that occur with variations in temperature or pressure** *using models* **of matter**. MS-PS1-4 **Engaging in Argument from Evidence** ● Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could *respectfully receive critiques about models* [of] **global movements of water and its changes in form** [and how these are] **propelled by sunlight and gravity** *by responding to questions that elicit pertinent elaboration and detail*. MS-ESS2-4 **Obtaining, Evaluating, and Communicating Information** ● Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural world. Students could *critically read scientific texts adapted for classroom use to obtain scientific information to describe patterns* **of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents,** [which] **are major determinants of local weather patterns.** MS-ESS2-5 ● Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations. Students could *communicate scientific information through oral presentations* [about how] **substances are made from different types of atoms, which combine with one another in various ways** [and that] **atoms form molecules that range in size from two to thousands of atoms.** MS-PS1-1

Suggested Crosscutting Concepts Building to the PEs	**Systems and System Models** ● Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Students could describe *that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems* within the context that **water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land**. MS-ESS2-4 **Energy and Matter** ● The transfer of energy can be tracked as energy flows through a designed or natural system. Students could *track the transfer of energy as energy flows through* **the ocean which absorbs energy from the sun, releases it over time, and globally redistributes it through currents, exerting a major influence on weather and climate.** MS-ESS2-6 **Stability and Change** ● Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Students could *construct explanations of* **the changes of state** [of matter] **that occur with variations in temperature or pressure** *in natural systems by examining the changes over time and forces at different scales, including the atomic scale.* MS-PS1-4
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** ● Scientific explanations are subject to revision and improvement in light of new evidence. Students could [use the history of the discovery that] **substances are made from different types of atoms, which combine with one another in various ways** [to describe how] *scientific explanations are subject to revision and improvement in light of new evidence*. MS-PS1-1 **Science is a Way of Knowing** ● Science is both a body of knowledge and the processes and practices used to add to that body of knowledge. Students could describe that *science is both a body of knowledge and the processes and practices used to add to that body of knowledge* [as they plan for an investigation about] **the amount of energy transfer needed to change the temperature of a matter sample**. MS-PS3-4

Middle School Phenomenon Model Course 1 - Bundle 3
Chemical Reactions

This is the third bundle of the Middle School Phenomenon Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the *Course Flowchart*.

Bundle 1 Question: This bundle is assembled to address the questions of "What are chemical reactions?"	
Summary The bundle organizes performance expectations around helping to expand students' understanding of matter and interactions of matter that can create new substances. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations. **Connections between bundle DCIs** The idea that in a chemical process, the atoms that make up the original substances are regrouped into different molecules (PS1.B as in MS-PS1-2, MS-PS1-3 and MS-PS1-5) connects to the concept that some chemical reactions release energy while others store energy (MS-PS1-6). These ideas about chemical processes also connect to the concept that the total number of each type of atom is conserved, and thus the mass does not change (MS-PS1-6). The concept that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-3) could connect to multiple ideas such as that some chemical reactions release energy and others store energy (MS-PS1-6), substances react chemically in characteristic ways, and new substances have different properties from those of the reactants (PS1.A as in MS-PS1-2, MS-PS1-3, and MS-PS1-5). For example, students could be given the task of designing a device that operates as a result of a chemical reaction that releases energy, or a task of identifying what metal to use when building a bridge over a body of saltwater. In either task, students could first determine the criteria and constraints of the problem and then engage in the systematic process for evaluating solutions with respect to the criteria and constraints. **Bundle Science and Engineering Practices** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-PS1-5), analyzing and interpreting data (MS-PS1-2), constructing explanations and designing solutions (MS-PS1-6), and obtaining, evaluating, and communicating information (MS-PS1-3). Many other practice elements can be used in instruction. **Bundle Crosscutting Concepts** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-PS1-2), Energy and Matter (MS-PS1-5 and MS-PS1-6), and Structure and Function (MS-PS1-3). Many other crosscutting concepts elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	MS-PS1-2. **Analyze and interpret data on the properties of substances before and after substances interact to determine if a chemical reaction has occurred.** [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [*Assessment boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.*] MS-PS1-3. **Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.** [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [*Assessment Boundary: Assessment is limited to qualitative information.*]

Performance Expectations (Continued)	MS-PS1-5. **Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.** [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [*Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.*] MS-PS1-6. **Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.** [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [*Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.*] MS-ETS1-3. **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.**
Example Phenomena	When baking soda (a solid) and vinegar (a liquid) are combined, a gas is produced. Plastics (petroleum products) are found in thousands of everyday objects. When calcium chloride is dissolved in water, the temperature of the water decreases.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. Students could *ask questions* [about the] **characteristic physical and chemical properties that can be used to identify pure substance**. MS-PS1-2 and MS-PS1-3 **Developing and Using Models** • Develop and/or use a model to predict and/or describe phenomena. Students could *develop a model to describe phenomena* [related to] **chemical reactions** [that] **release energy** [rather than] **store energy**. MS-PS1-6 **Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. Students could *plan an investigation collaboratively* [to determine if] **a chemical process** [occurred based on whether there is] **a new substance** [with] **different properties from those of the reactants** *and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim*. MS-PS1-2, MS-PS1-3, and MS-PS1-5

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data to provide evidence for phenomena* [related to the concept that in a chemical reaction]**, mass does not change**. MS-PS1-5 **Using Mathematics and Computational Thinking** • Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem. Students could *use digital tools to test and compare proposed solutions to an engineering design problem* [that requires use of a*]* **chemical reaction** [that] **stores energy**. MS-PS1-6 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation* [that in a chemical reaction,] **the total number of each type of atom is conserved, and thus the mass does not change**. MS-PS1-5 **Engaging in Argument from Evidence** • Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could respectfully provide critiques about models [that describe how, in a chemical reaction]**, the total number of each type of atom is conserved, and thus the mass does not change** by citing relevant evidence and posing questions that elicit pertinent elaboration and detail. MS-PS1-5 **Obtaining, Evaluating, and Communicating Information** • Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations. Students could *communicate technical information in writing about a proposed object* [that] **releases** [**energy** [as a result of a chemical reaction]. MS-PS1-6
Additional Crosscutting Concepts Building to the PEs	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Students could use *models to represent systems and their interactions—such as* [the] *inputs, processes and outputs* [of a] **chemical** [reaction]—*and energy and matter flows within systems (e.g.,* **the atoms that make up the original substances are regrouped into different molecules** [and] **the release** [or storage of] **energy** [that results]**)**. MS-PS1-2, MS-PS1-3, MS-PS1-5, and MS-PS1-6

Additional Crosscutting Concepts Building to the PEs (Continued)	**Structure and Function** • Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function. Students could describe how *microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the composition and relationships among its parts* [using the idea that] **in a chemical process, the atoms that make up the original substances are regrouped into different molecules** [as an example]. Students can further describe that [the resulting] **substances** *can be analyzed to determine how they function* [as] **these new substances have different properties from those of the reactants.** MS-PS1-2, MS-PS1-5 **Stability and Change** • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Students could construct *explanations of* **substances that react chemically** *by examining the changes over time at different scales.* MS-PS1-2
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations. Students could describe how [scientists used] *logical and conceptual connections between evidence and the explanation* **that in a chemical reaction, atoms that make up the original substances are regrouped into different molecules.** MS-PS1-2 **Science is a Way of Knowing** • Science is a way of knowing used by many people, not just scientists. Students can identify ways that *many people, not just scientists, use scientific knowledge* [about the] **characteristic physical and chemical properties of each pure substance**. MS-PS1-2

Middle School Phenomenon Model Course 1 - Bundle 4
Energy, Force, and Motion: When Objects Collide

This is the fourth bundle of the Middle School Phenomenon Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the questions of "What happens when objects collide?"

Summary
The bundle organizes performance expectations around helping students understand how objects interact when in contact. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed (PS3.A as in MS-PS3-1). This idea can be connected to the concept that when the motion energy of an object changes, there is inevitably some other change in energy at the same time (PS3.B as in MS-PS3-5). The concept of motion also connects to the idea that the motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change (PS2.A as in MS-PS2-2). The idea of forces connects to the concept that for any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (PS2.A as in MS-PS2-1).

Concepts of force and motion also can connect to the ideas that a sound wave needs a medium through which it is transmitted (PS4.A as in MS-PS4-2), and the concept of sound waves connects to the idea that a simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude (PS4.Aas in MS-PS4-1). Finally, the concepts of waves connect to the idea of a wave model of light, and the idea that this wave model is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media (PS4.B as in MS-PS4-2).

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of planning and carrying out investigations (MS-PS2-2), developing and using models (MS-PS4-2), analyzing and interpreting data (MS-PS3-1), using mathematics and computational thinking (MS-PS4-1), constructing explanations and designing solutions (MS-PS2-1), and engaging in argument from evidence (MS-PS3-5 and MS-ETS1-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-PS4-1), Systems and System Models (MS-PS2-1), Stability and Change (MS-PS2-2), Scale, Proportion, and Quantity (MS-PS3-1), Energy and Matter (MS-PS3-5), and Structure and Function (MS-PS4-2). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-PS2-1. **Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*** [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [*Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.*] MS-PS2-2. **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [*Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.*] MS-PS3-1. **Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.** [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.] MS-PS3-5. **Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.** [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [*Assessment Boundary: Assessment does not include calculations of energy.*] MS-PS4-1. **Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.** [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [*Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.*] MS-PS4-2. **Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.** [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [*Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.*]
Example Phenomena	When a car collides with a fire hydrant, the car stops suddenly. A train does not stop when it hits a car. A chair supports a person when she/he sits in it. A strong echo returns when you shout from the rim of the Grand Canyon. A pencil appears to bend when it is inserted into a cup of water.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to determine relationships between dependent and independent variables, and relationships in models. Students could *ask questions to determine relationships between* t**he motion of an object** *(dependent variable)* **and the sum of the forces acting on it** *(independent variable)*. MS-PS2-2

Additional Practices Building to the PEs (Continued)	**Developing and Using Models** • Develop and/or use a model to predict and/or describe phenomena. Students could *develop a model to describe* [the] *phenomenon* [that] **for any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction**. MS-PS2-1 Students could *use a model to predict* **the motion of an object** [based on] **the sum of the forces acting on it**. MS-PS2-2 **Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. Students could *plan an investigation* **about the path that light travels [including] at surfaces between different transparent materials**. [Then], *in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim*. MS-PS4-2 • Evaluate the accuracy of various methods for collecting data. Students could *evaluate the accuracy of various methods for collecting data* [to determine the] **kinetic energy** [of an object]. MS-PS3-1 **Analyzing and Interpreting Data** • Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. Students could *analyze data to define an optimal operational range for a proposed tool [related to]* **the force** [exerted on each of two] **interacting objects**. MS-PS2-1 **Using Mathematics and Computational Thinking** • Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. Students could apply mathematical concepts and processes (e.g., rate, basic operations, simple algebra) to scientific questions related to the **kinetic energy** [of an object, which] **it is proportional to the mass of the moving object and grows with the square of its speed.** MS-PS3-1 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could construct an explanation [related to the concept that] **when the motion energy of an object changes, there is inevitably some other change in energy at the same time**. MS-PS3-5

	Engaging in Argument From Evidence • Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could r*espectfully receive critiques about* [their] *models* [of] **a simple wave** [that] **has a repeating pattern with a specific wavelength, frequency, and amplitude** *citing relevant evidence and responding to questions that elicit pertinent elaboration and detail*. MS-PS4-1 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). Students could *critically read scientific texts adapted for classroom use* [about] **sound waves** *to determine the central ideas*, [including that they] **need a medium through which [they are] transmitted.** MS-PS4-2
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems. Students could describe how they can *use cause and effect relationships to predict* **the motion of an object** [based on] **the sum of the forces acting on it**. MS-PS2-2 **Scale, Proportion, and Quantity** • Scientific relationships can be represented through the use of algebraic expressions and equations. Students could describe how they are able to *represent scientific relationships* [related to] **simple waves,** [which have] **a repeating pattern with a specific wavelength, frequency, and amplitude**, *through the use of equations.* MS-PS4-1 **Systems and System Models** • Models are limited in that they only represent certain aspects of the system under study. Students could describe how *models* [of] **the motion of an object** [based on] **the sum of the forces acting on it** *are limited in that they only represent certain aspects of the system under study*. MS-PS2-2
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Laws are regularities or mathematical descriptions of natural phenomena. Students could identify that *laws*— [such as] **for any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction**—*are regularities or mathematical descriptions of natural phenomena*. MS-PS2-1 **Science is a Human Endeavor** • Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas. Students could read about how the *scientist* [Sir Isaac Newton] *was guided by habits of mind* [that supported him in discovering that] **the motion of an object is determined by the sum of the forces acting on it.** MS-PS2-2

Middle School Phenomenon Model Course 1 - Bundle 5
Fields of Force

This is the fifth bundle of the Middle School Phenomenon Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the questions of "How can objects interact at a distance?"

Summary

The bundle organizes performance expectations with a focus on helping students understand the interaction of objects when they are not in physical contact with one another. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

The concept that, when two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object (PS3.C as in MS-PS3-2) can connect to the idea that forces that act at a distance (electric and magnetic) can be explained by fields that extend through space (PS2.B as in MS-PS2-5). These ideas also connect to the concept that electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects (PS2.B as in MS-PS2-3).

Additionally, these ideas about forces that act at a distance can be connected to the concept that gravitational forces are always attractive; there is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun (PS2.B as in MS-PS2-4). Then, gravitational forces connect to the concepts that the solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them (ESS1.B as in MS-ESS1-3 and MS-ESS1-2) and this model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year **(**ESS1.B as in MS-ESS1-1).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions and defining problems (MS-PS2-3), developing and using models (MS-PS3-2, MS-ESS1-1, and MS-ESS1-2), planning and carrying out investigations (MS-PS2-5), analyzing and interpreting data (MS-ESS1-3), and engaging in argument from evidence (MS-PS2-4). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-ESS1-1), Cause and Effect (MS-PS2-3 and MS-PS2-5), Systems and System Models (MS-PS2-4, MS-PS3-2, and MS-ESS1-2), and Scale, Proportion, and Quantity (MS-ESS1-3). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-PS2-3. **Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.** [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*] MS-PS2-4. **Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.** [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [*Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.*] MS-PS2-5. **Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.** [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [*Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.*] MS-PS3-2. **Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.** [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [*Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.*] MS-ESS1-1. **Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.** [Clarification Statement: Examples of models can be physical, graphical, or conceptual.] MS-ESS1-2. **Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.** [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [*Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.*] MS-ESS1-3. **Analyze and interpret data to determine scale properties of objects in the solar system.** [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [*Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.*]

Example Phenomena	Static electricity can make small objects like thread and grains of salt come up off the table. An electric motor uses electrical energy and produces motion. The pattern of the phases of the moon repeats over and over again. If you rub a balloon on your hair, your hair will stand up.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** ● Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation of phenomena or models* [related to the] **apparent motion of the sun, the moon, and stars in the sky** *to clarify and/or seek additional information*. MS-ESS1-1 **Developing and Using Models** ● Develop or modify a model— based on evidence – to match what happens if a variable or component of a system is changed. Students could *modify a model* [of] **fields that extend through space and their effect on an object**, *based on evidence, to match what happens if a variable or component of a system is changed*. MS-PS2-5 **Planning and Carrying Out Investigations** ● Collect data to produce data to serve as the basis for evidence to answer scientific questions Students could *collect data to serve as the basis for evidence to answer scientific questions* [about what effects] **the size of electric and magnetic forces**. MS-PS2-3 **Analyzing and Interpreting Data** ● Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. Students could *analyze data to define an optimal operational range for a proposed tool* [that incorporates] **electric forces,** [whose] **sizes depend on the magnitudes of the charges and currents involved and on the distances between the interacting objects**. MS-PS2-3 **Using Mathematics and Computational Thinking** ● Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem. Students could *use digital tools to test and compare proposed solutions* [that incorporate] **magnetic forces,** [which] **can be attractive or repulsive**. MS-PS2-3

Additional Practices Building to the PEs (Continued)	**Constructing Explanations and Designing Solutions** ● Construct an explanation using models or representations. Students could *construct an explanation using models or representations* [related to the concept that] **the solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them**. MS-ESS1-3 and MS-ESS1-3 **Engaging in Argument from Evidence** ● Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. Students could *evaluate competing design solutions* [that use] **stored (potential) energy –** [which] **depends on the relative positions** [of objects]. MS-PS3-2 **Obtaining, Evaluating, and Communicating Information** ● Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims or findings. Students could *integrate qualitative and/or quantitative scientific information in written text* [about the] **gravitational force between any two masses,** [which] **is very small except when one or both of the objects have large mass,** *with that contained in media and visual displays to clarify claims or findings*. MS-PS2-4
Additional Crosscutting Concepts Leading to the PEs	**Cause and Effect** ● Cause and effect relationships may be used to predict phenomena in natural or designed systems. Students could use *cause and effect relationships to predict phenomena in natural or designed systems* [related to the concept that] **a system of objects may contain stored (potential) energy, depending on their relative positions**.MS-PS3-2 **Systems and System Models** ● Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Students could *use a model to represent systems* [of] **forces that act at a distance (electric and magnetic)** *and their interactions and energy flows* [by] mapping their effect on an object (e.g., a charged object, or a ball). MS-PS2-5 **Scale, Proportion, and Quantity** ● Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Students could describe that *space phenomena*—such as **eclipses of the sun and the moon,** [as well as] **the seasons,** [which] **are a result of** [Earth's tilt] **relative to its orbit around the sun and are caused by the differential intensity of sunlight on different areas of Earth across the year—***can be observed at various scales using models to study systems that are too large* [to observe directly]. MS-ESS1-1

Additional Connections to Nature of Science	**Science is a Way of Knowing** ● Science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge. Students could describe how *science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge* [about how] **Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe**. MS-ESS1-2 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ● Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. *Science assumes that objects and events in natural systems* [such as] **the motion of the sun, the moon, and stars in the sky** *occur in consistent patterns that are understandable through measurement and observation*. MS-ESS1-1

Middle School Phenomenon Model Course 1

Narrative and Rationale: This course model arranges the Performance Expectations (PEs) outlined in the first year of the middle school conceptual progressions model from Appendix K of the Next Generation Science Standards into five different bundles of PEs using a phenomenon-based arrangement. The bundles in this model follow a conceptual flow throughout the year.

The first bundle focuses on the relationship between resource availability and geoscience processes. The second and third bundles focus on energy and matter flows, and the fourth and fifth bundles focus on object interactions. Each bundle is organized around the DCIs that would help students explain a unifying phenomenon and answer a guiding question. It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional practices and crosscutting concepts should be used throughout instruction toward each bundle.

Bundle 1: How important are our natural resources?" **~4 weeks**	**Bundle 2:** How does a change in thermal energy affect matter? **~4 weeks**	**Bundle 3:** What are chemical reactions? **~4 weeks**	**Bundle 4:** What happens when objects collide? **~4 weeks**	**Bundle 5:** How can objects interact at a distance? **~4 weeks**
MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. **MS-LS2-2**. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. **MS-ESS2-2**. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.[1] **MS-ESS2-3**. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions. **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.	**MS-PS1-1**. Develop models to describe the atomic composition of simple molecules and extended structures. **MS-PS1-4**. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. **MS-PS3-3**. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. **MS-PS3-4**. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. **MS-ESS2-4**. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. **MS-ESS2-5**. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.[1] **MS-ESS2-6**. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine global climates.[1]	**MS-PS1-2**. Analyze and interpret data on the properties of substances before and after substances interact to determine if a chemical reaction has occurred. **MS-PS1-3**. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. **MS-PS1-5**. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. **MS-PS1-6**. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. **MS-ETS1-3**. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	**MS-PS2-1**. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.* **MS-PS2-2**. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. **MS-PS3-1**. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. **MS-PS3-5**. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. **MS-PS4-1**. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. **MS-PS4-2**. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.	**MS-PS2-3**. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. **MS-PS2-4**. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. **MS-PS2-5**. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. **MS-PS3-2**. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. **MS-ESS1-1**. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. **MS-ESS1-2**. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

	MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.			**MS-ESS1-3**. Analyze and interpret data to determine scale properties of objects in the solar system.

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

Middle School Phenomenon Model Course 1 Flowchart

Bundle 1

LS2.A as found in MS-LS2-1
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
- Growth of organisms and population increases are limited by access to resources.

LS2.A as found in MS-LS2-2
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

ESS1.C as found in MS-ESS2-3
- Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches.

ESS2.A as found in MS-ESS2-2
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

to ESS2.C and ESS2.D in Bundle 2

ESS2.B as found in MS-ESS2-3
- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.

ESS2.C as found in MS-ESS2-2
- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

to ESS2.C and ESS2.D in Bundle 2 and to PS2.A in Bundle 4

ESS3.A as found in MS-ESS3-1
- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

to ESS2.C and ESS2.D in Bundle 2

Bundle 2

PS1.A as found in MS-PS1-1
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.A as found in MS-PS1-4
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

PS3.A as found in MS-PS1-4
- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material.

PS3.B as found in MS-PS3-3
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

PS3.A as found in MS-PS3-3 and MS-PS3-4
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B as found in MS-PS3-4
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.

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Bundle 3

PS1.A as found in MS-PS1-2 and MS-PS1-3
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

PS1.B as found in MS-PS1-2, MS-PS1-3, and MS-PS1-5
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

PS1.B as found in MS-PS1-5
- The total number of each type of atom is conserved, and thus the mass does not change.

PS1.B as found in MS-PS1-6
- Some chemical reactions release energy, others store energy.

ETS1.B as found in MS-PS1-6
- A solution needs to be tested, and then modified on the basis of the test results in order to improve it.

ETS1.B as found in MS-ETS1-3
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.
- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.

ETS1.C as found in MS-PS1-6 and MS-ETS1-3
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.

ETS1.C as found in MS-ETS1-3
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Bundle 4

PS2.A as found in MS-PS2-1
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

PS2.A as found in MS-PS2-2
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

PS3.A as found in MS-PS3-1
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.

PS3.B as found in MS-PS3-5
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.

PS4.A as found in MS-PS4-1
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

PS4.A as found in MS-PS4-2
- A sound wave needs a medium through which it is transmitted.

PS4.B as found in MS-PS4-2
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Bundle 5

PS2.B as found in MS-PS2-3
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.

PS2.B as found in MS-PS2-4
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.

PS2.B as found in MS-PS2-5
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).

PS3.A as found in MS-PS3-2
- A system of objects may also contain stored (potential) energy, depending on their relative positions.

PS3.C as found in MS-PS3-2
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

ESS1.A as found in MS-ESS1-1
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

ESS1.A as found in MS-ESS1-2
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

ESS1.B as found in MS-ESS1-2 and MS-ESS1-3
- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

ESS1.B as found in MS-ESS1-1
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

ESS1.B as found in MS-ESS1-2
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

ESS2.C as found in MS-ESS2-4
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- Global movements of water and its changes in form are propelled by sunlight and gravity.

ESS2.C as found in MS-ESS2-5
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

ESS2.C as found in MS-ESS2-6
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

to PS1.B in Bundle 3

ESS2.D as found in MS-ESS2-6
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography all of which can affect oceanic and atmospheric flow patterns.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

ESS2.D as found in MS-ESS2-5
- Because these patterns are so complex, weather can only be predicted probabilistically.

ETS1.A as found in MS-PS3-3
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

ETS1.B as found in MS-PS3-3 and MS-ETS1-4
- A solution needs to be tested, and then modified on the basis of the test results in order to improve it.

ETS1.B as found in MS-PS3-3
- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.

ETS1.B as found in MS-ETS1-4
- Models of all kinds are important for testing solutions.

ETS1.C as found in MS-ETS1-4
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Middle School Phenomenon Model Course 2 – Bundle 1
Transfer of Energy and Matter in Earth's Systems

This is the first bundle of the Middle School Phenomenon Model Course 2. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "why do people live and farm on volcanoes?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of the transfer of energy and matter between Earth Systems, including the biosphere. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials (ESS2.A as in MS-ESS2-1). These ideas connect to the concept that the planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years (ESS2.A as in MS-ESS2-2). Many of these interactions involve the movement of water both on the land and underground which cause weathering and erosion, changing the land's surface features and creating underground formations (ESS2.C as in MS-ESS2-2).

The energy that flows and matter that cycles within Earth systems also produce chemical and physical changes in living organisms (ESS2.A as in MS-ESS2-1). Matter and energy are transferred between producers, consumers, and decomposers within an ecosystem, and the atoms that make up the matter are cycled repeatedly between the living and nonliving parts of an ecosystem (LS2.B as in MS-LS2-3). This idea connects to the concept that plants, algae, and many other microorganisms use the energy from light to make sugars from carbon dioxide and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use (LS1.C as in MS-LS1-6, PS3.D as in MS-LS1-6). Connecting to ideas about photosynthesis, food moves through a series of chemical reactions known as cellular respiration in which it is broken down and rearranged to form new molecules, to support growth, or to release energy within individual organisms (LS1.C as in MS-LS1-7, PS3.D as in MS-LS1-7).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing models (MS-LS1-7, MS-LS2-3, and MS-ESS2-1) and constructing explanations (MS-LS1-6 and MS-ESS2-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Scale, Proportion, and Quantity (MS-ESS2-2), Energy and Matter (MS-LS1-6, MS-LS1-7, and MS-LS2-3), and Stability and Change (MS-ESS2-1). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-LS1-6. **Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.** [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.] MS-LS1-7. **Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.** [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.] MS-LS2-3. **Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.** [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.] MS-ESS2-1. **Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.** [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [Assessment Boundary: Assessment does not include the identification and naming of minerals.] MS-ESS2-2. **Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]
Example Phenomena	Sand from different beaches looks different. Some mushrooms grow on dead tree logs.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation of phenomena to seek additional information* [about how] ***the energy that flows and matter that cycles within and among the planet's systems produce chemical and physical changes in Earth's materials and living organisms***. MS-ESS2-1 **Developing and Using Models** • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Students could *develop and/or revise a model to show the relationships among* ***plants, photosynthesis, and sugars***. MS-LS1-6

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *revise an experimental design to produce data to serve as the basis for evidence* [that] ***plants use the energy from light to make sugars from carbon dioxide from the atmosphere and water***. MS-LS1-6 **Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data to provide evidence* [that] ***producers, consumers, and decomposers interact***. MS-LS2-3 **Using Mathematical and Computational Thinking** • Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems. Students could apply mathematical concepts [to show that] ***food webs demonstrate how matter and energy are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem***. MS-LS2-3 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using models or representations* [of how] ***all Earth processes are the result of energy flowing and matter cycling within and among the planet's systems***. MS-ESS2-1 **Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. Students could *construct and present an oral argument supported by empirical evidence and scientific reasoning to refute an explanation* [for how] ***transfers of matter into and out of the physical environment occur at every level in a food web***. MS-LS2-3 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world. Students could *critically read scientific texts to obtain scientific information to describe evidence* [for how] ***within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy***. MS-LS1-7

Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems. Students could construct an argument [for how] ***water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formation*** and [for how these] *cause and effect relationships may be used to predict phenomena in natural systems*. MS-ESS2-2 **Systems and System Models** • Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Students could construct an argument that ***all Earth processes are the result of energy flowing and matter cycling within and among the planet's*** *systems and sub-systems* and [that] ***these systems range from microscopic to global in size, and they operate over fractions of a second to billions of years***. MS-ESS2-1 and MS-ESS2-2 **Energy and Matter** • Energy may take different forms (e.g. energy in fields, thermal energy, energy in motion). Students could ask questions [about how] *energy may take different forms* [when] ***flowing within and among the Earth's systems as it is derived from the sun and Earth's hot interior***. MS-ESS2-1
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence** • Science disciplines share common rules of obtaining and evaluating empirical evidence. Students could construct an argument supporting the claim that *science disciplines share common rules of obtaining and evaluating empirical evidence*, [using as evidence the way that biologists] *obtained and evaluated empirical evidence* [about how] ***within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy***. MS-LS1-7 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science carefully considers and evaluates anomalies in data and evidence. Students could construct an argument about why *science carefully considers and evaluates anomalies in data and evidence*, [using as an example evidence for] ***how matter and energy are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem***. MS-LS2-3

Middle School Phenomenon Model Course 2 – Bundle 2
Climate Diversity

This is the second bundle of the Middle School Phenomenon Model Course 2. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 2 Question: This bundle is assembled to address the question "what causes climates to be so different across the Earth?"

Summary
The bundle organizes performance expectations with a focus on helping students build understanding of causes of diverse climates. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things (ESS2.D as in MS-ESS2-6). The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents (ESS2.D as in MS-ESS2-6). Additionally, the complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns (ESS2.C as in MS-ESS2-5). And because these patterns are so complex, weather can only be predicted probabilistically (ESS2.D as in MS-ESS2-5). However, mapping the history of natural hazards in a region combined with an understanding of related geological forces, can help forecast the locations and likelihoods of future events (ESS3.B as in MS-ESS3-2). Mitigating effects from natural hazards requires effective communication methods, such as using digitized signals as a more reliable way to encode and transmit information (PS4.C as in MS-PS4-3).

The engineering design idea that the more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful (ETS1.A as in MS-ETS1-1) could connect to several science concepts, such as using digitized signals as a more reliable way to encode and transmit information (PS4.C as in MS-PS4-3) or mapping the history of natural hazards in a region to help forecast the locations and likelihoods of future hazardous natural events (ESS3.B as in MS-ESS3-2). Connections could be made through engineering design tasks such as asking questions to determine the necessary criteria and constraints, including limitations, that are needed for either a communication system to warn people of an upcoming storm, or construction of storm shelters to mitigate adverse effects of hazardous events.

Additionally, the engineering design idea that there are systematic processes for evaluating solutions with respect to how well a design solution meets the criteria and constraints of a problem (ETS1.B as in MS-ETS1-2) could connect to several science concepts, such as using digitized signals as a more reliable way to encode and transmit information (PS4.C as in MS-PS4-3) or mapping the history of natural hazards in a region to help forecast the locations and likelihoods of future hazardous natural events (ESS3.B as in MS-ESS3-2). Connections could be made through engineering design tasks such as engaging in argument from evidence about either how well a warning system communicates information or how well a computer model meets the criteria and constraints for predicting future hazardous events.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (MS-ETS1-1), developing and using models (MS-ESS2-6), planning and carrying out investigations (MS-ESS2-5), analyzing and interpreting data (MS-ESS3-2), engaging in argumentation (MS-ETS1-2), and obtaining, evaluating, and communicating information (MS-PS4-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-ESS3-2), Cause and Effect (MS-ESS2-5), Systems and System Models (MS-ESS2-6), and Structure and Function (MS-PS4-3). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	MS-PS4-3. **Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.** [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.] MS-ESS2-5. **Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.** [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.] MS-ESS2-6. **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.] MS-ESS3-2. **Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.** [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).] MS-ETS1-1. **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.** MS-ETS1-2. **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**
Example Phenomena	Thunderstorms come more often in the afternoon than in the morning. Hurricanes cause more damage to human property than do thunderstorms.

Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. Students could *ask questions to identify and/or clarify evidence* [about how] ***mapping the history of natural hazards in a region can help forecast the locations and likelihoods of future events***. MS-ESS3-2 **Developing and Using Models** • Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. Students could *develop or modify a model based on evidence to match what happens if* [the] ***way to encode and transmit information*** [is changed from analog to] ***digitized signals***. MS-PS4-3 **Planning and Carrying Out Investigations** • Evaluate the accuracy of various methods for collecting data. Students could *evaluate the accuracy of various methods for collecting data* [about] ***the history of natural hazards in a region*** [to] ***help forecast the locations and likelihoods of future events***. MS-ESS3-2 **Analyzing and Interpreting Data** • Use graphical displays of large data sets to identify temporal and spatial relationships. Students could *use graphical displays of large data sets to identify temporal and spatial relationships* [between] ***the ocean*** [and] ***weather*** [due to the ocean's ability to] ***absorb energy from the sun, release it over time, and globally redistribute it through ocean currents***. MS-ESS2-6 **Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use digital tools to analyze very large data sets for patterns and trends* [related to] ***the ocean absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents***. MS-ESS2-6 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events. Students could *apply scientific ideas, and evidence to construct an explanation* [of how] ***landforms*** [affect] ***the movement of water in the atmosphere.*** MS-ESS2-5 **Engaging in Argument from Evidence** • Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints. Students could *make an oral argument that refutes the advertised performance of a device based on empirical evidence for whether or not the technology meets relevant criteria and constraints* [for] ***more reliably encoding and transmitting information.*** MS-PS4-3

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Gather, read, synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. Students could *gather, read, and synthesize information from multiple sources* [about] ***the complex patterns of the changes and movement of water in the atmosphere*** *and assess the credibility and accuracy of each publication*. MS-ESS2-5
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Patterns can be used to identify cause and effect relationships. Students could construct an argument from evidence for how ***mapping the history of natural hazards in a region, combined with an understanding of related geologic forces*** [can be used to] *identify patterns in cause and effect relationships*, [helping to] ***forecast the locations and likelihoods of future events***. MS-ESS3-2 **Systems and System Models** • Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Students could develop a model [for how] *systems may interact with other systems, may have sub-systems, and may be part of a larger complex systems*, [including as evidence that] ***weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things***. MS-ESS2-6 **Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could analyze and interpret data on how *stability* ***of local weather patterns*** *might be disturbed either by sudden events* [due to] ***winds, landforms, and ocean temperatures and currents***. MS-ESS2-5
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods** • Science investigations use a variety of methods and tools to make measurements and observations. Students could ask questions about why *science investigations use a variety of methods and tools to make measurements and observations* [to] ***map the history of natural hazards in a region***. MS-ESS3-2 **Science is a Human Endeavor (CCC):** • Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas. Students could construct an argument from evidence for how *scientists' habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas* [affect their understanding of how] ***weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things***. MS-ESS2-6

Middle School Phenomenon Model Course 2 – Bundle 3
The Earth's Place in the Solar System

This is the third bundle of the Middle School Phenomenon Model Course 2. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question "why can we predict solar eclipses?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of why planetary bodies orbit, and what happens when they do. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

The Earth and its solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them (ESS1.B as in MS-ESS1-2). The solar system is part of the Milky Way galaxy (ESS1.A as in MS-ESS1-2) and appears to have formed from a disk of dust and gas, drawn together by gravity (ESS1.B as in MS-ESS1-2). This gravitational force also means that each object in the system exerts a force on the others that can cause energy to be transferred to or from the objects (PS3.C as in MS-PS3-2).

Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models (ESS1.A as in MS-ESS1-1). The model of the solar system with the Earth and moon held in orbit around the sun can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year (ESS1.B as in MS-ESS1-1).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practice of developing models. Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-ESS1-1) and Systems and System Models (MS-PS3-2 and MS-ESS1-2). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-PS3-2. **Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.** [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.]

Performance Expectations (Continued)	MS-ESS1-1. **Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.** [Clarification Statement: Examples of models can be physical, graphical, or conceptual.] MS-ESS1-2. **Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.** [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as their school or state).] [Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.]
Example Phenomena	Constellations appear in different locations in the sky at different times of the year. The moon sometimes looks round and sometimes like a sickle.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation to seek additional information* [about how] ***the apparent motion of the sun, moon, and stars in the sky can be predicted and explained***. MS-ESS1-1 **Developing and Using Models** • Evaluate limitations of a model for a proposed object or tool. Students could *evaluate limitations of a model* ***of the solar system,*** [describing its ability to] ***explain eclipses of the sun and the moon***. MS-ESS1-1 **Planning and Carrying Out Investigations** • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *evaluate the experimental design of an investigation to [see if it can] produce data to serve as the basis for evidence* [that] ***when two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object***. MS-PS3-2 **Analyzing and Interpreting Data** • Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. Students could *construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear relationships* [in the] ***energy transferred to or from two objects when*** [they] ***interact***. MS-PS3-2

Additional Practices Building to the PEs (Continued)	**Using Mathematical and Computational Thinking** • Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems. Students could *apply mathematical concepts and/or processes* [to describe] ***patterns of the apparent motion of the sun, the moon, and stars in the sky***. MS-ESS1-1. **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using models or representations* [for how] ***a collection of objects, including planets, their moons, and asteroids are held in orbit around the sun by its gravitational pull on them***. MS-ESS1-2 **Engaging in Argument from Evidence** • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. Students could *compare and critique two arguments about how* ***the solar system appears to have formed from a disk of dust and gas****, and analyze whether they emphasize similar or different evidence and/or interpretation of facts*. MS-ESS1-2 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). Students could *critically read scientific texts to obtain scientific information* [about how] ***a model of the solar system can explain eclipses of the sun and the moon***. MS-ESS1-1
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural and designed systems. Students could develop and use a model to explain how *cause and effect relationships may be used to predict* ***the differential intensity of sunlight on different areas of Earth across the year***. MS-ESS1-1 **Scale, Proportion, and Quantity** • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Students could evaluate the limitations of *models used to study systems that are* [very] *large* [such as] ***the solar system***. MS-ESS1-2 **Systems and System Models** • Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Students could develop a model of the ***causes of the season*** (e.g., summer, winter), and describe the components of the model in terms of *sub-systems that interact and are part of larger complex systems*. MS-ESS1-1

Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Science theories are based on a body of evidence developed over time. Students could construct an argument about how *science theories are based on a body of evidence developed over time*, [including the theory that] ***a system of objects may contain stored energy, depending on*** [the objects'] ***relative positions***. MS-PS3-2 **Science is a Human Endeavor** • Advances in technology influence the progress of science and science has influenced advances in technology. Students could obtain, evaluate, and communicate information about how *advances in technology influence the progress of science and science has influenced advances in technology*, [using as an example our ability to] ***observe, predict, and explain patterns in the apparent motion of the sun, the moon, and the stars in the sky***. MS-ESS1-1

Middle School Phenomenon Model Course 2 – Bundle 4
Organization of Living Things

This is the fourth bundle of the Middle School Phenomenon Model Course 2. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 4 Question: This bundle is assembled to address the question "why are bones so hard?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of cells and how they work together in particular body functions. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular) (LS1.A as in MS-LS1-1). Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell (LS1.A as in MS-LS1-2). In multicellular organisms, the body is a system of multiple interacting subsystems, which are groups of cells that work together to form tissues and organs that are specialized for particular body functions (LS1.A as in MS-LS1-3).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-LS1-2), conducting investigations (MS-LS1-1), and engaging in argument (MS-LS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Scale, Proportion, and Quantity (MS-LS1-1), Systems and System Models (MS-LS1-3), and Structure and Function (MS-LS1-2). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-LS1-1. **Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.** [Clarification Statement: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living cells, and understanding that living things may be made of one cell or many and varied cells.] MS-LS1-2. **Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.** [Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.] [Assessment Boundary: Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane. Assessment of the function of the other organelles is limited to their relationship to the whole cell. Assessment does not include the biochemical function of cells or cell parts.]

Performance Expectations (Continued)	MS-LS1-3. **Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.** [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.]
Example Phenomena	When I swab inside my cheek and look at it through a microscope, I can see cells. Tomatoes on the vine split open after a big rainstorm.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that require sufficient and appropriate empirical evidence to answer. Students could *ask questions about how* ***tissues and organs are specialized for particular body functions***, [ensuring that their questions] *require sufficient and appropriate empirical evidence to answer.* MS-LS1-3 **Developing and Using Models** • Develop a model to describe unobservable mechanisms. Students could *develop a model to describe* [that] ***body subsystems are groups of cells that work together to form tissues and organs***. MS-LS1-3 **Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. Students could *collaboratively plan a* [hypothetical] *investigation* [to determine whether] ***all living things are made up of cells*** *and in the plan,* students could *identify independent and dependent variables and controls and how many data would be needed to support a claim*. MS-LS1-2 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). Students could *consider limitations of data analysis, including measurement error*, [when determining whether] ***cells are the smallest unit that can be said to be alive***. MS-LS1-1 **Using Mathematical and Computational Thinking** • Apply mathematical representations to describe and/or support scientific conclusions and design solutions Students could *apply mathematic representations to describe* [the relationship between the] ***numbers and types of cells in an organism***. MS-LS1-1

	Constructing Explanations and Designing Solutions • Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion. Students could *apply scientific reasoning to show why the evidence* [that] ***the cell membrane forms the boundary that controls what enters and leaves the cell is adequate for the explanation***. MS-LS1-2 **Engaging in Argument from Evidence** • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretation of facts. Students could *compare and critique two arguments that* **cells are the smallest unit that can be said to be alive**, *and analyze whether the arguments emphasize similar or different evidence and/or interpretation of facts*. MS-LS1-1 **Obtaining, Evaluating, and Communicating Information** • Communicate scientific and/or technical information in writing and/or through oral presentations. Students could *communicate scientific information through oral presentations* [about how] ***within cells, special structures are responsible for particular functions***. MS-LS1-2
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Students could ask questions about how *macroscopic patterns are related to the nature of microscopic and atomic-level* structure ***in multicellular organisms,*** [where] ***groups of cells work together to form tissues and organs that are specialized for particular body functions***. MS-LS1-3 **Systems and System Models** • Models are limited in that they only represent certain aspects of the system under study. Students could construct an argument that *models are limited in that they only represent certain aspects of the system under study, [using as evidence a model of]* ***special structures within cells that are responsible for particular functions***. MS-LS1-2 **Stability and Change** • Small changes in one part of a system might cause large changes in another part. Students could construct an argument that *small changes in one part of a* ***multicellular organism*** *might cause large changes in another part* ***of the organism*** [because] ***the body is a system of multiple interacting subsystems***. MS-LS1-3
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories are explanations for observable phenomena. Students could obtain and communicate information about how *theories are explanations for observable phenomena*, [including that] ***all living things are made up of cells***. MS-LS1-1 **Science Addresses Questions About the Natural and Material World** • Scientific knowledge is constrained by human capacity, technology, and materials. Students could construct an argument for how *scientific knowledge is constrained by human capacity and technology*, [using as evidence the scientific knowledge that] ***all living things are made up of cells***. MS-LS1-1

Middle School Phenomenon Model Course 2 – Bundle 5
Growth and Reproduction of Organisms

This is the fifth bundle of the Middle School Phenomenon Model Course 2. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 5 Question: This bundle is assembled to address the question "why do some parents and offspring look different?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how organisms grow and reproduce. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring (LS1.B as in MS-LS3-2). In order to increase the odds of reproduction, animals engage in characteristic behaviors, and plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction (LS1.B as in MS-LS1-4). Genetic information is passed from parent to offspring in the form of genes, which are located in the chromosomes of cells. Each distinct gene chiefly controls the production of specific proteins, which in turn affect the traits of the individual (LS3.A as in MS-LS3-1).

Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes inherited (LS3.A as in MS-LS3-2). In sexually reproducing organisms, each parent contributes half of the genes acquired by the offspring. Individuals have two of each chromosome and hence two alleles of each gene. These versions may be identical or may differ from each other (LS3.B as in MS-LS3-2). In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations (LS3.B as in MS-LS3-1). Though rare, mutations to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits (LS3.A as in MS-LS3-1). Some changes are beneficial, others harmful, and some neutral to the organism (LS3.B as in MS-LS3-1). Furthermore, genetic factors as well as local conditions affect the growth of the adult plant (LS1.B as in MS-LS1-5).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-LS3-1 and MS-LS3-2), constructing explanations (MS-LS1-5), and engaging in argument (MS-LS1-4). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (MS-LS1-4, MS-LS1-5, and MS-LS3-2) and Structure and Function (MS-LS3-1). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-LS1-4. **Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.** [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds; and, creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.] MS-LS1-5. **Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.] MS-LS3-1. **Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.** [Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.] [Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.] MS-LS3-2. **Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.** [Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]
Example Phenomena	Some species of lizards don't need males to reproduce. A child can have red hair even if no one else in their family has red hair.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation to seek additional information* [about how] ***specific proteins affect the traits of the individual***. MS-LS3-1 **Developing and Using Models** • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Students could develop a model to show relationships among variables [of] ***animals engaging in characteristic behaviors and the odds of reproduction***. MS-LS1-4

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *conduct an investigation to produce data to serve as the basis for evidence* [that] ***genetic factors, as well as local conditions, affect the growth of adult plants***. MS-LS1-5 **Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data to provide evidence* [that] ***mutations are rare.*** MS-LS3-1 **Using Mathematical and Computational Thinking** • Use mathematical representations to describe and/or support scientific conclusions and design solutions. Students could *use mathematical representations to describe* [that] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using models or representations* [of how] ***plants reproduce in a variety of ways***. MS-LS1-4 **Engaging in Argument from Evidence** • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. Students could *compare and critique two arguments* [about how] ***variations of inherited traits between parent and offspring arise from genetic differences*** *and analyze whether they emphasize similar or different evidence*. MS-LS3-2 **Obtaining, Evaluating, and Communicating Information** • Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts. Students could *evaluate data, hypotheses, and/or conclusions in light of competing information* [about how] ***genetic factors as well as local conditions affect the growth of the adult plant.*** MS-LS1-5
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Graphs, charts, and images can be used to identify patterns in data. Students could *use graphs, charts, and images to identify patterns in data* [of how] ***local conditions affect the growth of adult plants***. MS-LS1-5

Additional Crosscutting Concepts Building to the PEs (Continued)	**Cause and Effect** • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Students could construct an argument for how the *relationship between* ***changes to proteins and traits of the individual*** *can be classified as causal or correlational, and that correlation does not necessarily imply causation*. MS-LS3-1 **Stability and Change** • Stability might be disturbed by either sudden events or gradual changes that accumulate over time. Students could construct an argument for how *stability* ***in inherited traits between parent and offspring*** [over generations] *might be disturbed by either sudden events or gradual changes* [(mutations)] *that accumulate over time*. MS-LS3-2
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific explanations are subject to revision and improvement in light of new evidence. Students could obtain, evaluate, and communicate information about how *scientific explanations* [of how] ***each gene chiefly controls the production of specific proteins*** [have been] *revised and improved in light of new evidence*. MS-LS3-1 **Science Addresses Questions About the Natural and Material World** • Scientific knowledge is constrained by human capacity, technology, and materials. Students could construct an argument about how *scientific knowledge* [about] ***genetic factors affecting the growth of plants*** *is constrained by human capacity, technology, and materials*. MS-LS1-5

Middle School Phenomenon Model Course III – Bundle 1
The Earth Affects Life

This is the first bundle of the Middle School Phenomenon Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "How have Earth processes changed populations of organisms?"

Summary
The bundle organizes performance expectations with a focus on helping students begin to understand how populations change in response to environmental factors. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
The geologic time scale interpreted from rock strata provides a way to organize Earth's history (ESS1.C as in MS-ESS1-4). The collection of fossils and their placement in chronological order is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth (LS4.A as in MS-LS4-1). Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale (ESS1.C as in MS-ESS1-4). Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent (LS4.A as in MS-LS4-2). Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy (LS4.A as in MS-LS4-3).

Natural selection leads to the predominance of certain traits in a population, and the suppression of others (LS4.B as in MS-LS4-4). Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common (LS4.C as in MS-LS4-6). Environmental conditions have changed over time and are affected by weather and climate, which are in turn are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns (ESS2.D as in MS-ESS2-6). The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns (ESS2.C as in MS-ESS2-5), which change the environment and affect living things.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing models (MS-ESS2-6), planning and carrying out investigations (MS-ESS2-5), analyzing and interpreting data (MS-LS4-1 and MS-LS4-3), using mathematics and computational thinking (MS-LS4-6), and constructing explanations (MS-LS4-2, MS-LS4-4, MS-ESS1-4). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-LS4-1, MS-LS4-2 and MS-LS4-3), Cause and Effect (MS-LS4-4, MS-LS4-6 and MS-ESS2-5), Scale, Proportion, and Quantity (MS-ESS1-4), and Systems and System Models (MS-ESS2-6). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations MS-LS4-6 is partially assessable.	MS-LS4-1. **Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.** [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.] MS-LS4-2. **Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.** [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.] MS-LS4-3. **Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.** [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.] MS-LS4-4. **Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.** [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.] MS-LS4-6. **Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.** [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [*Assessment Boundary: Assessment does not include Hardy Weinberg calculations.* MS-ESS1-4. **Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.** [Clarification Statement: Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of Earth's major events could range from being very recent (such as the last Ice Age or the earliest fossils of homo sapiens) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant volcanic eruptions.] [*Assessment Boundary: Assessment does not include recalling the names of specific periods or epochs and events within them.*] MS-ESS2-5. **Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.** [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]

Performance Expectations (Continued)	MS-ESS2-6. **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*]
Example Phenomena	Human embryos have tails. Fossils can be found of organisms that look very different from any organisms alive today.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that require sufficient and appropriate empirical evidence to answer. Students could *ask questions about the* ***traits*** [in different] ***populations*** [that show evidence of] ***adaptation to regional weather and climate***. MS-LS4-6 and MS-ESS2-6 **Developing and Using Models** • Develop a model to describe unobservable mechanisms Students could *develop a model to describe* [how] ***natural selection leads to the predominance of certain traits in a population***. MS-LS4-4 **Planning and Carrying Out Investigations** • Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *conduct an investigation* [with containers of sediment] *to produce data* [about how the relative] ***geologic time scale*** [can be] ***interpreted from rock strata.*** MS-ESS1-4 **Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data on* ***anatomical similarities and differences between various organisms*** *to provide evidence* [for] ***lines of descent***. MS-LS4-2 **Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use computers to analyze very large data sets for patterns* [in the] ***fossil record*** [of the] ***diversity of life forms throughout the history of life on Earth***. *(MS-LS4-1)* **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using a model* [of changing] ***weather and climate*** [affecting] ***the distribution of traits in a population***. MS-LS4-6 and MS-ESS2-6

Additional Practices Building to the PEs (Continued)	**Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon. Students could *present a written argument to support the explanation that* ***traits that support successful survival and reproduction become more common; those that do not become less common***. MS-LS4-6 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). Students could *critically read scientific texts to describe patterns in the* ***comparison of embryological development of different species***. MS-LS4-3
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Patterns in rates of change and other numerical relationships can provide information about natural systems. Students ask questions about *patterns* [in] ***rock strata and the fossil record*** [to obtain] *information about natural systems*. MS-ESS1-4 **Scale, Proportion, and Quantity** • Phenomena that can be observed at one scale may not be observable at another scale. Students could support claims with evidence [that] ***the change of many life forms throughout the history of life on Earth*** *may not be observable* [on the] *scale* [of a human lifetime, but that it can be observed on a much longer timespan]. MS-LS4-1 **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. Students could obtain information about the *structure of* ***anatomical similarities and differences between various organisms*** *to infer the functions of the systems*. MS-LS4-2
Additional Connections to Nature of Science	**Science Investigations Use a Variety of Methods** • Scientific values function as criteria in distinguishing between science and non-science. Students could construct an argument that *scientific values are used as criteria in distinguishing between science and non-science* [when describing how scientists interpret] ***the fossil record***. MS-LS4-1 and MS-ESS1-4 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science carefully considers and evaluates anomalies in data and evidence. Students could obtain, evaluate, and communicate information about how *anomalies in data and evidence were considered* [in the development of scientific explanations about] ***natural selection***. MS-LS4-4

Middle School Phenomenon Model Course III - Bundle 2
Life Affects Life

This is the second bundle of the Middle School Phenomenon Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 2 Question: This bundle is assembled to address the question "How can people influence other organisms?"

Summary
The bundle organizes performance expectations with a focus on helping students build understanding of ways that humans have influenced organisms both directly (through artificial selection) and indirectly (by affecting their environments). Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations (LS2.C as in MS-LS2-4). When ecosystem conditions change, organisms must respond appropriately. To do so, they use sense receptors that respond to 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.D as in MS-LS1-8).

When organisms cannot respond appropriately to changes in environmental conditions, the species may change over time via adaptation by natural selection. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common (LS4.C as in MS-LS2-6). Humans can also influence certain characteristics of organisms by selective breeding via artificial selection. One can choose desired parental traits determined by genes, which are then passed on to offspring (LS4.B as in MS-LS4-5).

One factor that changes ecosystems over time is climate change. Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities (ESS3.D as found in MS-ESS3-5).

The engineering design ideas that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-3), and that a solution needs to be tested, and then modified on the basis of the test results, in order to improve it (ETS1.B as in MS-ETS1-4) could connect to many different science ideas, including that disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations (LS2.C as in MS-LS2-4), and that in artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding (LS4.B as in MS-LS4-5). Connections could be made by having students evaluate different solutions systematically, whether solutions for reducing disruptions to ecosystems or for breeding strains of plants with the desired characteristics. In either case, students could identify any modifications that need to be made to the solution in order to improve it.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions (MS-ESS3-5), developing and using models (MS-ETS1-4), analyzing and interpreting data (MS-ETS1-3), using mathematics and computational thinking (MS-LS4-6), engaging in argument from evidence (MS-LS2-4), and obtaining, evaluating, and communicating information (MS-LS1-8 and MS-LS4-5). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (MS-LS1-8, MS-LS4-5, and MS-LS4-6) and Stability and Change (MS-LS2-4 and MS-ESS3-5). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations MS-LS4-6 is partially assessable.	MS-LS1-8 **Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.** [Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.] MS-LS2-4. **Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.** [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.] MS-LS4-5. **Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.** [Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.] MS-LS4-6. **Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.** [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [*Assessment Boundary: Assessment does not include Hardy Weinberg calculations.*] MS-ESS3-5. **Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.** [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.] MS-ETS1-3 **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.** MS-ETS1-4 **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.**
Example Phenomena	Cabbage, broccoli, and Brussels sprouts are all the same species. Fields near diversion dams grow crops even with very little rainfall.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to determine relationships between independent and dependent variables and relationships in models. Students could *ask questions to determine the* [effects of] ***a disruption to a biological component of an ecosystem***. MS-LS2-4

Additional Practices Building to the PEs (Continued)	**Developing and Using Models** • Evaluate limitations of a model for a proposed object or tool. Students could *evaluate limitations of a model for a proposed tool* [that could help] ***reduce human vulnerability to whatever climate changes occur***. MS-ESS3-5 **Planning and Carrying Out Investigations** • Collect data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. Students could *collect data to serve as the basis for evidence to answer scientific questions* [about whether] ***traits that support successful survival and reproduction in a new environment become more common***. MS-LS4-6 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). Students could *consider limitations of data analysis* [when analyzing whether] ***signals processed in the brain result in immediate behavior or memories***. MS-LS1-8 **Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use digital tools to analyze very large data sets for patterns and trends* ***in the current rise in Earth's mean surface temperature***. MS-ESS3-5 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events. Students could *apply scientific ideas, principles, and evidence to construct an explanation* [that] ***humans influence certain characteristics of organisms by selective breeding***. MS-LS4-5 **Engaging in Argument from Evidence** • Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could *respectfully provide critiques about models by citing relevant evidence and posing questions that elicit pertinent elaboration and detail* [about how] ***the distribution of traits in a population changes.*** *MS-LS4-6*

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world. Students could *critically read scientific texts to determine evidence* [that] ***disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.*** MS-LS2-4
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Students could analyze data to *classify relationships* [between] ***disruptions to a physical component of an ecosystem*** [and] ***shifts in its populations*** *as either causal or correlational*. MS-LS2-4 **Structure and Function** • Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function. Students could analyze ***sense receptors*** *to describe how their function depends on the shapes and relationships among their parts*. MS-LS1-8 **Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could analyze data to compare the effects of *sudden events or gradual changes* in ***the distribution of traits in a population.*** MS-LS4-6
Additional Connections to Nature of Science	**Scientific Investigations us a Variety of Methods** • Science depends on evaluating proposed explanations. Students could construct an argument for why *science depends on evaluating proposed explanations*, [including for how] ***the distribution of traits in a population changes***. MS-LS4-6 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. Students could construct an argument [for how the assumption] *that events in natural systems occur in consistent patterns that are understandable through measurement and observation* [affects their understanding that] ***parental traits are determined by genes, which are then passed on to offspring***. MS-LS4-5

Middle School Phenomenon Model Course III – Bundle 3
Life Affects Earth

This is the third bundle of the Middle School Phenomenon Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question "How can people influence Earth?"

Summary
The bundle organizes performance expectations with a focus on helping students build understanding of engineering solutions related to human effects on their environment. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health (LS2.C as in MS-LS2-5). Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on, such as water purification and recycling (LS4.D as in MS-LS2-5).

Just as changes in biodiversity can affect humans, human activities can alter the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. Changes to Earth's environments can also have different impacts (negative and positive) for different living things (ESS3.C as in MS-ESS3-3). However, typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise (ESS3.C as in MS-ESS3-3 and MS-ESS3-4).

The engineering design idea that the more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful (ETS1.A as in MS-ETS1-1) and that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-LS2-5 and MS-ETS1-2) could connect to several different science concepts, such as that changes in biodiversity can influence humans' resources (LS4.D as in MS-LS2-5), or that changes to Earth's environments can have different impacts for different living things (ESS3.C as in MS-ESS3-3). Connections could be made through engineering design tasks such as defining problems related to humans' resources or impacts on living things to determine the necessary criteria and constraints for successful solutions, and then using those criteria and constraints to evaluate proposed solutions.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (MS-ETS1-1), constructing explanations and designing solutions (MS-ESS3-3), and engaging in argumentation (MS-LS2-5, MS-ESS3-4, and MS-ETS1-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (MS-ESS3-4 and MS-ESS3-5) and Stability and Change (MS-LS2-5). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-LS2-5**. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*** [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.] MS-ESS3-3. **Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.*** [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).] MS-ESS3-4. **Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.** [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.] MS-ETS1-1. **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.** MS-ETS1-2. **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**
Example Phenomena	My city was built on former wetlands. Some urban areas outside the flood zone now flood regularly.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. Students could *ask questions to identify evidence* [about why] ***the completeness or integrity of an ecosystem's biodiversity is used as a measure of its health***. MS-LS2-5 **Developing and Using Models** • Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. Students could *develop a model based on evidence to match what happens if* ***human activities alter the biosphere***. MS-ESS3-3 **Planning and Carrying Out Investigations** • Evaluate the accuracy of various methods for collecting data. Students could *evaluate the accuracy of various methods for collecting data* [about how] ***changes in biodiversity can influence humans' resources***. MS-LS2-5

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Use graphical displays of large data sets to identify temporal and spatial relationships. Students could *use graphical displays of large data sets to identify relationships* [between] ***per-capita consumption of natural resources*** [and] ***negative impacts on Earth***. MS-ESS3-3 and MS-ESS3-4 **Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use digital tools to analyze very large data sets for patterns and trends* [to determine if there is evidence that] ***human activities*** [might] ***cause the extinction of other species***. MS-ESS3-3 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events. Students could *apply scientific ideas, and evidence to construct an explanation* [of how] ***changes in biodiversity can influence humans'*** [access to] ***food, energy, and medicines.*** MS-LS2-5 **Engaging in Argument from Evidence** • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. Students could *compare and critique two arguments* [about the effects of] ***human activities*** [on] ***the biosphere***, *analyzing whether the arguments emphasize similar or different evidence.* MS-ESS3-3 **Obtaining, Evaluating, and Communicating Information** • Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts. Students could *evaluate data and conclusions in technical texts* [related to] ***engineered activities and technologies*** [that can help reduce] ***negative impacts on Earth*** [from] ***consumption of natural resources***. MS-ESS3-3 and MS-ESS3-4
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Patterns can be used to identify cause and effect relationships. Students could construct an argument from evidence for how *patterns can be used to identify cause and effect relationships* [between] ***increases in human populations*** [and] ***negative impacts on Earth***. MS-ESS3-3 and MS-ESS3-4 **Systems and System Models** • Models are limited in that they only represent certain aspects of the system under study. Students could describe that *models* [of] ***biodiversity influencing humans' resources*** *are limited in that they only represent certain aspects of the system under study*. MS-ESS2-6

Additional Crosscutting Concepts Building to the PEs (Continued)	**Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could analyze and interpret data on how *stability* [of] ***the biosphere*** *might be disturbed either by sudden events* or *gradual changes that accumulate over time* [due to] ***human activities***. MS-ESS3-3
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods** • Scientific values function as criteria in distinguishing between science and non-science. Students could ask questions about how *scientific values* [are used to] *distinguish between science and non-science* [in understanding how] ***changes to Earth's environment can have different impacts for different living things***. MS-ESS3-3 **Science is a Human Endeavor** • Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas. Students could construct an argument from evidence for how *scientists' habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas* [affect their understanding of how] ***changes in biodiversity can influence ecosystem services*** [such as] ***water purification***. MS-LS2-5

Middle School Phenomenon Model Course III

Narrative and Rationale: This course model arranges the Performance Expectations (PEs) outlined in the third year of the middle school conceptual progressions model from Appendix K of the Next Generation Science Standards into three different bundles of PEs using a phenomenon-based arrangement. The bundles in this model follow a conceptual flow throughout the year.

The first bundle focuses on effects of Earth processes on organisms and populations. The second bundle focuses on the ability of humans to influence the environment and other organisms. The third bundle focuses on the ability of humans to not only influence the Earth, but also to engineer solutions to help ensure that any negative influences on the Earth are mitigated. Each bundle is organized using the DCIs that would help students explain a unifying phenomenon and answer a guiding question.

It is important to note that the SEPs and CCCs described are intended as end-of-instructional unit expectations and not curricular designations. Additional SEPs and CCCs should be used throughout instruction toward each bundle.

Unit 1: How have Earth processes changed populations of organisms? **~ 12 weeks**	**Unit 2:** How can people influence other organisms? **~ 10 weeks**	**Unit 3:** How can people influence Earth? **~ 7 weeks**
MS-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. **MS-LS4-2**. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. **MS-LS4-3**. Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy. **MS-LS4-4.** Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. **MS-LS4-6.** Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.[1] **MS-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history. **MS-ESS2-5.** Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions. **MS-ESS2-6.** Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.[1]	**MS-LS1-8.** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories. **MS-LS2-4.** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. **MS-LS4-5.** Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. **MS-LS4-6.** Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. [1] **MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. **MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	**MS-LS2-5.** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* **MS-ESS3-3**. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* **MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

Middle School Phenomenon Model Course III Flowchart

Bundle 1

LS4.A as found in MS-LS4-1
- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.

LS4.A as found in MS-LS4-2
- Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.

LS4.A as found in MS-LS4-3
- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.

LS4.B as found in MS-LS4-4
- Natural selection leads to the predominance of certain traits in a population, and the suppression of others.

LS4.C as found in MS-LS4-6
- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

ESS1.C as found in MS-ESS1-4
- The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.

ESS2.C as found in MS-ESS2-5
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

ESS2.C as found in MS-ESS2-6
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

Bundle 2

LS1.D as found in MS-LS1-8
- 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.

LS2.C as found in MS-LS2-4
- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

LS4.B as found in MS-LS4-5
- In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.

LS4.C as found in MS-LS4-6
- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

ESS3.D as found in MS-ESS3-5
- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

ETS1.B as found in MS-ETS1-3
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

Bundle 3

LS2.C as found in MS-LS2-5
- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

LS4.D as found in MS-LS2-5
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

ESS3.C as found in MS-ESS3-3
- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

ESS3.C as found in MS-ESS3-3 and MS-ESS3-4
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ETS1.A as found in MS-ETS1-1
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

ETS1.B as found in MS-LS2-5 and MS-ETS1-2
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

ESS2.D as found in MS-ESS2-5
- Because these patterns are so complex, weather can only be predicted probabilistically.

ESS2.D as found in MS-ESS2-6
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

ETS1.B as found in MS-ETS1-4
- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
- Models of all kinds are important for testing solutions.

ETS1.C as found in MS-ETS1-3
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process - that is, some of the characteristics may be incorporated into the new design.

ETS1.C as found in MS-ETS1-4
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Middle School Phenomenon Model - Course II Summary

Storyline/Narrative: This course model arranges the Performance Expectations (PEs) outlined in the second year of the middle school conceptual progressions model from Appendix K of the Next Generation Science Standards into five different bundles of PEs using a phenomenon-based arrangement. The bundles in this model follow a conceptual flow throughout the year.

The first bundle focuses on the transfer of energy and matter between Earth's systems. The second bundle applies this understanding of energy and matter transfer to a study of climate diversity on the Earth. The third bundle focuses on gravity and Earth's place in the solar system, the fourth on cells and body systems, and the fifth on growth and reproduction. Each bundle is organized around the DCIs that would help students explain a unifying phenomenon and answer a guiding question. It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional practices and crosscutting concepts should be used throughout instruction toward each bundle.

Bundle 1: Why do people live and farm on volcanoes? ***~ 6 weeks***	**Bundle 2:** What causes climates to be so different across the Earth? ***~ 6 weeks***	**Bundle 3:** Why can we predict solar eclipses? ***~ 4 weeks***	**Bundle 4:** Why are bones so hard? ***~ 4 weeks***	**Bundle 5:** Why do some parents and offspring look different? ***~ 6 weeks***
MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and the flow of energy into and out of organisms. **MS-LS1-7.** Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. **MS-LS2-3**. Develop a model to describe the cycling of matter and flow of energy among living and non-living parts of an ecosystem. **MS-ESS2-1**. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. **MS-ESS2-2**. Construct an explanation based on evidence for how geosciences processes have changed Earth's surface at varying time and spatial scales.	**MS-PS4-3.** Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. **MS-ESS2-5**. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions. **MS-ESS2-6**. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. **MS-ESS3-2**. Analyze and interpret data on natural hazards to forecast catastrophic events and inform the development of technologies to mitigate their effects. **MS-ETS1-1**. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts.	**MS-PS3-2**. Develop and use a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. **MS-ESS1-1.** Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. **MS-ESS1-2**. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.	**MS-LS1-1.** Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells. **MS-LS1-2**. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. **MS-LS1-3**. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.	**MS-LS1-4.** Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. **MS-LS1-5**. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. **MS-LS3-1**. Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. **MS-LS3-2**. Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and

Bundle 1: Why do people live and farm on volcanoes? ***~ 6 weeks***	**Bundle 2:** What causes climates to be so different across the Earth? ***~ 6 weeks***	**Bundle 3:** Why can we predict solar eclipses? ***~ 4 weeks***	**Bundle 4:** Why are bones so hard? ***~ 4 weeks***	**Bundle 5:** Why do some parents and offspring look different? ***~ 6 weeks***
	on people and the natural environment that may limit possible solutions. **MS-ETS1-2:** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.			sexual reproduction results in offspring with genetic variation.

Middle School Phenomenon Model Course 2 Flowchart

Bundle 1

PS3.D as found in MS-LS1-6
- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.

PS3.D as found in MS-LS1-7
- Cellular respiration in plants and animals involve 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.

LS1.C as found in MS-LS1-6
- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

to LS1.A in Bundle 4

LS1.C as found in MS-LS1-7
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.

LS2.B as found in MS-LS2-3
- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

to LS1.B in Bundle 5

ESS2.A as found in MS-ESS2-1
- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.

ESS2.A as found in MS-ESS2-2
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

ESS2.C as found in MS-ESS2-2
- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

to ESS2.C in Bundle 2

Bundle 2

PS4.C as found in MS-PS4-3
- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

ESS2.C as found in MS-ESS2-5
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

ESS2.C as found in MS-ESS2-6
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

ESS2.D as found in MS-ESS2-5
- Because these patterns are so complex, weather can only be predicted probabilistically.

ESS2.D as found in MS-ESS2-6
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

ESS3.B as found in MS-ESS3-2
- Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

ETS1.A as found in MS-ETS1-1
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

ETS1.B as found in MS-ETS1-2
- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.

Bundle 3

PS3.A as found in MS-PS3-2
- A system of objects may also contain stored (potential) energy, depending on their relative positions.

PS3.C as found in MS-PS3-2
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

ESS1.A as found in MS-ESS1-1
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

ESS1.A as found in MS-ESS1-2
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

ESS1.B as found in MS-ESS1-2
- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

ESS1.B as found in MS-ESS1-1
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

Bundle 4

LS1.A as found in MS-LS1-1
- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).

LS1.A as found in MS-LS1-2
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.

LS1.A as found in MS-LS1-3
- 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.

Bundle 5

LS1.B as found in MS-LS1-4
- Animals engage in characteristic behaviors that increase the odds of reproduction.
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.

LS1.B as found in MS-LS1-5
- Genetic factors as well as local conditions affect the growth of the adult plant.

LS1.B as found in MS-LS3-2
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.

LS3.A as found in MS-LS3-1
- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

LS3.A as found in MS-LS3-2
- Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.

LS3.B as found in MS-LS3-1
- In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.

LS3.B as found in MS-LS3-2
- In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

Middle School Topics Model Course 1-Bundle 1
Body Systems

*This is the first bundle of the Middle School Topics Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](). *

Bundle 1 Question: This bundle is assembled to address the question of "How do the structures of organisms enable life's functions?"

Summary
The bundle organizes performance expectations with a focus on helping students begin to understand how the structures of organisms enable life's functions. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism can be composed of one single cell or many different numbers and types of cells (LS1.A as in MS-LS1-1). This concept is expanded with the idea of special structures within cells that are responsible for particular functions (LS1.A as in MS-LS1-2). The concept of cells connects to the concept of body systems with the idea that 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 as in MS-LS1-3). This concept of subsystems connects to the idea of the nervous system, which is made up of specialized nerve cells (LS1.D as in MS-LS1-8).

The concept that the more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful (ETS1.A as in MS-ETS1-1) could connect to concepts of the cell membrane (LS1.A as in MS-LS1-2) or how sense receptors respond to different inputs (LS1.D as in MS-LS1-8). Connections could be made through an engineering design task such as defining the criteria and constraints for designing prosthetic limbs for amputees. Alternatively, students could be asked to consider the role of nerve cells in skin grafts for burn victims, and to consider that role in identifying the criteria and constraints with which to evaluate two similar processes for grafting skin.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining a design problem (MS-ETS1-1), developing and using a model (MS-LS1-2), conducting an investigation (MS-LS1-1), engaging in argumentation (MS-LS1-3), and obtaining, evaluating, and communicating information (MS-LS1-8). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (MS-LS1-8), Scale, Proportion, and Quantity (MS-LS1-1), Systems and System Models (MS-LS1-3), Structure and Function (MS-LS1-2), and Influence of Science, Engineering, and Technology on Society and the Natural World (MS-ETS1-1) Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

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Performance Expectations MS-LS1-3 and MS-LS1-8 are partially assessable	MS-LS1-1 **Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.** [Clarification Statement: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living cells, and understanding that living things may be made of one cell or many and varied cells.] MS-LS1-2 **Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.** [Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.] [Assessment Boundary: Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane. Assessment of the function of the other organelles is limited to their relationship to the whole cell. Assessment does not include the biochemical function of cells or cell parts.] **MS-LS1-3 Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.** [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.] MS-LS1-8 **Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.** [Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.] MS-ETS1-1 **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.**
Example Phenomena	Muscle tissue, fat, blood, and bone are all very different from one another. We can remember things that happened in the past.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation to clarify* [whether] ***cells are the smallest unit that can be said to be alive***. MS-LS1-1 **Developing and Using Models** • Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. Students could *use a model to generate data* [for how] ***an organism may consist of one single cell or many different numbers and types of cells***. MS-LS1-1

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. Students could *plan an investigation and in the design: identify the independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim* [for how] ***special structures within cells are responsible for particular functions***. HS-LS1-2 **Analyzing and Interpreting Data** • Distinguish between causal and correlational relationships in data. Students could *distinguish between causal and correlational relationships in data* [for how] ***in multicellular organisms, groups of cells work together to form tissues and organs that are specialized for particular body functions***. MS-LS1-3 **Using Mathematical and Computational Thinking** • Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems. Students could *apply mathematical concepts and/or processes* [to determine the rate at which] ***each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain***. MS-LS1-8 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using models or representations* [for how] ***in multicellular organisms, the body is a system of multiple interacting subsystems***. MS-LS1-3 **Engaging in Argument from Evidence** • Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could *respectfully receive critiques about their explanations by citing relevant evidence and responding to questions* [about how] ***special structures within cells are responsible for particular functions***. HS-LS1-2 **Obtaining, Evaluating, and Communicating Information** • Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings. Students could *integrate qualitative scientific information to clarify claims* [for how] ***in multicellular organisms, the body is a system of multiple interacting subsystems and these subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions***. MS-LS1-3

Additional Crosscutting Concepts Leading to PE	**Cause and Effect** • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Students could ask questions about *causal* [versus] *correlational relationships* [for how] ***each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain and how these signals are then processed in the brain, resulting in immediate behaviors or memories***. MS-LS1-8 **Systems and System Models** • Models are limited in that they only represent certain aspects of the system under study. Students could analyze how a *model* of ***multicellular organisms*** [as] ***systems of multiple interacting subsystems*** *is limited in that the model only represents certain aspects of the* **organisms**. MS-LS1-3 **Stability and Change** • Small changes in one part of a system might cause large changes in another part. Students could plan and conduct an investigation to gather data about how *small changes in one part of* ***a cell*** *(e.g.,* ***the cell membrane****) might cause large changes in another part* of ***the cell***. MS-LS1-2
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods (SEP):** • Science investigations use a variety of methods and tools to make measurements and observations. Students could obtain and evaluate information about how *science investigations use a variety of methods and tools to make measurements and observations* [for how] ***each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain and how these signals are then processed in the brain, resulting in immediate behaviors or memories***. MS-LS1-8 **Science is a Way of Knowing (CCC):** • Science is a way of knowing used by many people, not just scientists. Students could construct an argument from evidence for how *science is a way of knowing used by many people, not just scientists* [to learn about how] ***groups of cells work together to form tissues and organs that are specialized for particular body functions***. MS-LS1-3

Middle School Topics Course Model 1-Bundle 2
Reproduction and Growth

This is the second bundle of the Middle School Topics Course Model 1. Each bundle has connections to the other bundles in the course, as shown in the [*Course Flowchart*].

Bundle 2 Question: This bundle is assembled to address the question of "How do organisms grow and reproduce?"

Summary

The bundle organizes performance expectations with a focus on helping students understand the conditions of successful reproduction, development, and growth. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

All living things are made up of cells. 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. As in MS-LS1-3). These specialized tissues and organs support organisms as they grow and reproduce. Animals engage in characteristic behaviors that increase the odds of reproduction and plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (LS1.B as in MS-LS1-4). The nervous system is made up of specialized nerve cells. These nerve cells enable each sense receptor to respond 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.D as in MS-LS1-8) further enabling animals to grow and reproduce.

The ideas about reproduction in this bundle connect to the concept that organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring (LS1.B as in MS-LS3-2). The concept of sexual reproduction and transfer of genetic information connects to the idea that variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes inherited (LS3.A as in MS-LS3-2). Another connection to sexual reproduction is the idea that in sexually reproducing organisms, each parent contributes half of the genes acquired by the offspring, thus individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other (LS3.B as in MS-LS3-2). Additionally, genetic factors as well as local conditions affect the growth of the adult plant (LS1.B as in MS-LS1-5).

Finally, specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (ETS1.A as in MS-ETS1-1), and there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-2, MS-ETS1-3). Although the design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design (ETS1.C as in MS-ETS1-3). Thus, a solution needs to be tested, and then modified on the basis of the test results, in order to improve it (ETS1.B as in MS-ETS1-4). These engineering design concepts could connect to many different science ideas, including about how animals and plants may have specialized features that increase the odds of reproduction (LS1.B as in MS-LS1-4), how each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain where they result in immediate behaviors or memories (LS1.D as in MS-LS1-8), and how local conditions affect the growth of plants (LS1.B as in MS-LS1-5). Connections could be made through an engineering design task by identifying criteria and constraints including those that could limit possible solutions (ETS1.A as in MS-ETS1-1) for how a local zoo could optimize the habitat of animals and plants to increase the odds of reproduction (LS1.B as in MS-LS1-4) or for designing lighting systems in a greenhouse to maximize the growth of plants (LS1.B as in MS-LS1-5).

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (MS-ETS1-1), developing and using models (MS-LS3-2 and MS-ETS1-4), analyzing and interpreting data (MS-ETS1-3), constructing explanations (MS-LS1-5), engaging in argument from evidence (MS-LS1-3, MS-LS1-4, and MS-ETS1-2), and obtaining, evaluating, and communicating information (MS-LS1-8). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (MS-LS1-4, MS-LS1-5, MS-LS1-8, and MS-LS3-2), and Systems and System Models (MS-LS1-3). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations MS-LS1-3 and MS-LS1-8 are partially assessable	MS-LS1-3 **Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.** [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.] MS-LS1-4 **Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.** [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds; and, creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.] MS-LS1-5 **Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.] MS-LS1-8 **Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.** [Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.] MS-LS3-2 **Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.** [Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]

Performance Expectations (Continued)	MS-ETS1-1 **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.** MS-ETS1-2 **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.** MS-ETS1-3 **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.** MS-ETS1-4 **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.**
Example Phenomena	A male peacock has a spectacular display of colorful feathers. In times of drought, some plants lose their leaves.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to determine relationships between independent and dependent variables and relationships in models. Students could *ask questions to* [seek information about] *relationships between independent and dependent variables* [for how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Developing and Using Models** • Evaluate limitations of a model for a proposed object or tool. Students could *evaluate limitations of a model* [used to determine which parental] ***genes*** [end up in the] ***offspring of sexual reproducing organisms***. MS-LS3-2 **Planning and Carrying Out Investigations** • Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. Students could *collect data to serve as the basis for evidence to answer scientific questions* [about how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). Students could *consider limitations of data analysis* [about how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5

Additional Practices Building to the PEs (Continued)	**Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use digital tools to analyze very large data sets for patterns and trends* [about how] ***animals engage in characteristic behaviors that increase the odds of reproduction***. MS-LS1-4 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events. Students could *apply scientific ideas, principles, and/or evidence to construct an explanation* [for how] ***variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes inherited***. MS-LS3-2 **Engaging in Argument from Evidence** • Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could *respectfully provide critiques about models by citing relevant evidence and posing questions that elicit pertinent elaboration and detail* [for how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world. Students could *critically read scientific text to determine the central ideas to describe evidence* [for how] ***animals engage in characteristic behaviors that increase the odds of reproduction*** and [how] ***plants sometimes depend on animal behavior and specialized features for reproduction***. MS-LS1-4
Additional Crosscutting Concepts Leading to PE	**Cause and Effect** • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Students could analyze data to *classify relationships as causal or correlational* [for how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Structure and Function** • Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function. Students could analyze *complex structures to describe how their function depends on the shapes, composition, and relationships among its* parts [related to how] ***plants sometimes depend on animal behavior and specialized features for reproduction***. MS-LS1-4

Additional Crosscutting Concepts Leading to PE (Continued)	**Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could analyze data about how *sudden events or gradual changes* in ***local conditions affect the growth of the adult plant***. MS-LS1-5
Additional Connections to Nature of Science	**Scientific Investigations us a Variety of Methods** • Science depends on evaluating proposed explanations. Students could construct an argument for why *science depends on evaluating proposed explanations*, [including for how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. Students could construct an argument [for how the assumption] *that events in natural systems occur in consistent patterns that are understandable through measurement and observation* [affects their understanding that] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5

Middle School Topics Model Course 1-Bundle 3
Energy Transfer

This is the third bundle of the Topics Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question of "How can we measure the flow of energy in a system?"

Summary

The bundle organizes performance expectations around the theme of energy flows in systems. Instruction leading to this bundle provides the energy transfer knowledge students will need for a deeper understanding of the concepts in bundle 4. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Temperature is a measure of the average kinetic energy of particles in matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present (PS3.A as in MS-PS3-3, MS-PS3-4) and when the motion energy of an object changes, there is inevitably some other change in energy at the same time (PS3.B as in MS-PS3-5). These ideas connect to the concept that the amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment (PS3.B as in MS-PS3-4), which also connects to the idea that since temperature is a measure of the average kinetic energy (energy of motion) of particles in matter, energy is spontaneously transferred out of hotter regions or objects and into colder ones (PS3.B as in MS-PS3-3).

There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-3) and although the design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process (ETS1.C as in MS-ETS1-3). These concepts could connect to how energy is spontaneously transferred out of hotter regions or objects and into colder ones (PS3.B as in MS-PS3-3) or for how the amount of energy transfer needed to change the temperature of matter depends on the nature of the matter, the size of the sample, and the environment (PS3.B as in MS-PS3-4). Connections could be made through an engineering design task such as evaluating how well a design meets the criteria and constraints for a device that either increases or decreases the temperature of food for human consumption or in selecting materials to insulate a dog house or other animal shelter.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of designing solutions (MS-PS3-3), planning an investigation (MS-PS3-4), engaging in argumentation (MS-PS3-5), and analyzing and interpreting data (MS-ETS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Scale, Proportion, and Quantity (MS-PS3-4), and Energy and Matter (MS-PS3-3 and MS-PS3-5). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

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Performance Expectations	MS-PS3-3 **Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*** [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.] MS-PS3-4 **Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.] MS-PS3-5 **Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.** [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.] MS-ETS1-3 **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.**
Example Phenomena	At the same temperature, metal feels colder to the touch than wood. A solar oven using only the sun's energy can get hot enough to bake a cake.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to clarify and/or refine a model, an explanation, or an engineering problem. Students could *ask questions to clarify an explanation* [for how] **energy is spontaneously transferred out of hotter regions or objects and into colder ones.** MS-PS3-4 **Developing and Using Models** • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Students could *develop a model to show* [that] ***the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present***. MS-PS3-3 and MS-PS3-4 **Planning and Carrying Out Investigations** • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *revise the experimental design of an investigation* [that focuses on collecting] *data* [about how] ***the amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment***. MS-PS3-4

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Distinguish between causal and correlational relationships in data. Students could *distinguish between causal and correlational relationships in data* [about] ***the relationship between the temperature and the total energy of a system***. MS-PS3-3 and MS-PS3-4 **Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use digital tools to analyze very large data sets for patterns and trends* [about how] ***the amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment***. MS-PS3-4 **Constructing Explanations and Designing Solutions** • Construct an explanation that includes qualitative and quantitative relationships between variables that predict(s) and/or describe(s) phenomena. Students could *construct an explanation that includes* ***the relationship between the temperature and the total energy of a system***. MS-PS3-3 and MS-PS3-4 **Engaging in Argument from Evidence** • Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could *respectfully provide critiques about* [experimental] *procedures* [that tested whether] ***energy is spontaneously transferred out of hotter regions or objects and into colder ones*** *by citing relevant evidence and posing questions*. MS-PS3-3 **Obtaining, Evaluating, and Communicating Information** • Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations. Students could *communicate technical information in writing* [for how well the] *proposed* ***design solution meets the criteria and constraints*** [related to the] ***spontaneous transfer of energy out of hotter regions or objects and into colder ones***. MS-PS3-3 and MS-ETS1-3
Additional Crosscutting Concepts Leading to PE	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems. Students could identify *cause and effect relationships* for the ***characteristics of the design that performed the best in each test*** [of slowing the] ***energy transfer*** [between objects of different temperatures]. MS-PS3-3 and MS-ETS1-3

Additional Crosscutting Concepts Leading to PE (Continued)	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Students could construct a *model to represent the systems and their interactions, such as inputs, processes and outputs* [involved in] ***the relationship between the temperature and the total energy of a system, which depends on the types, states, and amounts of matter present***. MS-PS3-3 and MS-PS3-4 **Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes. Students could construct a model of how *matter is conserved* [even when] ***the kinetic energy of particles of matter*** [changes]. MS-PS3-4
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence (SEP):** • Scientific explanations are subject to revision and improvement in light of new evidence. Students could *revise an explanation in light of new evidence* [for how] ***the amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment***. MS-PS3-4 **Science is a Human Endeavor(CCC):** • Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination, and creativity. Students could construct an argument for why *scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination, and creativity* [in order to] ***evaluate solutions*** [to problems of] ***energy transfer with respect to how well they meet the criteria and constrains of a problem***. MS-PS3-3 and MS-ETS1-3

Middle School Topics Model Course 1-Bundle 4
Understanding the Rise in Global Temperature

This is the fourth bundle of the Middle School Topics Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 4 Question: This bundle is assembled to address the question of "What is contributing to the rise in global temperature?"

Summary
The bundle organizes performance expectations around the theme of understanding the rise in global temperature, with a focus on the water cycle, regional climates, and the relationship of humans to the environment. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
Human activities have significantly altered the biosphere. But changes to Earth's environments can have different impacts (negative and positive) for different living things (ESS3.C as in MS-ESS3-3). These concepts of the impact of human activities connect to the idea that human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (ESS3.D as in MS-ESS3-5).

The rise in Earth's mean surface temperature (ESS3.D as in MS-ESS3-5) connects to the idea that the complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns (ESS2.C as in MS-ESS2-5). Movements of water in the atmosphere connect to the idea that global movements of water and its changes in form are propelled by sunlight and gravity (ESS2.C as in MS-ESS2-4). Finally, ideas about movements of water in the atmosphere and oceans also connect to the idea that the ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents (ESS2.D as in MS-ESS2-6).

The idea that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-2) could connect to the idea that human activities have significantly altered the biosphere. But changes to Earth's environments can have different impacts (negative and positive) for different living things (ESS3.C as in MS-ESS3-3). This connection could be shown through a task such as a report that reviewed two possible solutions that could mitigate global warming, analyzing those solutions through criteria and constraints.

Alternatively, idea that the complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns (ESS2.C as in MS-ESS2-5) could connect to the idea that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-2). Students could demonstrate this by proposing a process for monitoring changes in wind and corresponding changes to ocean temperatures, and then evaluating each other's proposed processes using criteria and constraints developed by the class.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing a model (MS-ESS2-4), carrying out investigations (MS-ESS2-5), developing and using a model (MS-ESS2-6), designing solutions (MS-ESS3-3), and asking questions (MS-ESS3-5). Many

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other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Energy and Matter (MS-ESS2-4), Cause and Effect (MS-ESS2-5 and MS-ESS3-3), Systems and System Models (MS-ESS2-6), and Stability and Change (MS-ESS3-5). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-ESS2-4 **Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.** [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.] [*Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.*] MS-ESS2-5 **Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.** [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*] MS-ESS2-6 **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*] MS-ESS3-3 **Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.*** [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).] MS-ESS3-5 **Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.** [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.] MS-ETS1-2 **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**

Example Phenomena	Sometimes there are strong winds. Rain can start or stop suddenly. There are distinctly different climates around the country and around the world. Industrial, transportation, and other human activities can produce air pollution. Many waterways near population centers are cleaner than they were just decades ago.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. Students could *ask questions about* **the complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents,** [to determine how they affect] **major determinants of local weather patterns**. MS-ESS2-5 • Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. Students could *define a design problem to create a process to monitor [how]* **human activities can alter the biosphere.** MS-ESS3-3 **Developing and Using Models** • Develop and/or use a model to predict and/or describe phenomena. Students could *develop a model to describe* [local] **weather**. MS-ESS2-5 **Planning and Carrying Out Investigations** • Collect data about the performance of a proposed object, tool, process or system under a range of conditions. Students could *collect data about* [the effectiveness of] *a method for* [monitoring] **a human impact on the environment**. MS-ESS3-3 **Analyzing and Interpreting Data:** • Analyze and interpret data to determine similarities and differences in findings. Students could *analyze data from different* [studies that show how] **human activities affect current rise in Earth's mean surface temperature**. MS-ESS3-5

Additional Practices Building to the PEs (Continued)	**Using Mathematics and Computational Thinking:** • Use mathematical representations to describe and/or support scientific conclusions and design solutions. Students could *use a mathematical model to describe how* **human activities can alter the biosphere**. MS-ESS3-3 **Constructing Explanations and Designing Solutions:** • Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process, or system. Students could apply *scientific principles to test a process* [for altering the effects of] **human activities on natural habitats.** MS-ESS3-3 **Engaging in Argument from Evidence:** • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. Students could *evaluate design solutions* [that use] **probabilistic methods of predicting weather** based on how well they meet design criteria and constraints. MS-ESS2-6 **Obtaining, Evaluating, and Communicating Information:** • Gather, read, and synthesize information from multiple appropriate sources and asses the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. Students could *gather, read, and synthesize information from multiple appropriate sources about the way that* **the release of greenhouse gases from burning fossil fuels affect Earth's mean surface temperature,** *and asses the credibility and accuracy of each publication*. HS-ESS3-5
Additional Crosscutting Concepts Leading to PE	**Energy and Matter: Flows, Cycles, and Conservation** • The transfer of energy can be tracked as energy flows through a designed or natural system. Students could describe *how the transfer of energy can be tracked as energy flows through the ocean,* **exerting a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents**. MS-ESS2-6 **Stability and Change** • Small changes in one part of a system might cause large changes in another part. Students could identify how *small changes in one part of a system might cause large changes in another part* [by gathering information about how] **changes in sunlight affect global movements of water and its changes in form**. MS-ESS2-4

Additional Crosscutting Concepts Leading to PE (Continued)	**Scale, Proportion, and Quantity** • Phenomena that can be observed at one scale may not be observable at another scale. Students could describe how *phenomena that can be observed at one scale may not be observable at another scale* [by investigating evidence for the idea that] **the release of greenhouse gases from burning fossil fuels affect Earth's mean surface temperature** [and observing the scale of data points that are necessary for observing phenomena related to this concept]. HS-ESS3-5
Additional Connections to Nature of Science	**Scientific knowledge is Based on Empirical Evidence** • Science disciplines share common rules of obtaining and evaluating empirical evidence. Students could [look back to previous life sciences instruction to compare the] *rules of obtaining and evaluating empirical evidence* [with those used in the Earth sciences in this unit of instruction]. **Science Addresses questions about the Natural and Material World** • Science knowledge can describe consequences of actions but is not responsible for society's decisions. Students could describe how *science knowledge can describe consequences of actions but is not responsible for society's decisions* [related to] **understanding human behavior and human vulnerability to climate changes**. MS-ESS3-5

Middle School Topic Model Course 1

Narrative and Rationale: This course model arranges the Performance Expectations (PEs) outlined in the first year of the California Integrated Middle School Model into four different bundles of PEs using a topical arrangement. The disciplinary core ideas of each standard were used in this model to arrange bundles that addressed the topics of human body systems, reproduction and growth, energy transfer and weather, and climates and human impacts.
The Disciplinary Core Ideas (DCIs) in physical science focus on the transfer of energy in systems and the kinetic energy of objects. In the life sciences, the DCIs address the growth and development of organisms, cell structures, and processes. Finally, in the earth and space sciences, the DCIs emphasize the role of water in shaping the processes of the Earth. These DCIs build conceptually throughout the year.

In this model, students begin to develop proficiency in the middle school-level Science and Engineering Practices over the course of the year, and the level of sophistication at which they are able to engage in them increases over time. It is important to note that the Practices and Crosscutting Concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional Practices and Crosscutting Concepts should be used throughout instruction toward each bundle.

Bundle 1: "How do the structures of organisms enable life's functions?" **~6 weeks**	**Bundle 2:** "How do organisms grow and reproduce?" **~6 weeks**	**Bundle 3:** "How can we measure the flow of energy in a system?" **~6 weeks**	**Bundle 4:** "What is contributing to the rise in global temperature?" **~6 weeks**
MS-LS1-1. Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells. **MS-LS1-2.** Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. **MS-LS1-3.** Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.[1] **MS-LS1-8.** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.[1] **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	**MS-LS1-3.** Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.[1] **MS-LS1-4.** Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. **MS-LS1-5.** Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. **MS-LS1-8.** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.[1] **MS-LS3-2.** Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into	**MS-PS3-3.** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* **MS-PS3-4.** Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. **MS-PS3-5.** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. **MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	**MS-ESS2-4.** Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. **MS-ESS2-5.** Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions. **MS-ESS2-6.** Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. **MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* **MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Bundle 1: "How do the structures of organisms enable life's functions?" **~6 weeks**	**Bundle 2:** "How do organisms grow and reproduce?" **~6 weeks**	**Bundle 3:** "How can we measure the flow of energy in a system?" **~6 weeks**	**Bundle 4:** "What is contributing to the rise in global temperature?" **~6 weeks**
	account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. **MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. **MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.		

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

Middle School Topics Model Course 1 Flowchart

Bundle 1

LS1.A as found in MS-LS1-1
- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).

LS1.A as found in MS-LS1-2
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.

LS1.A as found in MS-LS1-3
- 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.D as found in MS-LS1-8
- 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.

ETS1.A as found in MS-ETS1-1
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

Bundle 2

LS1.A as found in MS-LS1-3
- 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.B as found in MS-LS1-4
- Animals engage in characteristic behaviors that increase the odds of reproduction.
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.

LS1.B as found in MS-LS1-5
- Genetic factors as well as local conditions affect the growth of the adult plant.

LS1.B as found in MS-LS3-2
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.

LS1.D as found in MS-LS1-8
- 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.

LS3.A as found in MS-LS3-2
- Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.

LS3.B as found in MS-LS3-2
- In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

ETS1.A as found in MS-ETS1-1
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

ETS1.B as found in MS-ETS1-2 and MS-ETS1-3
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

ETS1.B as found in MS-ETS1-4
- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
- Models of all kinds are important for testing solutions.

Bundle 3

PS3.A as found in MS-PS3-3 and MS-PS3-4
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B as found in MS-PS3-3
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

PS3.B as found in HS-PS3-4
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.

PS3.B as found in HS-PS3-5
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.

ETS1.A as found in MS-PS3-3
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.

ETS1.B as found in MS-PS3-3
- A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.

ETS1.B as found in MS-ETS1-3
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

ETS1.C as found in MS-ETS1-3
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.

Bundle 4

ESS2.C as found in MS-ESS2-4
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- Global movements of water and its changes in form are propelled by sunlight and gravity.

ESS2.C as found in MS-ESS2-5
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

ESS2.C as found in MS-ESS2-6
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

ESS2.D as found in MS-ESS2-5
- Because these patterns are so complex, weather can only be predicted probabilistically.

ESS2.D as found in MS-ESS2-6
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

ESS3.C as found in MS-ESS3-3
- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ESS3.D as found in MS-ESS3-5
- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

ETS1.B as found in MS-ETS1-2
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

ETS1.B as found in MS-ETS1-3

- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

ETS1.C as found in MS-ETS1-3

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.

ETS1.C as found in MS-ETS1-4

- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Middle School Topic Model Course II – Bundle 1
Properties of Matter

This is the first bundle of the Middle School Topics Model Course II. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "what causes changes in matter?"

Summary

The bundle organizes performance expectations with a focus on helping students begin to understand *properties of matter*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Each pure substance has characteristic physical and chemical properties that can be used to identify it (PS1.A as in MS-PS1-2 and MS-PS1-3). This idea connects to the concepts that substances can be classified as gases, liquids, or solids. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide (PS1.A as in MS-PS1-4). Solids may be formed from molecules, or they may be extended structures with repeating subunits (PS1.A as in MS-PS1-1). Changes of state can occur with variations in temperature or pressure and can be described and predicted (PS1.A as in MS-PS1-4). Consequently, the state, the temperature, and the total number of atoms in the system all determine the total thermal energy of a system (PS3.A as in MS-PS1-4).

Substances are made from different types of atoms, which combine with one another in various ways (PS1.A as in MS-PS1-1). However, the total number of each type of atom is conserved, and thus the mass does not change (PS1.B as in MS-PS1-5). These ideas connect to the concept that when substances react chemically, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants (PS1.B as in MS-PS1-2, MS-PS1-3, and MS-PS1-5). Some chemical reactions release energy, others store energy (PS1.B as in MS-PS1-6). These ideas about chemical reactions in the physical sciences connect closely to their application in the life sciences; within organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy (LS1.C as in MS-LS1-7). One example is cellular respiration, which involves chemical reactions with oxygen that release stored energy (PS3.D as in MS-LS1-7).

The engineering design ideas that sometimes, parts of different solutions may be incorporated into a new design based on the characteristics of the design that performed the best in each test (ETS1.B and ETS1.C as in MS-PS1-6 and MS-ETS1-3) could connect to many science ideas, such as how heat refers to the energy transferred due to the temperature difference between two objects (PS3.A as in MS-PS1-4), or how food moves through a series of chemical reactions in which it is broken down and rearranged to support growth (LS1.C as in MS-LS1-7). Connections could be made through engineering design tasks such as identifying the best characteristics of various designs for insulating a house or developing simulations of various feed rations for cattle.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing models (MS-PS1-1, MS-PS1-4, MS-PS1-5, and MS-LS1-7), analyzing and interpreting data (MS-PS1-2 and MS-ETS1-3), designing solutions (MS-PS1-6), and obtaining, evaluating, and communicating information (MS-PS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-PS1-2), Cause and

Effect (MS-PS1-4), Scale, Proportion, and Quantity (MS-PS1-1), Energy and Matter (MS-PS1-5, MS-PS1-6, and MS-LS1-7), and Structure and Function (MS-PS1-3). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations MS-PS1-1 and MS-LS1-7 are partially assessable.	MS-PS1-1. **Develop models to describe the atomic composition of simple molecules and extended structures.** [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.] MS-PS1-2. **Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.** [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [Assessment Boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.] MS-PS1-3. **Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.** [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Assessment is limited to qualitative information.] MS-PS1-4. **Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.** [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.] MS-PS1-5. **Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.** [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.] MS-PS1-6. **Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*** [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.] MS-LS1-7. **Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.** [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.] MS-ETS1-3. **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.**

Example Phenomena	Before a big race, game, or meet, athletes often eat lots of pasta and starchy foods. Aerosol cans can explode if left in a hot car.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation to clarify* [how] ***changes of state occur with variations in temperature or pressure***. MS-PS1-4 **Developing and Using Models** • Develop and/or use a model to describe phenomena. Students could *develop a model to describe* [that when combining two substances, the resulting] ***new substances*** [can] ***have different properties from those of the reactants***. MS-PS1-2 **Planning and Carrying Out Investigations** • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *evaluate and revise an experimental design* [intended to] *serve as the basis for evidence* [that] ***each pure substance has characteristic physical and chemical properties that can be used to identify it.*** MS-PS1-2 **Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data to provide evidence* [that] ***the mass does not change*** [during chemical reactions]. MS-PS1-5 **Using Mathematical and Computational Thinking** • Use mathematical representations to describe and/or support scientific conclusions and design solutions. Students could *use mathematical representations to support conclusions* [that, after a chemical reaction, the] ***new substances*** [formed] ***have different properties from those of the reactants***. MS-PS1-2, MS-PS1-3, and MS-PS1-5 **Constructing Explanations and Designing Solutions** • 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. Students could *construct a scientific explanation based on valid and reliable evidence* [about how organisms get energy from food, including that] ***food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy***. MS-LS1-7

Additional Practices Building to the PEs (Continued)	**Engaging in Argument from Evidence** • Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could *respectfully provide and receive critiques by citing relevant evidence and posing and responding to questions about models* [of how] ***chemical reactions of food supports growth***. MS-LS1-7 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). Students could *critically read scientific texts adapted for classroom use to obtain scientific information about the pattern* [that] ***solids may be formed from molecules, or they may be extended structures with repeating subunits***. MS-PS1-1
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Patterns can be used to identify cause and effect relationships. Students could analyze data on *patterns* [of] ***chemical reactions*** [that] ***release energy*** [versus**]** ***others that store energy*** *to identify cause and effect relationships*. MS-PS1-6 **Scale, Proportion, and Quantity** • Phenomena that can be observed at one scale may not be observable at another scale. Students could support claims with evidence [that] ***the motion of atoms or molecules within a substance*** *may not be observable at* [the macroscopic] *scale*, [but that] ***thermal energy*** *is observable at* [the macroscopic] *scale*. MS-PS1-4 **Structure and Function** • Complex natural and designed structures/systems can be analyzed to determine how they function. Students could describe evidence that *complex designed systems can be analyzed to determine how they function*, [including that the] ***chemical reactions*** [used in design solutions that] ***release energy*** [can be analyzed to determine how they contribute to the function of the design system]. MS-PS1-6 and MS-ETS1-3
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Theories are explanations for observable phenomena. Students could construct an argument that *theories are explanations*, [using as evidence the theory that] ***gases and liquids are made of molecules or inert atoms that are moving about relative to each other and that in a solid, atoms are closely spaced and may vibrate in position but do not change relative locations***. MS-PS1-4 **Science is a Way of Knowing** • Science knowledge is cumulative and many people, from many nations, have contributed to science knowledge. Students could obtain, evaluate, and communicate information about how *science knowledge is cumulative and many people have contributed to science knowledge*, [including knowledge about how] ***each pure substance has characteristic physical and chemical properties that can be used to identify it***. MS-PS1-2 and MS-PS1-3

Middle School Topic Model Course II – Bundle 2
Interactions Within Ecosystems

This is the second bundle of the Middle School Topics Model Course II. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 2 Question: This bundle is assembled to address the question "how do organisms and ecosystems interact?"

Summary

The bundle organizes performance expectations with a focus on helping students begin to understand interactions within ecosystems. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Ecosystems are dynamic in nature. Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and nonliving factors (LS2.A as in MS-LS2-1). Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations, (LS2.C as in MS-LS2-4) affecting biodiversity. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health (LS2.C as in MS-LS2-5). Changes in biodiversity can also influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on (LS4.D as in MS-LS2-5).

In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction (LS2.A as in MS-LS2-1). Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival (LS2.A as in MS-LS2-2) as shown through food webs, which are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Matter and energy transferring connects to the idea that the atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem (LS2.B as in MS-LS2-3), which in turn connects to how plants, algae, and many microorganisms use the process of photosynthesis (LS1.C as in MS-LS1-6). This chemical reaction requires an energy input (i.e., from sunlight), combining carbon dioxide and water to form carbon-based organic molecules and oxygen (PS3.D as in MS-LS1-6), which are used by consumers in the food web.

The engineering design idea that the more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful (ETS1.A as in MS-ETS1-1) could connect to many different science concepts, including how plants, algae, and many microorganisms use the energy from light to make sugars from carbon dioxide and water through the process of photosynthesis, which also releases oxygen (LS1.C as in MS-LS1-6), or to how disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations (LS2.C as in MS-LS2-4). Connections could be made through engineering design tasks such as defining the criteria and constraints for using algae or other microorganisms to produce biofuels, or for minimizing disruptions to physical components of an ecosystem by minimizing soil erosion or runoff from a waste treatment plant.

The engineering design idea that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-2) could connect to many different science concepts, including how plants, algae, and many microorganisms use the energy from light to make sugars from carbon dioxide and water through the process of photosynthesis (LS1.C as in MS-LS1-6), or how disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations (LS2.C as in MS-LS2-4). Connections could be made through engineering design tasks such as evaluating how well solutions meet the identified criteria and constraints for how well various plants work in making biofuels or for how well a local wildlife sanctuary or highway minimizes the impact on organisms.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (MS-ETS1-1), developing models (MS-LS2-3), analyzing and interpreting data (MS-LS2-1), constructing explanations (MS-LS1-6 and MS-LS2-2), and engaging in argument (MS-LS2-4, MS-LS2-5, and MS-ETS1-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-LS2-2), Cause and Effect (MS-LS2-1), Energy and Matter (MS-LS1-6 and MS-LS2-3), and Stability and Change (MS-LS2-4 and MS-LS2-5). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-LS1-6. **Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.** [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.] MS-LS2-1. **Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.** [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.] MS-LS2-2. **Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.** [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.] MS-LS2-3. **Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.** [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.] MS-LS2-4. **Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.** [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.] MS-LS2-5. **Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*** [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.] MS-ETS1-1. **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.** MS-ETS1-2. **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**

Example Phenomena	Goldfish grow larger in ponds than in fish tanks. Cows can survive and grow only eating grass and drinking water.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to determine relationships between independent and dependent variables and relationships in models. Students could *ask questions to determine relationships between* ***the atoms that make up*** [one part of] ***an ecosystem and the atoms that make up*** [another part of the] ***ecosystem***. MS-LS2-3 **Developing and Using Models** • Develop a model to describe unobservable mechanisms. Students could *develop a model to describe* [that] ***plants, algae, and many microorganisms use the energy from light to make sugars from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen***. MS-LS1-6 **Planning and Carrying Out Investigations** • Collect data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. Students could co*llect data to serve as the basis for evidence* [that] ***organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors***. MS-LS2-1 **Analyzing and Interpreting Data** • Distinguish between causal and correlational relationships in data. Students could *distinguish between causal and correlational relationships in data* [on] ***mutually beneficial interactions in ecosystems***. MS-LS2-2 **Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use digital tools to analyze very large data sets for patterns and trends* [related to the dependence of] ***organisms on their environmental interactions both with other living things and with nonliving factors***. MS-LS2-1 **Constructing Explanations and Designing Solutions** • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. Students could *undertake a design project that meets specific design criteria and constraints* [for a solution to the problem that] ***disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations***. MS-LS2-4

Additional Practices Building to the PEs (Continued)	**Engaging in Argument from Evidence** • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. Students could compare and critique two arguments [for how] ***changes in biodiversity can influence humans' resources,*** and analyze whether the arguments emphasize similar or different evidence. MS-LS2-5 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to obtain scientific and/or technical information to describe evidence about the natural and designed world(s). Students could *critically read scientific texts to obtain scientific information to describe evidence* [that] ***in any ecosystem, organisms and populations with similar requirements for food, water, oxygen, and other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction***. MS-LS2-1
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Students could evaluate scientific information about *relationships* [between] ***changes in biodiversity*** [and] ***humans' resources*** to determine if *the relationship can be classified as causal or correlational*. MS-LS2-5 **Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Students could develop and use a *model to represent systems and their inputs, process, and outputs* as ***energy and matter is transferred between producers, consumers, and decomposers in ecosystems***. MS-LS2-3 **Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could obtain, evaluate, and communicate information about how *stability* [of an] ***ecosystem*** *might be disturbed by sudden events*, [including by] ***predatory interactions of organisms***. MS-LS2-2
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence** • Science disciplines share common rules of obtaining and evaluating empirical evidence. Students could construct an argument for how *science disciplines share common rules of obtaining and evaluating empirical evidence* [using as an example the rules biologists use to] ***measure the health of an ecosystem***. MS-LS2-5 **Science is a Way of Knowing** • Science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge. Students could obtain, evaluate, and communicate information for how *science knowledge is cumulative and many people, from many generations and nations, have contributed to* [knowledge of how] ***disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations***. MS-LS2-4

Middle School Topic Model Course II – Bundle 3
Geologic Changes to the Earth

This is the third bundle of the Middle School Topics Model Course II. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "how has the Earth changed?"
Summary The bundle organizes performance expectations with a focus on helping students begin to understand geologic changes that take place on Earth. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations. **Connections between bundle DCIs** Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources that are distributed unevenly around the planet as a result of past geologic processes (ESS3.A as in MS-ESS3-1). This concept connects to the idea that Earth's plates have moved great distances, collided, and spread apart (ESS2.A as in MS-ESS2-3). All Earth processes, including the movement of plates, are the result of energy flowing and matter cycling within and among the planet's systems, shaping Earth's history (ESS2.A as in MS-ESS2-2). This idea connects to the concept that the energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms (ESS2.A as in MS-ESS2-1), and also that water's movements cause weathering and erosion, which can further change the land's surface features and create underground formations (ESS2.C as in MS-ESS2-2). Understanding the history of natural hazards and related geologic forces can help forecast the locations and likelihoods of future events (ESS3.B as in MS-ESS3-2). The engineering design idea that the iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution (ETS1.C as in MS-ETS1-4) could connect to many science ideas, including that water's movements cause weathering and erosion (ESS2.C as in MS-ESS2-2) or that mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events (ESS3.B as in MS-ESS3-2). Connections could be made through engineering design tasks such as testing and refining a solution for minimizing the effects of water on soil erosion in a housing development, or modifying solutions for forecasting tornados. **Bundle Science and Engineering Practices** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-ESS2-1 and MS-ETS1-4), analyzing and interpreting data (MS-ESS2-3 and MS-ESS3-2), and constructing scientific explanations (MS-ESS2-2 and MS-ESS3-1). Many other practice elements can be used in instruction. **Bundle Crosscutting Concepts** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-ESS2-3 and MS-ESS3-2), Cause and Effect (MS-ESS3-1), Scale, Proportion, and Quantity (MS-ESS2-2), and Stability and Change (MS-ESS2-1). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*

Performance Expectations	MS-ESS2-1. **Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.** [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [Assessment Boundary: Assessment does not include the identification and naming of minerals.] MS-ESS2-2. **Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.] MS-ESS2-3. **Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.** [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.] MS-ESS3-1. **Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.** [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).] MS-ESS3-2. **Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.** [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado prone regions or reservoirs to mitigate droughts).] MS-ETS1-4. **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.**
Example Phenomena	Fossils of sea creatures can be found in areas that are thousands of miles away from an ocean. Oil wells can be found in some states but not others.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that require sufficient and appropriate empirical evidence to answer. Students could *ask questions that require sufficient and appropriate empirical evidence* [about how] ***maps of ancient land and water patterns make clear how Earth's plates have moved great distances, collided, and spread apart***. MS-ESS2-3

Additional Practices Building to the PEs (Continued)	**Developing and Using Models** • Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. Students could *modify a model based on evidence* [about how] ***water's movements cause weathering and erosion, which change the land's surface features and create underground formations***. MS-ESS2-2 **Planning and Carrying Out Investigations** • Collect data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. Students could *collect data to serve as the basis for evidence* [that] ***mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events***. MS-ESS3-2 **Analyzing and Interpreting Data** • Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. Students could *use graphical displays of large data sets to identify temporal and spatial relationships* [between] ***the uneven distribution of resources around the planet and past geologic processes***. MS-ESS3-1 **Using Mathematical and Computational Thinking** • Use digital tools to test and compare proposed solutions to an engineering design problem. Students could *use digital tools to test and compare proposed solutions to a problem* [caused by] ***chemical and physical changes in Earth's materials due to the energy that flows and matter that cycles within and among the planet's systems***. MS-ESS2-1 **Constructing Explanations and Designing Solutions** • Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. Students could *apply scientific ideas to test a design of process* [for how] ***mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events***. MS-ESS3-2 **Engaging in Argument from Evidence** • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. Students could *evaluate competing design solutions based on jointly developed and agreed-upon design criteria* [for] ***forecasting the locations and likelihoods of future events***. MS-ESS3-2

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Gather, read, synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. Students could *gather, read, synthesize information from multiple sources and assess the credibility, accuracy, and possible bias of each publication* [about how] ***maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart***. MS-ESS2-3
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Patterns can be used to identify cause and effect relationships. Students could *use patterns to identify cause and effect relationships* [between] ***water's movements*** [and] ***erosion.*** MS-ESS2-2 **Scale, Proportion, and Quantity** • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Students could evaluate the limitations of a *model* [that makes use of the fact that] *time and space can be observed at various scales* [using] ***maps of ancient land and water patterns, making clear how Earth's plates have moved great distances, collided, and spread apart***. MS-ESS2-3 **Energy and Matter** • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. Students could obtain, evaluate, and communicate information about how *the transfer of energy drives the motion and/or cycling of matter* [and these] ***cycles produce chemical and physical changes in Earth's materials and living organisms***. MS-ESS2-1
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based on logical and conceptual connections between evidence and explanations. Students could construct an argument about how *science knowledge is based on logical and conceptual connections between evidence and explanations,* [including for how] ***Earth's plates have moved great distances, collided, and spread apart***. MS-ESS2-3 **Science is a Way of Knowing** • Science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge. Students could obtain, evaluate, and communicate information about how *science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge* [about how] ***mineral, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes.*** MS-ESS3-1

Middle School Topics Model Course III – Bundle 1
Forces and Energy

This is the first bundle of the Middle School Topics Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "How do objects affect other objects?"

Summary
The bundle organizes performance expectations with a focus on helping students build understanding of *how interactions between objects can be explained and predicted*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
This course includes a study of forces and energy, helping to prepare students to explain phenomena in later units on waves, mechanisms of diversity, and Earth's place in the Universe. Motion energy is called kinetic energy and it is proportional to the mass of the moving object and grows with the square of its speed (PS3.A as in MS-PS3-1). A system of objects may also contain stored energy, depending on their relative positions (PS3.A as in MS-PS3-2). When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object (PS3.C as in MS-PS3-2).

The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change (PS2.A as in MS-PS2-2). For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first but in the opposite direction (PS2.A as in MS-PS2-1) and all the positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and units of size (PS2.A as in MS-PS2-2).

Forces that act at a distance, such as electric, magnetic, and gravitational forces, can be explained by fields that extend through space (PS2.B as in MS-PS2-5). Electric and magnetic forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects (PS2.B as in MS-PS2-3). Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass (PS2.B as in MS-PS2-4) such as in our solar system. The solar system consists of the sun and a collection of objects that are held in orbit around the sun by its gravitational pull on them (ESS1.B as in MS-ESS1-2). Earth and its solar system formed from a disk of dust and gas, drawn together by gravity, (ESS1.B as in MS-ESS1-2) and is part of the Milky Way galaxy (ESS1.A as in MS-ESS1-2).

The engineering design idea that the more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful (ETS1.A as in MS-ETS1-1) could connect to many different science ideas, such as how kinetic energy is proportional to the mass of the moving object and grows with the square of its speed (PS3.A as in MS-PS3-1) or to the idea that electric and magnetic forces can be attractive or repulsive (PS2.B as in MS-PS2-3). Connections could be made through an engineering design task such as precisely defining the criteria and constraints for the relationship between size of motor vehicles and the distance needed to stop, for the relationship between size of an airplane and its speed, or for the design of an electromagnetic motor in a wind turbine or in a car.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions (MS-PS2-3); defining problems (MS-ETS1-1); developing and using models (MS-PS3-2 and MS-ESS1-2); planning and conducting investigations (MS-PS2-2 and MS-PS2-5); analyzing and interpreting data (MS-PS3-1); constructing explanations and designing solutions (MS-PS2-1); and engaging in argumentation (MS-PS2-4). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (MS-PS2-3 and MS-PS2-5); Scale, Proportion, and Quantity (MS-PS3-1); Systems and System Models (MS-PS2-1, MS-PS2-4, MS-PS3-2, and MS-ESS1-2); and Stability and Change (MS-PS2-2). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations MS-ESS1-2 is partially assessable.	MS-PS2-1. **Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*** [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.] MS-PS2-2. **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.] MS-PS2-3. **Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.** [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.] MS-PS2-4. **Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.** [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.] MS-PS2-5. **Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.** [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.] MS-PS3-1. **Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.** [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.] MS-PS3-2. **Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.** [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.]

Performance Expectations (Continued)	MS-ESS1-2. **Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.** [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.] MS-ETS1-1. **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.**
Example Phenomena	Iron filings make a pattern surrounding magnets. A ball released higher on a hill can push objects farther than can a ball released from lower on the hill.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions to seek additional information* [about how] ***the motion of an object is determined by the sum of the forces acting on it***. MS-PS2-2 **Developing and Using Models** • Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. Students could *modify a model based on* [new] *evidence* [about how] ***the force exerted by*** [one] ***object on a second object is equal in strength to the force that the second object exerts on the first.*** MS-PS2-1 **Planning and Carrying Out Investigations** • Evaluate the accuracy of various methods for collecting data. Students could *evaluate the accuracy of various methods for collecting data* [about how] ***when two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object***. MS-PS3-2 **Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data to provide evidence* [that the] ***sizes of electric and magnetic forces depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects***. MS-PS2-3 **Using Mathematical and Computational Thinking** • Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems. Students could *apply mathematical concepts and/or processes to engineering problems* [related to] ***relative positions*** [of] ***a system of objects with stored (potential) energy***. MS-PS3-2

Additional Practices Building to the PEs (Continued)	**Constructing Explanations and Designing Solutions** • Construct a scientific explanation based on valid and reliable evidence obtained from sources 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. Students could *construct a scientific explanation based on valid and reliable evidence* [that] ***the solar system appears to have formed from a disk of dust and gas, drawn together by gravity***. MS-ESS1-2 **Engaging in Argument from Evidence** • Compare and critique two arguments on the same tropic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. Students could *compare and critique two arguments and analyze whether they emphasize similar or different evidence* [for the claim that] ***a collection of objects*** [is] ***held in orbit around the sun by its gravitational pull on them***. MS-ESS1-2 **Obtaining, Evaluating, and Communicating Information** • Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings. Students could *integrate qualitative scientific information in written text with that contained in media and visual displays to clarify claims and findings* [about how] ***forces that act at a distance can be explained by fields that extend through space and can be mapped by their effect on a test object***. MS-PS2-5
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Patterns can be used to identify cause and effect relationships. Students could analyze data for *patterns* [that] *can be used to identify cause and effect relationships* [between] ***any pair of interacting objects,*** [such that] ***the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction***. MS-PS2-1 **Cause and Effect** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. Students could develop a model for how ***the motion of an object is determined by*** *more than one cause* [due to] ***the sum of the forces acting on it***. MS-PS2-2 **Scale, Proportion, and Quantity** • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Students could construct an argument that ***the solar system consists of the sun and a collection of objects***, [and] *can be observed at various scales using models to study systems that are too large to observe directly*. MS-ESS1-2

Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Laws are regularities or mathematical descriptions of natural phenomena. Students could describe an example of how Newton's second law uses *mathematical descriptions of natural phenomena* [related to] ***larger forces causing larger changes in motion***. MS-PS2-2 **Science is a Way of Knowing** • Science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge. Students could obtain, evaluate, and communicate information for how *people from many generations and nations have contributed to knowledge* [about how] ***a system of objects may contain stored (potential) energy, depending on their relative positions***. MS-PS3-2

Middle School Topics Model Course III – Bundle 2
Energy in Waves

This is the second bundle of the Middle School Topics Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "How do waves transfer energy and information?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of *how waves transfer energy and information*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle concepts

While applying energy concepts to waves, students will develop a deeper understanding of how waves work and their applications and influences on many facets of their lives. All waves have some features in common. A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude (PS4.A as in MS-PS4-1). Waves can be combined with other waves of the same type to produce complex information-containing patterns, and digitized signals are a more reliable way to encode and transmit information (PS4.C as in MS-PS4-3).

A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media (PS4.B as in MS-PS4-2). When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency of the light (PS4.B as in MS-PS4-2). The path that light travels can be traced as straight lines, except at surfaces between different transparent materials where the light path bends (PS4.B as in MS-PS4-2). However, because light can travel through space, it cannot be a matter wave, like sound or water waves (PS4.B as in MS-PS4-2), because a sound wave needs a medium through which it is transmitted (PS4.A as in MS-PS4-2).

The engineering design idea that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-2) could connect to many different science ideas, such as that an object's material and frequency affects whether light is reflected, absorbed, or transmitted through the object (PS4.B as in MS-PS4-2) or that digitized signals are a more reliable way to encode and transmit information (PS4.C as in MS-PS4-3). Connections could be made through an engineering design task such as evaluating the alignment between solutions (such as radios versus cell phones) and the criteria and constraints of problems, such as the need to transmit signals through various objects or over different distances.

Additionally, the engineering design ideas that models of all kinds are important for testing solutions (ETS1.B as in MS-ETS1-4) and the iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution (ETS1.C as in MS-ETS1-4) could connect to many different science ideas, such as how an object's material and frequency affects whether light is reflected, absorbed, or transmitted through the object (PS4.B as in MS-PS4-2), or how digitized signals are a more reliable way to encode and transmit information (PS4.C as in MS-PS4-3). Connections could be made through an engineering design task, such as using computer programs to model solutions for the color quality of pictures taken from digital cameras and cell phones or to iteratively test and improve the sound quality of hearing aids or musical instruments.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-PS4-2 and MS-ETS1-4); using mathematical representations (MS-PS4-1); engaging in argument (MS-ETS1-2); and obtaining, evaluating, and communicating information (MS-PS4-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-PS4-1) and Structure and Function (MS-PS4-2 and MS-PS4-3). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	MS-PS4-1. **Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.** [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.] MS-PS4-2. **Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.** [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.] MS-PS4-3. **Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.** [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.] MS-ETS1-2. **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.** MS-ETS1-4. **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.**
Example Phenomena	You can see rainbows by shining when through a prism. I can see and hear my favorite music and television shows using the internet.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to clarify and/or refine a model, an explanation, or an engineering problem. Students could *ask questions to refine a model* [for how] ***when light shines on an object, it is reflected, absorbed, or transmitted through the object***. MS-PS4-2 **Developing and Using Models** • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Students could *develop a model to show the relationships* [between the] ***wavelength, frequency, and amplitude*** [of a] ***wave***. MS-PS4-1 **Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, and how many data are needed to support a claim. Students could *plan an investigation* [to determine whether] ***digitized signals are a more reliable way to encode and transmit information*** [than are analog signals]. MS-PS4-3

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data to provide evidence for* [the] ***repeating pattern*** [of a] ***simple wave.*** MS-PS4-1 **Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use digital tools to analyze very large data sets for patterns and trends* [to determine whether] ***digital signals are a more reliable way to encode and transmit information*** [than are analog signals]**.** MS-PS4-3 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using representations* [of how] ***the path that light travels can be traced as straight lines, except at surfaces between different transparent materials where the light path bends***. MS-PS4-2 **Engaging in Argument from Evidence** • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. Students could *compare and critique two arguments* [for how] ***a wave model of light is useful for explaining brightnes****s and analyze whether they emphasize similar or different evidence*. MS-PS4-2 **Obtaining, Evaluating, and Communicating Information** • Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts. Students could *evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information* [about how] ***when light shines on an object, it is reflected, absorbed, or transmitted through the object***. MS-PS4-2
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems. Students could construct an argument from evidence for how the *cause and effect relationship* [between an] ***object's material and reflection, absorption, or transmission of light*** *may be used to predict a phenomenon*. MS-PS4-2 **Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Students could develop a model to *represent* ***frequency-dependent bending of light at a surface between media*** *as a system,* [including] *its inputs, processes, and outputs.* MS-PS4-2

Additional Crosscutting Concepts Building to the PEs (Continued)	**Stability and Change** • Small changes in one part of a system might cause large changes in another part. Students could obtain, evaluate, and communicate information [about how] *small changes in one part of a* ***digitized signal*** *(**sent as wave pulses**) might cause large changes in another part*. MS-PS4-3
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations. Students could construct an argument that *science knowledge is based on logical and conceptual connections between evidence and explanations*, [using as evidence scientists' understanding that] ***a wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media***. MS-PS4-2 **Science is a Human Endeavor** • Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination and creativity. Students could obtain and evaluate information about how *engineers rely on human qualities such as logic, imagination, and creativity*, [using as evidence how engineers have developed new ways to use] ***digitized signals to encode and transmit information***. MS-PS4-3

Middle School Topics Model Course III – Bundle 3
Mechanisms of Diversity

This is the third bundle of the Middle School Topics Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question "What makes organisms different from one another?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of *how there can be so many similarities among organisms and yet there is so much diversity*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Genetic variation of traits enables populations to change over time. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes or mutations to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits (LS3.A as in MS-LS3-1). Some changes are beneficial, others harmful, and some neutral to the organism (LS3.B as in MS-LS3-1).

In *artificial* selection, humans can choose desired parental traits determined by genes, which are then passed on to offspring (LS4.B as in MS-LS4-5) while changing environmental conditions cause adaptation by *natural* selection acting over generations (LS4.C as in MS-LS4-6). Natural selection leads to the predominance of certain traits in a population, and the suppression of others (LS4.B as in MS-LS4-4). Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common (LS4.C as in MS-LS4-6).

Collection of fossils and their placement in chronological order is known as the fossil record, which documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth (LS4.A as in MS-LS4-1). Comparison of the embryological development of different species (LS4.A as in MS-LS4-3) and anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent (LS4.A as in MS-LS4-2), showing how populations have changed over time.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-LS3-1); analyzing and interpreting data (MS-LS4-1 and MS-LS4-3); using mathematics and computational thinking (MS-LS4-6); constructing explanations and designing solutions (MS-LS4-2 and MS-LS4-4); and obtaining, evaluating, and communicating information (MS-LS4-5). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-LS4-2, MS-LS4-1, and MS-LS4-3); Cause and Effect (MS-LS4-4, MS-LS4-5, and MS-LS4-6); and Structure and Function (MS-LS3-1). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations MS-LS4-1 and MS-LS4-2 are partially assessable	MS-LS3-1. **Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.** [Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.] [Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.] MS-LS4-1. **Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.** [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.] MS-LS4-2. **Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.** [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.] MS-LS4-3. **Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.** [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.] MS-LS4-4. **Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.** [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.] MS-LS4-5. **Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.** [Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.] MS-LS4-6. **Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.** [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [Assessment Boundary: Assessment does not include Hardy Weinberg calculations.]
Example Phenomena	The first ears of corn in the wild were small and didn't have many kernels. There are hundreds of different breeds of dogs that vary in size, strength, temperament, and speed.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. Students could *ask questions to identify evidence* [for how] ***the fossil record documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.*** MS-LS4-1

Additional Practices Building to the PEs (Continued)	**Developing and Using Models** • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Students could *develop a model to show relationships* [between] ***species changing over time*** [and] ***changes in environmental conditions***. MS-LS4-6 **Planning and Carrying Out Investigations** • Evaluate the accuracy of various methods for collecting data. Students could *evaluate the accuracy of various methods for collecting data* [about how] ***humans influence certain characteristics of organisms by selective breeding***. MS-LS4-5 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). Students could *consider limitations of data analysis* [for data on the] ***differences between various organisms living today***. MS-LS4-2 **Using Mathematical and Computational Thinking** • Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems. Students could *apply mathematical concepts and processes* [to describe how] ***certain characteristics of organisms are influenced by selective breeding***. MS-LS4-5 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using models* [describing that] ***proteins affect the structures and functions of the organisms and thereby change traits***. MS-LS3-1 **Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. Students could *construct and present an oral argument supported by empirical evidence* [for how] ***mutations may result in changes to the structure and function of proteins***. MS-LS3-1

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). Students could *critically read scientific texts to obtain scientific information* [about how] ***the fossil record documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth***. MS-LS4-1
Additional Crosscutting Concepts Building to the PEs	**Scale, Proportion, and Quantity** • Phenomena that can be observed at one scale may not be observable at another scale. Students could construct an argument for how ***natural selection,*** [which] ***leads to the predominance of certain traits in a population, and the suppression of others,*** *can be observed at one scale*, [but] *may not be observable at another scale*. MS-LS4-4 **Systems and System Models** • Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Students could develop and use a model describing how ***adaptation by natural selection*** [may affect parts of ecosystems and these] *systems may interact with other systems*. MS-LS4-6 **Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could communicate ideas about how ***many life forms*** [have] ***changed throughout the history of life on Earth*** and [that these] ***life forms*** *might* [have been] *disturbed either by sudden events or gradual changes that accumulate over time*. MS-LS4-1
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations. Students could obtain, evaluate, and communicate information about how *science knowledge* about ***adaptation by natural selection*** *is based on logical and conceptual connections between evidence and explanations*. MS-LS4-6 **Science is a Way of Knowing** • Science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge. Students could obtain, evaluate, and communicate information about how *many people have contributed to science knowledge* about how ***each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual***. MS-LS3-1

Middle School Topics Model Course III – Bundle 4
Changing Earth

This is the fourth bundle of the Middle School Topics Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "What has the history of Earth looked like?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how Earth has evolved over time. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe (ESS1.A as in MS-ESS1-2). The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them (ESS1.B as in MS-ESS1-2, MS-ESS1-3). Models of the solar system can be used to explain patterns of the apparent motion of the sun, the moon, and stars in the sky (ESS1.A as in MS-ESS1-1) including eclipses of the sun and the moon, the Earth's spin axis, and seasons (ESS1.B as in MS-ESS1-1).

Earth and its solar system appear to have been formed from a disk of dust and gas, drawn together by gravity (ESS1.B as in MS-ESS1-2). The geologic time scale interpreted from rock strata provides a way to organize Earth's history, including its formation and the fossil record (ESS1.C as in MS-ESS1-4). The fossil record documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth (LS4.A as in MS-LS4-1). Similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent (LS4.A as in MS-LS4-2).

Earth is still changing today, and as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise (ESS3.C as in MS-ESS3-4). The engineering design ideas that there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-3) and that identifying the characteristics of the design that performed the best in each test can provide useful information for the new design (ETS1.C as in MS-ETS1-3) could connect to many different science ideas, such as that seasons are caused by the differential intensity of sunlight on different areas of Earth across the year (ESS1.B as in MS-ESS1-1), or that as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth (ESS3.C as in MS-ESS3-4). Connections could be made through evaluating solutions such as how to maximize energy capture of solar cells, maximize photosynthesis for plants based on the angle of a greenhouse roof, decrease the amount of human garbage that is generated each year, or develop alternative sources of energy to minimize the negative impacts on Earth.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-ESS1-1 and MS-ESS1-2); analyzing and interpreting data (MS-LS4-1, MS-ESS1-3, and MS-ETS1-3); constructing explanations (MS-LS4-2 and MS-ESS1-4); and engaging in argument (MS-ESS3-4). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-LS4-2, MS-LS4-1, and MS-ESS1-1); Cause and Effect (MS-ESS3-4); Scale, Proportion, and Quantity (MS-ESS1-3 and MS-ESS1-4); and Systems and System Models (MS-ESS1-2). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations MS-LS4-1 and MS-LS4-2 are partially assessable.	MS-LS4-1. **Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.** [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.] MS-LS4-2. **Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.** [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.] MS-ESS1-1. **Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.** [Clarification Statement: Examples of models can be physical, graphical, or conceptual.] MS-ESS1-2. **Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.** [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.] MS-ESS1-3. **Analyze and interpret data to determine scale properties of objects in the solar system.** [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.] MS-ESS1-4. **Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.** [Clarification Statement: Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of Earth's major events could range from being very recent (such as the last Ice Age or the earliest fossils of homo sapiens) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant volcanic eruptions.] [Assessment Boundary: Assessment does not include recalling the names of specific periods or epochs and events within them.] MS-ESS3-4. **Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.** [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.] MS-ETS1-3. **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.**
Example Phenomena	The island of Surtsey was formed in 1963 after a volcanic eruption from beneath the sea. Dinosaurs don't roam the Earth today.

Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. Students could *ask questions to identify evidence* [that] ***the fossil record documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth***. MS-LS4-1 **Developing and Using Models** • Develop a model to describe unobservable mechanisms. Students could *develop a model to describe* [that] ***typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth***. MS-ESS3-4 **Planning and Carrying Out Investigations** • Evaluate the accuracy of various methods for collecting data. Students could *evaluate the accuracy of various methods for collecting data* [on the effects of] ***gravity*** [on the] ***formation*** [of] ***the solar system***. MS-ESS1-2 **Analyzing and Interpreting Data** • Distinguish between causal and correlational relationships in data. Students could *distinguish between causal and correlational relationships in data* [on] ***the increase of per-capita consumption of natural resources and the increase of negative impacts on Earth***. MS-ESS3-4 **Using Mathematical and Computational Thinking** • Use mathematical representations to describe and/or support scientific conclusions and design solutions. Students could *use mathematical representations to support scientific conclusions* [about how] ***the seasons are caused by the differential intensity of sunlight on different areas of Earth across the year***. MS-ESS1-1 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using models or representations* [of how] ***the seasons are a result of the Earth's tilt relative to its orbit around the sun***. MS-ESS1-1 **Engaging in Argument from Evidence** • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretation of facts. Students could *critique two arguments and analyze whether they emphasize similar or different evidence* [about] ***anatomical similarities and differences between various organisms living today and organisms in the fossil record.*** MS-LS4-2

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). Students could *critically read texts to obtain scientific information* [about why scientists think that] ***the solar system consists of the sun and a collection of objects including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them***. MS-ESS1-2 and MS-ESS1-3
Additional Crosscutting Concepts Building to the PEs	**Systems and System Models** • Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Students could obtain and evaluate information about ***the Milky Way galaxy,*** [including that it] *may interact with other systems* [as well as] *have* [interacting] *sub-systems*. MS-ESS1-2 **Structure and Function** • Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function. Students could construct an explanation *to describe how the structure of* ***the solar system*** *can be analyzed to determine how it functions*. MS-ESS1-1 **Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could obtain, evaluate, and communicate information for how the *stability* [of Earth's systems] *might be disturbed either by sudden events or by gradual changes that accumulate over time* [when either] ***human populations*** [or] ***per-capita consumption of natural resources increase***. MS-ESS3-4
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific explanations are subject to revision and improvement in light of new evidence. Students could evaluate and communicate information about why *scientific explanations,* [such as that] ***solar system objects are held in orbit around the sun by its gravitational pull on them,*** *are subject to revision and improvement in light of new evidence*. MS-ESS1-2 and MS-ESS1-3 **Science is a Human Endeavor** • Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination and creativity. Students could construct an argument for why *scientists have relied on human qualities such as persistence, precision, reasoning, logic, imagination and creativity* [to help them explain] ***patterns of the apparent motion of the sun***. MS-ESS1-1

Middle School Topic Model Course III

Narrative and Rationale: This course model arranges the Performance Expectations (PEs) outline in the third year of the California Integrated Middle School Model into four different bundles of PEs using a topical arrangement. The disciplinary core ideas of each eighth grade standard were used in this model to arrange units into topics. The authors found that the 8th grade PEs fell naturally into the following topic areas: forces and energy, energy in waves, mechanisms of diversity, and the changing Earth. The bundle focused on forces and energy was placed early in the year so that students' understandings developed may be used to explain phenomena within later units on the topics of waves, mechanisms of diversity, and the cosmos.

It is important to note that the SEPs and CCCs described are intended as end-of-unit expectations and not curricular designations. Additional SEPs and CCCs should be used throughout instruction in each unit.

Unit 1: Forces and Energy: How do objects affect other objects? **~ 8 weeks**	**Unit 2:** Energy in Waves: How do waves transfer energy and information? **~ 4 weeks**	**Unit 3:** Mechanisms of Diversity: What makes organisms different from one another? **~ 9 weeks**	**Unit 4:** Changing Earth: What has the history of Earth looked like? **~ 8 weeks**
MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.* **MS-PS2-2.** Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. **MS-PS2-3.** Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. **MS-PS2-4.** Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. **MS-PS2-5.** Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. **MS-PS3-1.** Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. **MS-PS3-2.** Develop a model to describe that when the arrangement of objects	**MS-PS4-1.** Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. **MS-PS4-2.** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. **MS-PS4-3.** Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. **MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	**MS-LS3-1.** Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. **MS-LS4-1**. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.[1] **MS-LS4-2.** Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.[1] **MS-LS4-3.** Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evidence in the fully formed anatomy. **MS-LS4-4.** Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving	**MS-LS4-1.** Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.[1] **MS-LS4-2.** Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.[1] **MS-ESS1-1.** Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. **MS-ESS1-2.** Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system. **MS-ESS1-3.** Analyze and interpret data to determine scale properties of objects in the solar system. **MS-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.

Unit 1: Forces and Energy: How do objects affect other objects? **~ 8 weeks**	**Unit 2:** Energy in Waves: How do waves transfer energy and information? **~ 4 weeks**	**Unit 3:** Mechanisms of Diversity: What makes organisms different from one another? **~ 9 weeks**	**Unit 4:** Changing Earth: What has the history of Earth looked like? **~ 8 weeks**
interacting at a distance changes, different amounts of potential energy are stored in the system. **MS-ESS1-2.** Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.[1] **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.		and reproducing in a specific environment. **MS-LS4-5.** Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. **MS-LS4-6.** Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.	**MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. **MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

Middle School Topics Model Course 3 Flowchart

Bundle 1

PS2.A as found in MS-PS2-1
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

To ESS1.A in Bundle 4

PS2.A as found in MS-PS2-2
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

PS2.B as found in MS-PS2-3
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.

To ESS1.B in Bundle 4

PS2.B as found in MS-PS2-4
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.

PS2.B as found in MS-PS2-5
- Forces that act at a distance (electric and magnetic) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).

PS3.A as found in MS-PS3-1
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.

To ESS1.B in Bundle 4

PS3.A as found in MS-PS3-2
- A system of objects may also contain stored (potential) energy, depending on their relative positions.

PS3.C as found in MS-PS3-2
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Bundle 2

PS4.A as found in MS-PS4-1
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

PS4.A as found in MS-PS4-2
- A sound wave needs a medium through which it is transmitted.

PS4.B as found in MS-PS4-2
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

PS4.C as found in MS-PS4-3
- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

ETS1.B as found in MS-ETS1-2
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of problem.

ETS1.B as found in MS-ETS1-4
- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
- Models of all kinds are important for testing solutions.

ETS1.C as found in MS-ETS1-4
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Bundle 3

LS3.A as found in MS-LS3-1
- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

LS3.B as found in MS-LS3-1
- In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.

LS4.A as found in MS-LS4-1
- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.

LS4.A as found in MS-LS4-2
- Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.

LS4.A as found in MS-LS4-3
- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.

LS4.B as found in MS-LS4-4
- Natural selection leads to the predominance of certain traits in a population, and the suppression of others.

LS4.B as found in MS-LS4-5
- In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.

LS4.C as found in MS-LS4-6
- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Bundle 4

LS4.A as found in MS-LS4-1
- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.

LS4.A as found in MS-LS4-2
- Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.

ESS1.A as found in MS-ESS1-1
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

ESS1.A as found in MS-ESS1-2
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

ESS1.B as found in MS-ESS1-2 and MS-ESS1-3
- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.

ESS1.B as found in MS-ESS1-2
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

ESS1.B as found in MS-ESS1-1
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

ESS1.C as found in MS-ESS1-4
- The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.

ESS3.C as found in MS-ESS3-4
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ESS1.A as found in MS-ESS1-2

- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

ESS1.B as found in MS-ESS1-2

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

ETS1.A as found in MS-ETS1-1

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

ETS1.B as found in MS-ETS1-3

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

ETS1.C as found in MS-ETS1-3

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.

Middle School Topic Model Course II

Narrative and Rationale: This course model arranges the Performance Expectations (PEs) outlined in the second year of the California Integrated Middle School Model into three different bundles of PEs using a topical arrangement. The disciplinary core ideas (DCIs) of each PE were used in this model to arrange bundles that address the topics of the properties of matter, dynamic interactions within ecosystems, and geologic changes in the Earth. The DCIs build conceptually throughout the year; in particular, the study of properties of matter in Bundle One lays the foundation for a deeper understanding of matter flow in ecosystems and Earth processes in bundles two and three respectively. In addition, engineering design PEs are incorporated in each bundle throughout the year.

Throughout the year, students develop their proficiency in the middle school-level Science and Engineering Practices (SEPs) and Crosscutting Concepts (CCCs), building on a foundation of SEPs and CCCs from Course I in middle school. It is important to note that the SEPs and CCCs described are intended as end-of-instructional unit expectations and not curricular designations. Additional SEPs and CCCs should be used throughout instruction toward each bundle.

Unit 1: What causes changes in matter? **~ 10 weeks**	**Unit 2:** How do organisms and ecosystems interact? **~ 10 weeks**	**Unit 3:** How has the Earth changed? **~ 10 weeks**
MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.[1] **MS-PS1-2**. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. **MS-PS1-3**. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. **MS-PS1-4**. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. **MS-PS1-5**. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. **MS-PS1-6**. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.* **MS-LS1-7**. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [1] **MS-ETS1-3**. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	**MS-LS1-6**. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. **MS-LS2-1**. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. **MS-LS2-2**. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. **MS-LS2-3**. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. **MS-LS2-4**. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. **MS-LS2-5**. Evaluate competing design solutions for maintaining biodiversity and ecosystem services. **MS-ETS1-1**. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. **MS-ETS1-2**. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	**MS-ESS2-1**. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. **MS-ESS2-2**. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. **MS-ESS2-3**. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions. **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **MS-ESS3-2**. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. **MS-ETS1-4**. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

Middle School Topic Model Course II Flowchart

Bundle 1

To ESS3.A in Bundle 3

PS1.A as found in MS-PS1-1

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

To ESS2.A in Bundle 3

PS1.A as found in MS-PS1-4

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

PS1.A as found in MS-PS1-2 and MS-PS1-3

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

PS1.B as found in MS-PS1-2, MS-PS1-3, and MS-PS1-5

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

PS1.B as found in MS-PS1-5

- The total number of each type of atom is conserved, and thus the mass does not change.

To ESS2.A in Bundle 3

PS1.B as found in MS-PS1-6

- Some chemical reactions release energy, others store energy.

To ESS2.A in Bundle 3

PS3.A as found in MS-PS1-4

- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material.

Bundle 2

PS3.D as found in MS-LS1-6

- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.

LS1.C as found in MS-LS1-6

- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

LS2.A as found in MS-LS2-1

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
- Growth of organisms and population increases are limited by access to resources.

LS2.A as found in MS-LS2-2

- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

LS2.B as found in MS-LS2-3

- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

LS2.C as found in MS-LS2-4

- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

LS2.C as found in MS-LS2-5

- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

Bundle 3

ESS1.C as found in MS-ESS2-3

- Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches.

ESS2.A as found in MS-ESS2-1

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.

ESS2.A as found in MS-ESS2-2

- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

ESS2.B as found in MS-ESS2-3

- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.

ESS2.C as found in MS-ESS2-2

- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

ESS3.A as found in MS-ESS3-1

- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

ESS3.B as found in MS-ESS3-2

- Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

ETS1.B as found in MS-ETS1-4

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
- Models of all kinds are important for testing solutions.

PS3.D as found in MS-LS1-7
- Cellular respiration in plants and animals involve 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.

To PS3.D , LS1.C, and LS2.B in Bundle 2

LS1.C as found in MS-LS1-7
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.

To PS3.D , LS1.C, and LS2.B in Bundle 2

ETS1.B as found in MS-PS1-6
- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.

ETS1.B as found in MS-ETS1-3
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

ETS1.C as found in MS-PS1-6 and MS-ETS1-3
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process - that is, some of the characteristics may be incorporated into the new design.

ETS1.C as found in MS-PS1-6
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

LS4.D as found in MS-LS2-5
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

To ESS3.A in Bundle 3

ETS1.A as found in MS-ETS1-1
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

ETS1.B as found in MS-LS2-5 and MS-ETS1-2
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

ETS1.C as found in MS-ETS1-4
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

High School Conceptual Progressions Model Course 2

Narrative and Rationale: This model course map is the second course in a three-year course sequence. It uses a customized version of the High School Conceptual Progressions model from NGSS Appendix K as the instructional year end goals. The PEs from Course 2 were then arranged into five different bundles of PEs based on a conceptual flow throughout the year.

Course 2 begins by expanding upon what was learned in Course 1 about matter and energy by taking a deeper look into matter and energy in the universe, then on Earth, and finally within organisms. The course then focuses on how organisms and their body systems maintain stability, and finally on the structure of DNA and how an organism's genetic traits are determined, as well as the environmental influences on the expression of those traits.

It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations – additional practices and crosscutting concepts should be used throughout instruction in each bundle.

Bundle 1: Matter and Energy in the Universe **~6 Weeks**	**Bundle 2:** Matter and Energy in the Environment **~6 Weeks**	**Bundle 3:** Matter and Energy in Organisms **~5 Weeks**	**Bundle 4:** Stability in Body Systems **~3 Weeks**	**Bundle 5:** Inheritance of Genetic Variation **~4 Weeks**
HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. **HS-PS2-4.** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.[1] **HS-PS3-5.** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. **HS-ESS1-1.** Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. **HS-ESS1-3.** Communicate scientific ideas about the way stars, over their life cycle, produce elements.	**HS-LS2-4.** Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. **HS-ESS2-1.** Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. **HS-ESS2-2.** Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. **HS-ESS2-4.** Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. **HS-ESS2-5.** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. **HS-ESS2-6.** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	**HS-PS4-4.** Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. **HS-LS1-6.** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. **HS-LS1-7.** Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. **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. **HS-LS2-5.** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.	**HS-LS1-2.** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. **HS-LS1-3.** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. **HS-LS1-4.** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	**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. **HS-LS3-1.** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. **HS-LS3-2.** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. **HS-LS3-3.** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Bundle 1: Matter and Energy in the Universe **~6 Weeks**	**Bundle 2:** Matter and Energy in the Environment **~6 Weeks**	**Bundle 3:** Matter and Energy in Organisms **~5 Weeks**	**Bundle 4:** Stability in Body Systems **~3 Weeks**	**Bundle 5:** Inheritance of Genetic Variation **~4 Weeks**
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.	**HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	**HS-ETS1-4.** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.		

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

High School Conceptual Progressions Model Course 2 Flowchart

Bundle 1

PS1.C as found in HS-PS1-8

- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.

To ESS2.D in Bundle 2

PS2.B as found in HS-PS2-4

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

To LS1.C in Bundle 3

PS3.C as found in HS-PS3-5

- When two objects interacting through a field change relative position, the energy stored in the field is changed.

PS3.D as found in HS-ESS1-1

- Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.

To PS3.D and PS4.B in Bundle 3

ESS1.A as found in HS-ESS1-1

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

ESS1.A as found in HS-ESS1-3

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

ETS1.B as found in HS-ETS1-3

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Bundle 2

LS2.B as found in HS-LS2-4

- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.

ESS1.B as found in HS-ESS2-4

- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.

ESS2.A as found in HS-ESS2-4

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.A as found in HS-ESS2-1 and HS-ESS2-2

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.B as found in HS-ESS2-1

- Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. *(ESS2.B Grade 8 GBE)*

ESS2.C as found in HS-ESS2-5

- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

Bundle 3

PS3.D as found in HS-LS2-5

- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.

PS4.B as found in HS-PS4-4

- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.

LS1.C as found in HS-LS1-6

- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.

LS1.C as found in HS-LS1-6 and HS-LS1-7

- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

LS1.C as found in HS-LS1-7

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

LS2.B as found in HS-LS2-3

- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.

LS2.B as found in HS-LS2-5

- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

ETS1.B as found in HS-ETS1-4

- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.

Bundle 4

LS1.A as found in HS-LS1-2

- 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 as found in HS-LS1-3

- 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.

LS1.B as found in HS-LS1-4

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.

ETS1.A as found in HS-ETS1-1

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Bundle 5

LS1.A as found in HS-LS1-1

- Systems of specialized cells within organisms help them perform the essential functions of life.

LS1.A as found in HS-LS1-1 and HS-LS3-1

- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.

LS3.A as found in HS-LS3-1

- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

LS3.B as found in HS-LS3-2

- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.

LS3.B as found in HS-LS3-2 and HS-LS3-3

- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.

ESS2.D as found in HS-ESS2-2 and HS-ESS2-4

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

To PS4.B in Bundle 3

ESS2.D as found in HS-ESS2-6

- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

To LS2.B in Bundle 3

ETS1.C as found in HS-ETS1-2

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

High School Conceptual Progressions Model Course 1 - Bundle 1
Interactions Between Objects (Macroscopic)

This is the first bundle of the High School Conceptual Progressions Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "How do objects such as moons and satellites orbit the sun and/or planets such as the Earth?"
Summary The bundle organizes performance expectations with a focus on helping students understand *how objects move and interact*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations. **Connections between bundle DCIs** The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation that still fills the universe (ESS1.A as in HS-ESS1-2). The measured composition of stars and the movements of different galaxies connect the ideas of an atom's emission and absorption of characteristic frequencies of light (PS4.B as in HS-ESS1-2) with the idea that the study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth (ESS1.A as in HS-ESS1-2, HS-ESS1-3). Concepts related to the movement of different galaxies (PS4.B as in HS-ESS1-2) connect to the ideas of forces at a distance are explained by fields (PS2.B as in HS-PS2-4). These ideas of force then connect to concepts of Kepler's laws, which describe common features of the motions of orbiting objects, including their elliptical paths around the sun (ESS1.B as in HS-ESS1-4). Also, these ideas connect to the concept that Newton's second law accurately predicts changes in the motion of macroscopic objects (PS1.A as in HS-PS2-1). **Bundle Science and Engineering Practices** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of using models (HS-PS2-1); using mathematical representations (HS-PS2-4 and HS-ESS1-4); and constructing an explanation (HS-ESS1-2). Many other practice elements can be used in instruction. **Bundle Crosscutting Concepts** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-PS2-4), Cause and Effect (HS-PS2-1), Scale, Proportion, and Quantity (HS-ESS1-4), and Energy and Matter (HS-ESS1-2). Many other CCC elements can be used in instruction. *All instruction should be three-dimensional.*

Performance Expectations HS-PS2-4 is partially assessable	HS-PS2-1. **Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.** [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.] HS-PS2-4. **Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.] HS-ESS1-2. **Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).] HS-ESS1-4. **Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]
Example Phenomena	The moon is not observed in the same place in the sky at the same time or in the same way every night. Satellites in orbit do not regularly come crashing down to the surface of the Earth.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Students could *ask questions to clarify the* [cause and effect relationship between] ***the motions of orbiting objects and the gravitational effects from, or collisions with, other objects in the solar system***. HS-PS2-4 and HS-ESS1-4 **Developing and Using Models** • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. Students could *use a [computer] model or develop a drawn model* to ***describe common features of the motions of orbiting objecting, including their elliptical paths around the sun or show how orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system***. HS-ESS1-4 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *plan and carry out an investigation [including] making a directional hypothesis* ***predicting changes in the motion of macroscopic objects***. HS-PS2-1 **Analyzing and Interpreting Data** • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. Students could *evaluate the impact of new data on a working explanation and/or model* [used] ***to predict the motion of orbiting objects in the solar system due to the effects of gravitational forces***. HS-PS2-4 and HS-ESS1-4

Additional Practices Building to the PEs (Continued)	**Using Mathematical and Computational Thinking** • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Students could *apply techniques of algebra and functions to represent and solve scientific problems* [related to] ***the Big Bang theory*** [which is supported by] ***astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe***. HS-ESS1-2 **Constructing Explanations and Designing Solutions** • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. Students could *evaluate and/or refine a solution to a complex real-world problem* [by] ***describing common features of the motions of orbiting objects, including their elliptical paths around the sun and how their orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system***. HS-PS2-1, HS-PS2-4, and HS-ESS1-4 **Engaging in Argument from Evidence** • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. Students could *evaluate the claims, evidence, and/or reasoning* [for how] ***the Big Bang Theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation that still fills the universe***. HS-ESS1-2 **Obtaining, Evaluating, and Communicating Information** • 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). Students could *communicate scientific and/or technical information in multiple formats* [for how] ***stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earths.*** HS-ESS1-2
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Students could analyze ***changes in the motion of macroscopic objects such as the motion of orbiting objects in the solar system*** [to determine if an] *explanation at one scale may fail or need revision when* [compared to a different] *scale*. HS-PS2-1 and HS-ESS1-4

Additional Crosscutting Concepts Building to the PEs (Continued)	**Cause and Effect** • 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. Students could analyze and interpret data about the *cause and effect relationships* [between objects] *at a smaller scale* ***to predict the motion of orbiting objects, including their elliptical paths around the sun or how orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system***. HS-ESS1-4 **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. Students could describe how *models can be used to simulate systems and interactions within and between systems at different scales* [for how] ***Newton's law of gravitation*** *provides the mathematical model to* ***describe and predict*** *the effects of* ***gravitational forces*** *between distant objects.* HS-PS2-4
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods (SEP):** • Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge. Students could *obtain, evaluate, and communicate information* about *how scientific methods, tools, and techniques used* to gather ***observations [empirical evidence] to support the Big Bang Theory*** [have changed over time, enabling scientists to come to their current understandings]. HS-ESS1-2 **Science is a Way of Knowing (CCC):** • Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time. Students could ask questions about how *science knowledge has changed over time* [about how] ***Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun.*** HS-ESS1-4

High School Conceptual Progressions Model Course 1 - Bundle 2
Electrical Forces and Matter or Interactions Between Particles

This is the second bundle of the High School Conceptual Progressions Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 2 Question: This bundle is assembled to address the question of "How do substances combine or react to make new substances?

Summary

The bundle organizes performance expectations with a focus on helping students understand *how substances combine or react to make new substances.* Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons (PS1.A as in HS-PS1-1). This idea of a substructure connects to the periodic table by the way it orders elements horizontally by the number of protons in the atom's nucleus (PS1.A as in HS-PS1-1, HS-PS1-2). The charged substructure of an atom also connects to the concepts of attraction and repulsion between electric charges at the atomic scale (PS2.B as in HS-PS2-6) and the idea that at the bulk scale, atomic structure and the electrical forces within and between atoms thus determines the structure and interactions of matter (PS1.A as in HS-PS1-3). Because atoms are conserved along with knowledge of the chemical properties of elements, chemical reactions can be described and predicted (PS1.B as in HS-PS1-2).

The idea that it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts when evaluating solutions (ETS1.B as in HS-ETS1-3) could connect to several bundle DCIs, such as how the attraction and repulsion between electric charges explain the structure, properties, and transformations of matter (PS2.B as in HS-PS2-6) and how the structure and interactions of matter are determined by electrical forces within and between atoms (PS1.A as in HS-PS1-3). Because engineers match the best material to meet the design criteria and constraints (ETS1.B as in HS-ETS1-3), connections could be made through an engineering design task such as selecting materials to design insulation for a building or food storage for maximum energy conservation or selecting materials to design a roller coaster or car for maximum safety and longevity.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of using models (HS-PS1-1), planning and conducting an investigation (HS-PS1-3), constructing and revising an explanation (HS-PS1-2, HS-ETS1-3), and communicating scientific and technical information (HS-PS2-6). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-PS1-1, HS-PS1-2, HS-PS1-3) and Structure and Function (HS-PS2-6). Many other CCC elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations HS-PS2-6 and HS-ETS1-3 are partially assessable	HS-PS1-1. **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.] HS-PS1-2. **Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.] HS-PS1-3. **Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.] HS-PS2-6. **Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.] HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.**
Example Phenomena	A glass bottle of water breaks when the water freezes. Diamond is hard and clear while graphite is soft, opaque, and gray.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Students could *ask questions that arise from examining **the periodic table** to seek additional information and [identify] relationships* for how the ***table orders elements and places those with similar chemical properties in columns*** [based on] ***patterns of outer electron states.*** HS-PS1-1 and HS-PS1-2 **Developing and Using Models** • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. Students could *develop multiple types of models to predict* [how] ***the periodic table orders elements and places those with similar chemical properties in columns.*** HS-PS1-1 and HS-PS1-2 **Planning and Carrying Out Investigations** • Plan an investigation or test a design individually or collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Students could *plan an investigation to produce data to build a model* for how ***the chemical properties of the elements involved in a chemical reaction can be described and used to predict a chemical reaction.*** HS-PS1-2

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. Students could *analyze data to identify characteristics of a proposed* [design solution that makes use of] the ***attraction and repulsion between electric charges at the atomic scale***. HS-PS2-6 **Using Mathematical and Computational Thinking** • Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.). Students could *apply unit conversions* [to compare how] ***the structure and interactions of matter at the bulk scale are*** [related to] ***electrical forces within and between atoms***. HS-PS1-3 **Constructing Explanations and Designing Solutions** • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. Students could *evaluate a solution to a complex real-world problem, based on scientific knowledge* [about the relationship between] ***the structure of matter at the bulk scale*** [and] ***electrical forces within and between atoms***. HS-PS1-3 **Engaging in Argument from Evidence** • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations, new evidence, limitations (e.g. trade-offs), constraints, and ethical issues. Students could *evaluate the evidence behind currently accepted explanations* [for how the] ***structure, properties, and transformations of matter are important in the functioning of designed materials***. HS-PS2-6 **Obtaining, Evaluating, and Communicating Information** • Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. Students could *evaluate the validity and reliability of claims that appear in scientific texts* [about how the] ***structure, properties, and transformations of matter are important in the functioning of designed materials***. HS-PS2-6

Additional Crosscutting Concepts Building to PEs	**Patterns** • Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Students could *analyze and interpret patterns of performance of* ***designed materials*** [that make use of the] ***properties, matter***. HS-PS2-6 **Energy and Matter** • The total amount of energy and matter in closed systems is conserved. Students could [describe atomic interactions in a] *closed system where energy and matter is conserved* and ***predict chemical reactions***. HS-PS1-2 **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. Students could ask questions [about how] *the functions and properties of atoms can be inferred from their overall structure*. HS-PS1-1
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena (SEP):** • Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. Students could describe how *models* [aided] *in the development* of their understanding ***for [how] the outcome of a simple chemical reaction [***is***] based on the outermost electron states of atoms.*** HS-PS1-1 and HS-PS1-2 **Scientific Knowledge is Based on Empirical Evidence (SEP):** • Hypotheses that have been tested have been developed through observations of natural phenomena. Students could [describe] *hypotheses* [that have been developed] *based on observations of natural phenomena* [for how] ***attraction and repulsion between electric charges at the atomic scale explains the structure, properties, and transformations of matter.*** HS-PS2-6

High School Conceptual Progressions Model Course 1 - Bundle 3
Forces, Energy, and Motion

This is the third bundle of the High School Conceptual Progressions Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 3 Question: *This bundle is assembled to address the question of "What is energy? How can one predict an object's continued motion, changes in motion, or stability?"*

Summary

The bundle organizes performance expectations with a focus on helping students understand the relationships between *energy, motion, changes in motion, and stability*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. (PS3.A as in HS-PS3-2; PS3.B as in HS-PS3-4; PS3.D as in HS-PS3-4). This concept of energy connects to ideas about energy from Earth's interior, and the outward flow of that energy due to thermal convection (ESS2.A as in HS-ESS2-3). The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle providing the primary source of heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection (ESS2.B as in HS-ESS2-3).

The concepts of motion and interactions of matter within a system connect to the idea of momentum and changes in momentum. (PS2.A as in HS-PS2-2). (PS2.A as in HS-PS2-2, HS-PS2-3).

Finally, an understanding of energy, motion, changes in motion, and stability is essential for the engineering of solutions to problems [about how] the total momentum of the system can change, but any change is balanced by changes in the momentum of objects outside the system (PS2.A as in HS-PS2-2, HS-PS2-3) and [about how] uncontrolled systems always evolve toward more stable states (PS3.B as in HS-PS3-4). Connections could be made through an engineering design task such as designing a car or a package to minimize the force on an object during a collision (PS2.A as in HS-PS2-3). Criteria and constraints include satisfying requirements set by society (ETS1.A as in HS-ETS1-1) and sometimes, criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others may be needed (ETS1.C as in HS-ETS1-2) such as reducing risk to humans traveling in a car or minimizing damage to a piece of artwork or a plant packaged in a box for shipment from one location to another.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (HS-ETS1-1), developing and using a model (HS-PS3-2, HS-ESS2-3), planning and conducting an investigation (HS-PS3-4), using mathematical representations (HS-PS2-2), and designing solutions (HS-PS2-3, HS-ETS1-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-PS2-3), Systems and System Models (HS-PS2-2, HS-PS3-4), and Energy and Matter (HS-PS3-2, HS-ESS2-3). Many other CCC elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations HS-ESS2-3, HS-ETS1-1, and HS-ETS1-2 are partially assessable.	HS-PS2-2. **Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.** [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.] HS-PS2-3. **Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*** [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.] HS-PS3-2. **Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).** [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.] HS-PS3-4. **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.] HS-ESS2-3. **Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.] HS-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**
Example Phenomena	When a baseball bat hits a baseball, both the bat and ball feel warmer. Cars have crumple zones.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. Students could *ask questions that can be investigated* [to support the claim that] ***if a system interacts with objects outside itself, any such change is balanced by changes in the momentum of objects outside the system***. HS-PS2-2 and HS-PS2-3 **Developing and Using Models** • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. Students could *evaluate merits and limitations of two different models* [for] ***the energy distribution*** [over time in] ***uncontrolled systems.*** HS-PS3-4

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Select appropriate tools to collect, record, analyze, and evaluate data. Students could [discuss how to collect data and what] *tools are necessary to collect, record, analyze, and evaluate data* [to support the claim that] ***if a system interacts with objects outside itself, any such change is balanced by changes in the momentum of objects outside the system***. HS-PS2-3 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. Students could *consider limitations of data analysis* [to support the claim that] ***if a system interacts with objects outside itself, any such change is balanced by changes in the momentum of objects outside the system.*** HS-PS2-3 **Using Mathematical and Computational Thinking** • Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. Students could *revise a computational model* [that describes that] ***motions of the mantle and its plates occur primarily through thermal convection.*** HS-ESS2-3 **Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *assess the extent to which reasoning and data support the explanation* [that] ***energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.*** HS-PS3-4 **Engaging in Argument from Evidence** • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economical, societal, environmental, ethical considerations). Students could *evaluate competing design solutions to a problem based on scientific ideas* [about how] ***energy can be converted to less useful forms such as thermal energy being released into the environment.*** HS-PS3-4 **Obtaining, Evaluating, and Communicating Information** • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. Students could *evaluate scientific information from multiple authoritative sources, assessing the evidence and usefulness of each source* [to describe how] ***the total momentum of a system can change if the system interacts with objects outside itself, but any such change is balanced by changes in the momentum of objects outside the system.*** HS-PS2-3

Additional Crosscutting Concepts Building to the PEs	**Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Students could describe the ***flow of energy (momentum, force, thermal***) within a variety of systems at *different scales*. HS-PS2-2, HS-PS2-3, HS-PS3-4, and HS-ESS2-3 **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. Students could *use models to simulate systems and interactions within and between systems* [for how] ***the radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection***. HS-ESS2-3 **Energy and Matter** • The total amount of energy and matter in closed systems is conserved. Students could develop a model [for how] *the total amount of energy in a closed system is conserved* [including that] ***uncontrolled system always evolve toward more stable states or toward more uniform energy distribution***. HS-PS3-4
Additional Connections to Nature of Science	**Scientific Phenomena is Based on Empirical Evidence (SEP):** • Science arguments are strengthened by multiple lines of evidence supporting a single explanation. Students could construct an argument for how *science arguments are strengthened by multiple lines of evidence supporting the explanation* [for how] ***the total momentum of a system can change if the system interacts with objects outside itself*** [and how] ***any such change is balanced by changes in the momentum of objects outside the system***. HS-PS2-2 and HS-PS2-3 **Science is a Human Endeavor (CCC):** • Science and engineering are influenced by society and society is influenced by science and engineering. Students could describe how *science and engineering influence society and how society is influenced by science and engineering* [for example, when] ***designing a device, criteria and constraints include taking issues of risk mitigation into account***. HS-PS2-3, HS-ETS1-1, and HS-ETS1-2

High School Conceptual Progressions Model Course 1 - Bundle 4
Energy and Bonds

This is the fourth bundle of the High School Conceptual Progressions Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 4 Question: This bundle is assembled to address the question of "How do substances combine or change(react) to make new substances?"

Summary

The bundle organizes performance expectations with a focus on helping students understand the relationships between *energy and chemical bonding*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy (PS1.B as in HS-PS1-4 and HS-PS1-5). These ideas connect to the concepts that with knowledge of the chemical properties of the elements involved and because atoms are conserved, chemical reactions can be used to described and predicted (PS1.B as in HS-PS1-7).

The ideas of energy and chemical processes (PS1.B as in HS-PS1-4 and HS-PS1-5) also connect to the concept that although energy cannot be destroyed, it can be converted to less useful forms such as to thermal energy in the surrounding environment (PS3.D as in HS-PS3-4) enabling energy to be transported from one place to another and transferred between systems. This concept of energy and systems connects to the idea that uncontrolled systems always evolve toward more stable states, in other words, toward more uniform energy distribution (PS3.B as in HS-PS3-4).

Concepts of energy and chemical processes (PS1.B as in HS-PS1-4 and HS-PS1-5) and energy and systems connect (PS3.B as in HS-PS3-4) to the concepts of the stability of molecules and adding energy to take molecules apart (PS1.A as in HS-PS1-4). These concepts about energy connect to the process of photosynthesis, which coverts light energy to stored chemical energy by converting carbon dioxide plus water into sugars and released oxygen (LS1.C as in HS-LS1-5).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing a model (HS-PS1-4 and HS-LS1-5), planning and conducting an investigation (HS-PS3-4), using mathematical representations (HS-PS1-7), and applying scientific principles (HS-PS1-5). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-PS1-5), Systems and System Models (HS-PS3-4), Energy and Matter (HS-PS1-4, HS-PS1-7, and HS-LS1-5). Many other CCC elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	HS-PS1-4. **Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.] HS-PS1-5. **Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.] HS-PS1-7. **Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.] HS-PS3-4. **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.] HS-LS1-5. **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]
Example Phenomena	Cookies bake when I put them into a hot oven. Hand warmers heat up after I open the package.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. Students could *ask questions that can be investigated with available resources* [about the idea that] ***chemical processes and whether or not energy is stored or released*** [depends on] ***the collisions of molecules and the rearrangements of atoms into new molecules***. HS-PS1-5 **Developing and Using Models** • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. Students could *evaluate merits and limitations of two different models* [for how] ***the rates of chemical processes can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules***. HS-PS1-4 and HS-PS1-5

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. Students could *conduct an investigation [*to provide evidence that] ***atoms are conserved*** [during a chemical reaction]**.** HS-PS1-7 **Analyzing and Interpreting Data** • Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. Students could *compare and contrast various types of data sets to examine consistency of measurements and observations* [of] ***chemical processes, their rates, and whether or not energy is stored or released.*** HS-PS1-5 **Using Mathematical and Computational Thinking** • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Students could *apply techniques of algebra and functions* ***to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system.*** HS-PS3-4 **Constructing Explanations and Designing Solutions** • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized constraints, and tradeoff considerations. Students could *design and refine a solution to a real-world problem* [caused by the fact that] ***uncontrolled systems always evolve toward more stable states***. HS-PS3-4 **Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. Students could *construct, an argument based on data and evidence* [for how] ***a stable molecule has less energy than the same set of atoms separated***. HS-PS1-4 **Obtaining, Evaluating, and Communicating Information** • 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. Students could *read scientific literature to obtain information and summarize* [how] ***the process of photosynthesis converts light energy into stored chemical energy.*** HS-LS1-5

Additional Crosscutting Concepts Building to the PEs	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. Students could describe how *models could be used to simulate* ***the effects of changing temperature or concentration of particles***. HS-PS1-4 and HS-PS1-5 **Energy and Matter** • Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. Students could develop a model to describe that *energy cannot be created or destroyed, but only moves between one place and another place, between objects and/or fields, or between systems* and [for how] ***chemical processes and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy***. HS-PS1-4 and HS-PS1-5 **Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Students could describe *quantifications of change and rates of change* of ***chemical processes*** *over very short or very long periods of time*. HS-PS1-5
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena (SEP):** • Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. Students could describe how *models, mechanisms, and explanations collectively have served as tools* [scientists have used to describe] ***chemical processes, their rates, and whether or not energy is stored or released***. HS-PS1-5 **Science is a Way of Knowing (CCC):** • Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review. Students could describe how *empirical standards, logical arguments, and skeptical review* [are essential in supporting claims, such as] ***the claim that atoms are conserved***. HS-PS1-7

High School Conceptual Progressions Model I - Bundle 5
Changes in Energy

This is the fifth bundle of the High School Conceptual Progressions Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 5 Question: This bundle is assembled to address the question of "How is energy transferred between objects?"

Summary

The bundle organizes performance expectations with a focus on helping students understand *how energy is transferred between objects*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Energy can be better understood as part of a system. Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system (PS3.A as in HS-PS3-1). These concepts of energy connect to the idea that at the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy (PS3.A as in HS-PS3-3), and the concept that although energy cannot be destroyed (PS3.A as in HS-PS3-1), it can be converted to less useful forms such as to thermal energy in the surrounding environment (PS3.D as in HS-PS3-3) and conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system (PS3.B as in HS-PS3-1). Finally, the motion and interactions of matter and radiation within that system (PS3.A as in HS-PS3-1) connect to the idea that, in many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present (PS1.B as in HS-PS1-6).

When evaluating solutions, connections could be made for how energy depends on the motion and interactions of matter (PS3.A as in HS-PS3-1) and manifests itself in multiple ways (PS3.A as in HS-PS3-3), and how the changes in the energy of a system (PS3.B as in HS-PS3-1) allow that system to be understood from a design point of view. These connections could be made through an engineering design task such as designing a Rube Goldberg device or wind turbine. It is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts when designing solutions (ETS1.B as in HS-ETS1-3). Furthermore, criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) such are renewable energy or artistic appeal may be needed (ETS1.C as in HS-ETS1-2).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of creating a computational model (HS-PS3-1), refining a solution (HS-PS1-6), designing, evaluating, and/or refining a solution (HS-PS3-3), designing a solution to a complex real-world problem (HS-ETS1-2), and evaluating a solution to a complex real-world problem (HS-ETS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Systems and System Models (HS-PS3-1); Energy and Matter (HS-PS3-3); and Stability and Change (HS-PS1-6). Many other CCC elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations HS-ETS1-2 and HS-ETS1-3 are partially assessable	HS-PS1-6. **Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*** [Clarification Statement: Emphasis is on the application of Le Chatlier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.] HS-PS3-1. **Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.] HS-PS3-3. **Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.] HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.**
Example Phenomena	Batteries power electronic toys. When a gas grill is turned on, the flame gives off light and heat.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. Students could *define a design problem that involves* ***the conservation of energy.*** HS-PS3-1 **Developing and Using Models** • Develop a complex model that allows for manipulation and testing of a proposed process or system. Students could *develop a complex model that allows for manipulation and testing* [of] ***a dynamic and condition-dependent balance between a reaction and the reverse reaction.*** HS-PS1-6 **Planning and Carrying Out Investigations** • Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. Students could *manipulate variables and collect data to improve performance* [for a device that minimizes the] ***conversion of energy to less useful forms***. HS-PS3-3

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data using technological tools to make valid scientific claims* [for how] ***the conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.*** HS-PS3-1 **Using Mathematical and Computational Thinking** • Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. Students could *use simple limit cases to test mathematical expressions to see if a model "makes sense" by comparing the outcomes with what is known about* [how] ***kinetic energy depends on mass and speed***. HS-PS3-1 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could *apply scientific ideas to solve design problems, taking into account possible unanticipated effects* [for a device that] ***converts one form of energy such as motion into another less useful form of energy***. HS-PS3-3 and HS-ETS1-3 **Engaging in Argument from Evidence** • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. Students could *respectfully provide critiques on scientific arguments by probing reasoning and evidence* [about how] ***a dynamic balance between a reaction and the reverse reaction determines the numbers of all types of molecules present***. HS-PS1-6 **Obtaining, Evaluating, and Communicating Information** • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Students could *compare, integrate and evaluate sources of information presented in different media or formats* [for how] ***energy cannot be created or destroyed and can be converted to less useful forms such as thermal energy in the surrounding environment.*** HS-PS3-3

Additional Crosscutting Concepts Building to the PEs	**Scale, Proportion, and Quantity** • Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. Students could *compare models for two different scales* [for how] ***energy cannot be created or destroyed, but it can be converted to less useful forms such as thermal energy in the surrounding environment***. HS-PS3-1 and HS-PS3-3 **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions--including energy, matter, and information flows—within and between systems at different scales. Students could use *models to simulate energy flow within and between systems at different scales* [to show that] ***the total change of energy in any system is always equal to the total energy transferred into or out of the system.*** HS-PS3-1 **Energy and Matter** • Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. Students could develop a model for how *energy cannot be created or destroyed* [by using] ***mathematical expressions, which quantify how the stored energy in a system depends on its configuration and how kinetic energy depends on mass and speed***. HS-PS3-1
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence (SEP):** • Science knowledge is based on empirical evidence. Students could describe the [importance of using] *empirical evidence* [to support the claim that] ***the stored energy in a system depends on its configuration and how kinetic energy depends on mass and speed.*** HS-PS3-1 **Science is a Human Endeavor (CCC):** • Technological advances have influenced the progress of science and science has influenced advances in technology. Students could construct an explanation for how *technology has influenced the progress of science and for how science has influenced advances in technology* [related to devices that] ***convert energy from one form to another such as motion, sound, light, or thermal energy***. HS-PS3-3

High School Conceptual Progressions Course 1 - Bundle 6
Electric and Electromagnetic Energy

This is the sixth bundle of the High School Conceptual Progressions Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 6 Question: This bundle is assembled to address the question of "How are waves used to transfer energy and information?"

Summary
The bundle organizes performance expectations with a focus on helping students understand *how waves are used to transfer energy and information*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

The concept that forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space (PS2.B as in HS-PS2-5) connects to the ideas that attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, (PS2.B as in HS-PS2-6). Also, the idea of electric and magnetic fields (PS2.B as in HS-PS2-5) connect to the concepts of electromagnetic radiation (PS4.B as in HS-PS4-3).

Electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons (PS4.B as in HS-PS4-3), so this concept connects to the idea that the wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features (PS4.B as in HS-PS4-3). This concept of the particle model of electromagnetic radiation also connects to understandings of photoelectric materials (PS4.B as in HS-PS4-5).

The wave model of electromagnetic radiation (PS4.B as in HS-PS4-3) connects to the concepts of wavelength and frequency (PS4.A as in HS-PS4-1). Wavelength and frequency connect to the idea of wave pulses, and the idea that information can be digitized and sent over long distances (PS4.A as in HS-PS4-2, HS-PS4-5). The ideas of digitizing and sending information connect to understandings that multiple technologies are based on the understanding of waves (PS4.C as in HS-PS4-5).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of evaluating questions (HS-PS4-2), planning and conducting an investigation (HS-PS2-5), using mathematical representations (HS-PS4-1), engaging in argumentation (HS-PS4-3), and communicating scientific and technical information (HS-PS2-6 and HS-PS4-5). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-PS2-5, HS-PS4-1, and HS-PS4-5), Systems and System Models (HS-PS4-3), Structure and Function (HS-PS2-6), and Stability and Change (HS-PS4-2). Many other CCC elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations HS-PS2-6 is partially assessable	HS-PS2-5. **Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.** [Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.] HS-PS2-6. **Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.] HS-PS4-1. **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.] HS-PS4-2. **Evaluate questions about the advantages of using a digital transmission and storage of information.** [Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.] HS-PS4-3. **Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.** [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include using quantum theory.] HS-PS4-5. **Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*** [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]
Example Phenomena	Some flashlights have to be shaken to work and other flashlights need batteries to work. When I use wireless headphones, I can listen to music from my computer without a cord.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables. Students could *ask questions to determine relationships between* ***the wavelength and frequency of a wave.*** HS-PS4-1 **Developing and Using Models** • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. Students could *use multiple types of models based on merits and limitations* [for how] ***electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons***. HS-PS4-3

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make directional hypotheses* [about how] ***the wavelength and frequency of a wave are related to one another.*** HS-PS4-1 **Analyzing and Interpreting Data** • Analyze data to identify design features or characteristics of a proposed process or system to optimize it relative to criteria for success. Students could *analyze data to identify design features of a proposed system* [that uses] ***magnets or electric currents*** [to generate] ***magnetic fields***. HS-PS2-5 **Using Mathematical and Computational Thinking** • Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. Students could *create a computational model* [of how] ***the wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.*** HS-PS4-1 **Constructing Explanations and Designing Solutions** • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. Students could *refine a solution to a real-world problem based on scientific knowledge* [about how] ***the attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.*** HS-PS2-6 **Engaging in Argument from Evidence** • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. Students could *respectfully provide critiques on scientific arguments by probing reasoning and evidence* [for how] ***the wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.*** HS-PS4-1

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Students could *compare and evaluate sources of information presented in different media or formats* [about how] ***electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons***. HS-PS4-3
Additional Crosscutting Concepts Building to PEs	**Patterns** • Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Students could *analyze and interpret performance patterns of designed systems to reengineer and improve* ***a technological tool that produces, transmits, and captures signals as well as stores and interprets the information contained in them***. HS-PS4-5 **Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another. Students could use *algebraic thinking to examine scientific data and predict the effect of a change* ***in the medium through which a wave is passing on the speed of travel of the wave.*** HS-PS4-1 **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. Students could investigate the functions and properties of designed objects ***based on an understanding of*** [how] ***tools can produce, transmit, and capture signals and store and interpret the information contained in them***. HS-PS4-5
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods (SEP):** • New technologies advance scientific knowledge. Students could communicate how *new technologies advance scientific knowledge* [about how] ***electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields.*** HS-PS4-3 **Science is a Way of Knowing (CCC):** • Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time. Students could obtain, evaluate, and communicate information for how ***electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields or as particles called photons*** [and how the ideas about] **electromagnetic radiation** *have changed over time*. HS-PS4-3

High School Conceptual Progressions Model Course 1

Narrative and Rationale: This model course map is the first in a three-year course sequence that uses a customized version of the High School Conceptual Progressions model from NGSS Appendix K as the instructional year end goals. The PEs from year one were then arranged into six different bundles of PEs based on a conceptual flow throughout the year.

The understanding of the natural world both biological and non-biological starts with the understanding of matter, how it is constructed, and how it interacts and combines with other matter to make up all of the substances in the universe. Understanding the structure of and interactions between matter and the role energy has in changing or sustaining matter is essential. All life and earth processes have their foundation in matter and how it interacts, is constructed, and is altered. Energy plays a unique role in the understanding of matter. The addition or removal of energy from a system can change the physical motion of matter and in the right conditions, rearrange how matter is configured through the breaking and forming of bonds. The bundles for Course 1 seek to lay a foundation for understanding the complexities of the biological and physical domains by deeply understanding the driving principles that allow matter to exist and function as it does in the universe.

It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional practices and crosscutting concepts should be used throughout instruction toward each bundle.

Bundle 1: Interactions Between Objects (Macro) **~4 weeks**	**Bundle 2:** Electrical Forces and Matter or Interactions Between Particles **~4 weeks**	**Bundle 3:** Forces, Energy, and Motion **~4 weeks**	**Bundle 4:** Energy and Bonds **~4 weeks**	**Bundle 5:** Changes In Energy **~4 weeks**	**Bundle 6:** Electric and Electromagnetic Energy **~4 weeks**
HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. **HS-PS2-4.** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.[1] **HS-ESS1-2.** Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and	**HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. **HS-PS1-2.** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. **HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. **HS-PS2-6.** Communicate scientific and technical information about why the molecular-level structure is	**HS-PS2-2.** Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. **HS-PS2-3.** Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* **HS-PS3-2.** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). **HS-PS3-4.** Plan and conduct an investigation to provide evidence that the transfer of thermal	**HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. **HS-PS1-5.** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. **HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	**HS-PS1-6.** Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* **HS-PS3-1.** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. **HS-PS3-3.** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down	**HS-PS2-5.** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. **HS-PS2-6.** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [1] **HS-PS4-1.** Use mathematical representations to support a claim regarding relationships among the frequency, wave length, and speed of waves traveling in various media. **HS-PS4-2.** Evaluate questions about the advantages of using a digital transmission and storage of information.

Bundle 1: Interactions Between Objects (Macro) **~4 weeks**	**Bundle 2:** Electrical Forces and Matter or Interactions Between Particles **~4 weeks**	**Bundle 3:** Forces, Energy, and Motion **~4 weeks**	**Bundle 4:** Energy and Bonds **~4 weeks**	**Bundle 5:** Changes In Energy **~4 weeks**	**Bundle 6:** Electric and Electromagnetic Energy **~4 weeks**
composition of matter in the universe. **HS-ESS1-4.** Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.	important in the functioning of designed materials.[1] **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.[1]	energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). **HS-ESS2-3.** Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.[1] **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.[1] **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.[1]	**HS-PS3-4.** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). **HS-LS1-5.** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.	into smaller, more manageable problems that can be solved through engineering.[1] **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.[1]	**HS-PS4-3.** Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. **HS-PS4-5.** Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

High School Conceptual Progression Model Course 1 Flowchart

Bundle 1

PS2.A as found in HS-PS2-1
- Newton's second law accurately predicts changes in the motion of macroscopic objects.

PS2.B as found in HS-PS2-4
- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS4.B as found in HS-ESS1-2
- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.

ESS1.A as found in HS-ESS1-2
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

ESS1.B as found in HS-ESS1-4
- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

Bundle 2

PS1.A as found in HS-PS1-1
- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.

to ESS2.B in Bundle 3

PS1.A as found in HS-PS1-1 and HS-PS1-2
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

to ESS2.B in Bundle 3

PS1.A as found in HS-PS1-3 and HS-PS2-6
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

PS1.B as found in HS-PS1-2
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

PS2.B as found in HS-PS1-1, HS-PS1-3, and HS-PS2-6
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

ETS1.B as found in HS-ETS1-3
- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Bundle 3

PS2.A as found in HS-PS2-2
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.

PS2.A as found in HS-PS2-2 and HS-PS2-3
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

PS3.A as found in HS-PS3-2
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

PS3.B as found in HS-PS3-4
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution.

PS3.D as found in HS-PS3-4
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

PS4.A as found in HS-ESS2-3
- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.

Bundle 4

PS1.A as found in HS-PS1-4
- A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

PS1.B as found in HS-PS1-4 and HS-PS1-5
- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

PS1.B as found in HS-PS1-7
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

PS3.B as found in HS-PS3-4
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution.

PS3.D as found in HS-PS3-4
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

LS1.C as found in HS-LS1-5
- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.

Bundle 5

PS1.B as found in HS-PS1-6
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.

PS3.A as found in HS-PS3-1
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.A as found in HS-PS3-3
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

PS3.B as found in HS-PS3-1
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

PS3.D as found in HS-PS3-3
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ETS1.A as found in HS-PS3-3
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

ETS1.B as found in HS-ETS1-3
- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Bundle 6

PS1.A as found in HS-PS2-6
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

PS2.B as found in HS-PS2-5
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS2.B as found in HS-PS2-6
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

PS3.A as found in HS-PS2-5
- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.

PS3.D as found in HS-PS4-5
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.

PS4.A as found in HS-PS4-1
- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

PS4.A as found in HS-PS4-2 and HS-PS4-5
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

PS4.A as found in HS-PS4-3
- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.

PS4.B as found in HS-PS4-3
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.

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ESS2.A as found in HS-ESS2-3
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

to PS3.B and PS3.D in Bundle 4

ESS2.B as found in HS-ESS2-3
- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

ETS1.A as found in HS-PS2-3 and HS-ETS1-1
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

ETS1.A as found in HS-ETS1-1
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

ETS1.C as found in HS-PS2-3 and HS-ETS1-2
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

ETS1.C as found in HS
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

PS4.B as found in HS-PS4-5
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

PS4.C as found in HS-PS4-5
- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

High School Conceptual Progressions Model Course II – Bundle 1
Matter and Energy in the Universe

This is the first bundle of the High School Conceptual Progressions Model Course II. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "where do matter and energy in the universe come from?"

Summary

The bundle organizes performance expectations (PEs) with a focus on helping students understand matter and energy changes in the universe. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth (ESS1.A as in HS-ESS1-3). An example is the star called the sun, which is changing and will burn out over a lifespan of approximately 10 billion years (ESS1.A as in HS-ESS1-1). Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and that process releases electromagnetic energy (ESS1.A as in HS-ESS1-3). These ideas connect to the concepts that nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy (PS1.C as in HS-PS1-8) and that forces at a distance are explained by fields permeating space that can transfer energy through space (PS2.B as in HS-PS2-4). This last idea also connects to the concept that when two objects interacting through a field change relative positon, the energy stored in the field is also changed (PS3.C as in HS-PS3-5), and the concept that Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects (PS2.B as in HS-PS2-4).

The engineering design concept that it is important to take into account a range of constraints when evaluating solutions (ETS1.B as in HS-ETS1-3) could be applied to several bundle DCIs, such as that forces at a distance are explained by fields that permeate space and that can transfer energy through space (PS2.B as in HS-PS2-4) and that nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy (PS1.C as in HS-PS1-8). Students can make connections through an engineering design task such as researching safety considerations for using magnetic resonance imaging or for dealing with waste from electricity production at nuclear power plants.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (HS-PS1-8, HS-PS3-5, and HS-ESS1-1), using mathematical thinking (HS-PS2-4), and communicating information (HS-ESS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-PS2-4), Scale, Proportion, and Quantity (HS-ESS1-1), Energy and Matter (HS-PS1-8 and HS-ESS1-3), and Cause and Effect (HS-PS3-5). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.	
Performance Expectations HS-PS2-4 is partially assessable	HS-PS1-8. **Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.] HS-PS2-4. **Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.] HS-PS3-5. **Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.] HS-ESS1-1. **Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.** [Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.] HS-ESS1-3. **Communicate scientific ideas about the way stars, over their life cycle, produce elements.** [Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.] HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.**
Example Phenomena	I got a sunburn when I went outside. Pictures of the sun make it look like a burning ball.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to clarify and refine a model, an explanation, or an engineering problem. Students could *ask questions to clarify and refine a model* [for how] ***the light spectra and brightness of stars are used to identify compositional elements of stars***. HS-ESS1-3

Additional Practices Building to the PEs (Continued)	**Developing and Using Models** • Evaluate the merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. Students could *evaluate the merits and limitations of two different models in order to select or revise a model that best fits the evidence* [that] ***forces at a distance are explained by fields permeating space that can transfer energy through space***. HS-PS2-4 **Planning and Carrying Out Investigations** • Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Students could *plan an investigation to produce data to serve as the basis for evidence* [that] ***forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space***. HS-PS2-4 **Analyzing and Interpreting Data** • Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. Students could *compare and contrast various types of data sets to examine consistency of measurements* [for how] ***nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy***. HS-PS1-8 **Using Mathematical and Computational Thinking** • Create and/or revise a computational simulation of a phenomenon, designed device, process, or system. Students could *create a computational simulation of* ***the change in the energy stored in a field when two objects interacting through a field change relative position***. HS-PS2-4 **Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *apply scientific reasoning to link evidence to the claims* [for how] ***nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy***. HS-PS1-8 **Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. Students could *present an oral argument* [about how] ***nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy***. HS-ESS1-3

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Students could *compare, integrate and evaluate sources of information* [for how] ***the sun is changing and will burn out over a lifespan of approximately 10 billion years***. HS-ESS1-1
Additional Crosscutting Concepts Building to the PEs	**Scale, Proportion, and Quantity** • Patterns observable at one scale may not be observable or exist at other scales. Students could construct an argument for how *patterns observable at one scale may not be observable at other scales* ***when two objects interacting through a field change relative position causing the energy stored in the field to change***. HS-PS3-5 **Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. Students could develop a model representing *energy and matter flows into, out of, and within a system* [when] ***nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, release or absorption of energy***. HS-PS1-8 **Stability and Change** • Changes and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Students could *communicate information about changes and rates of change over very short or very long periods of time*, [such as how] ***the sun is changing and will burn out over a lifespan of approximately 10 billion years***. HS-ESS1-1
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence (SEP):** • Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. Students could construct an argument for how *most scientific knowledge is quite durable, but is subject to change based on new evidence and/or reinterpretation of existing evidence* [about how] ***nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy***. HS-ESS1-3 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems (CCC):** • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Students could construct an argument for [how the fact that] *scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do in the future* [affects our understanding of the origins of] ***elements heavier than iron.*** HS-ESS1-3

High School Conceptual Progressions Model Course II – Bundle 2
Matter and Energy in the Environment

This is the second bundle of the High School Conceptual Progressions Model Course II. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 2 Question: This bundle is assembled to address the question "how much is Earth constantly changing?"

Summary
The bundle organizes performance expectations with a focus on helping students understand matter and energy flows in Earth systems. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease changes (ESS2.A as in HS-ESS2-1 and HS-ESS2-2). This concept forms the foundation of the bundle, and connects to the idea that the geological record shows that changes to global and regional climate can be caused by interactions among many different factors, and these changes can occur on a variety of time scales (ESS2.A as in HS-ESS2-4).

The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space (ESS2.D as in HS-ESS2-4). This concept connects to the idea that the cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes (ESS1.B as in HS-ESS2-4).

Changes to climate caused by volcanic activity (ESS2.A as in HS-ESS2-4) connects to the concepts of plate tectonic movements being responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust (ESS2.A as in HS-ESS2-1). These ideas also connect to the concept that the abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties—including water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks—are central to the planet's dynamics (ESS2.C as in HS-ESS2-5).

The idea that, as Earth evolved, gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen (ESS2.D as in HS-ESS2-6) connects to the concept that changes in the atmosphere due to human activity are increasing carbon dioxide concentrations (ESS2.D as in HS-ESS2-6, HS-ESS2-4). These ideas connect to the concept that chemical elements that make up the molecules of an organism pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways, and that at each of these transitions in an ecosystem, matter and energy are conserved (LS2.B as in HS-LS2-4).

The engineering design concept that criteria may need to be broken down into simpler ones that can be approached systematically (ETS1.C as in HS-ETS1-2) could be applied to several bundle DCIs, such as that at each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward (LS2.B as in HS-LS2-4) and that the foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems (ESS2.D as in HS-ESS2-2). Students could make connections through an engineering design task such as creating their own food web and developing the criteria that the highest level of the web needs to be optimized for energy efficiency, and the students could break down each criterion into smaller pieces in order to address them. Alternately, when designing a solution with the criterion that changes the absorption rate of electromagnetic radiation from the sun into the ocean, the students could break down the criterion into smaller pieces in order to address them.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (HS-ESS2-1, HS-ESS2-4, and HS-ESS2-6), planning and conducting investigations (HS-ESS2-5), analyzing data (HS-ESS2-2), and using mathematical thinking (HS-LS2-4). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-ESS2-4); Energy and Matter (HS-LS2-4 and HS-ESS2-6); Structure and Function (HS-ESS2-5); and Stability and Change (HS-ESS2-1 and HS-ESS2-2). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	HS-LS2-4. **Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.** [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.] HS-ESS2-1. **Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.] HS-ESS2-2. **Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.** [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.] HS-ESS2-4. **Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.** [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]

Performance Expectations (Continued)	HS-ESS2-5. **Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).] HS-ESS2-6. **Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.** [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.] HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**
Example Phenomena	Ice forms in the winter, but melts in the spring. The temperature is higher inside cities than in the countryside surrounding them.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Students could *ask questions to clarify and/or seek additional information* [about how] ***gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen***. HS-ESS2-6 **Developing and Using Models** • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. Students could *evaluate merits and limitations of two different models* [for how] ***at each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward***. HS-LS2-4 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make directional hypotheses* [about how] ***changes in the atmosphere due to human activity have increased carbon dioxide concentrations***. HS-ESS2-4 and HS-ESS2-6 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. Students could *consider limitations of data analysis when interpreting data* [about] ***feedback effects*** [from one] ***Earth system that increase or decrease changes*** [in another] ***Earth system***. HS-ESS2-1 and HS-ESS2-2

Additional Practices Building to the PEs (Continued)	**Using Mathematical and Computational Thinking** • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Students could *apply techniques of algebra and functions* [to describe how] ***changes in the atmosphere due to human activity have increased carbon dioxide concentrations***. HS-ESS2-4 and HS-ESS2-6 **Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *apply scientific reasoning to link evidence to claims* [about how] ***global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities***. HS-ESS2-4 **Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. Students could *construct a counter-argument based on evidence* [that] ***the abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics***. HS-ESS2-5 **Obtaining, Evaluating, and Communicating Information** • 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. Students could *critically read scientific literature to determine the central ideas* [of how] ***Earth's systems cause feedback effects that can increase or decrease the original changes***. HS-ESS2-1 and HS-ESS2-2
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • 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. Students could construct an argument *suggesting and predicting the cause and effect relationships* [between] ***the planet's dynamics and the unique physical and chemical properties of liquid water***. HS-ESS2-5 **Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Students could develop and use a model [for how] ***water's properties include its exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks*** [and how these properties are] *dependent on the scale, proportion, and quantity at which they occur*. HS-ESS2-5

Additional Crosscutting Concepts Building to the PEs (Continued)	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. Students could construct an argument for how *much of science deals with constructing explanations of how things change and how they remain stable*, [including as evidence that scientists study] ***interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities***. HS-ESS2-4
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence (SEP):** • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. Students could describe evidence that *scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence*, [including about how] ***global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities***. HS-ESS2-4 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems (CCC):** • Science assumes the universe is a vast single system in which basic laws are consistent. Students could ask questions about how the principle that *science assumes the universe is a vast single system in which basic laws are consistent* [affects our understanding of] ***interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities.*** HS-ESS2-4

High School Conceptual Progressions Model Course II – Bundle 3
Matter and Energy in Organisms

This is the third bundle of the High School Conceptual Progressions Model Course II. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question "how does matter and energy cycle within living systems?"
Summary The bundle organizes performance expectations with a focus on helping students understand the cycling of energy and matter within living systems as energy-rich molecules are formed, moved, and used. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations. **Connections between bundle DCIs** The concept that when light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat) (PS4.B as in HS-PS4-4) can connect to the ideas that the main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis (PS3.D as in HS-LS2-5), which along with cellular respiration provide most of the energy for life processes (LS2.B as in HS-LS2-3). Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes (LS2.B as in HS-LS2-5). This idea connects to the concepts that as matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products (LS1.C as in HS-LS1-6 and HS-LS1-7) and the hydrocarbon backbones of sugars are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (LS1.C as in HS-LS1-6). As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment (LS1.C as in HS-LS1-7). The engineering design concept that models (both physical and computational) can be used in various ways to aid in the engineering design process (ETS1.B as in HS-ETS1-4) could be applied to the concept that photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes (LS2.B as in HS-LS2-5) as well as the concept that the main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis (PS3.D as in HS-LS2-5). Students could make connections through an engineering design task such as comparing and contrasting the utility of different computer simulations to model an alternative energy source to photosynthesis or designing a computer model that helps predict the effects of a disruption in one part of the carbon cycle. **Bundle Science and Engineering Practices** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using a model (HS-LS1-7 and HS-LS2-5), using computational thinking (HS-ETS1-4), constructing explanations (HS-LS1-6 and HS-LS2-3), and obtaining, evaluating, and communicating information (HS-PS4-4). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-PS4-4), Systems and System Models (HS-LS2-5 and HS-ETS1-4), and Energy and Matter (HS-LS1-6, HS-LS1-7, and HS-LS2-3). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	**HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.** [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.] **HS-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.** [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.] **HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.** [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.] **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.] **HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** [Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.] **HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**
Example Phenomena	Sunburns Your internal temperature can be 98.6^{o}F even if you sit outside on a 70^{0}F day.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. Students could *ask questions to clarify and seek information* [about how] ***the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles***. HS-LS1-7

Additional Practices Building to the PEs (Continued)	**Developing and Using Models** • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. Students could *develop multiple types of models to provide mechanistic accounts* [about the idea that] ***as matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products***. HS-LS1-6 and HS-LS1-7 **Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. Students could *plan an investigation to produce data to serve as the basis for evidence* [that] ***when light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy***. HS-PS4-4 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. Students could consider limitations of data analysis when analyzing and interpreting data [about how] ***carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes***. HS-LS2-5 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could use mathematical representations to support claims [that] ***photosynthesis and cellular respiration are important components of the carbon cycle***. HS-LS2-5 **Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *apply scientific reasoning and/or models to link evidence to the claims* [that] ***as matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products***. HS-LS1-6 and HS-LS1-7 **Engaging in Argument from Evidence** • Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. Students could *compare and evaluate competing arguments* [about the idea that] ***shorter wavelength electromagnetic radiation can ionize atoms and cause damage to living cells***. HS-PS4-4

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • 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). Students could *communicate scientific information orally and graphically* [about how] ***photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes***. HS-LS2-3
Additional Crosscutting Concepts Building to the PEs	**Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Students could *define the boundaries of the* ***carbon cycle*** *and analyze [its] inputs and outputs*. HS-LS2-5 **Energy and Matter** • The total amount of energy and matter in closed systems is conserved. Students could develop a model [showing that] *the total amount of energy and matter in closed systems is conserved* [when] ***energy is transferred from one system of interacting molecules to another as the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles***. HS-LS1-7 **Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. Students could construct an argument for [why] *designing a new* [use for the] *components of* ***sugar*** *requires a detailed examination of* [its] *structure* [as well as] *the properties of* [each of its molecular] *components*. HS-LS1-6
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena (SEP):** • Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. Students could construct an argument for how *models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory* [about how] ***photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes***. HS-LS2-5 **Science is a Way of Knowing (CCC):** • Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review. Students describe how *science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review* [by describing the characteristics of a scientific argument that] ***photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes***. HS-LS2-3

High School Conceptual Progressions Model Course II – Bundle 4
Stability in Body Systems

This is the fourth bundle of the High School Conceptual Progressions Model Course II. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 4 Question: This bundle is assembled to address the question "how do organisms maintain stability, even under different conditions?"

Summary

The bundle organizes performance expectations around helping students understand the various levels of organization and maintenance in body systems. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

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 as in HS-LS1-2). This concept connects to the idea that these systems are formed when individual cells grow and then divide via a process called mitosis. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism (LS1.B as in HS-LS1-4). Both of these ideas connect to the concept that complexity is supported by various feedback mechanisms that 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 (LS1.A as in HS-LS1-3).

The engineering design concept that humanity faces major global challenges today, such as the need for clean water and food or for energy sources that minimize pollution, which can be addressed through engineering (ETS1.A as in HS-ETS1-1) could be applied to many different science ideas, including to the idea that feedback mechanisms maintain a living system's internal conditions within certain limits even as external conditions change within some range (LS1.A as in HS-LS1-3). Connections could be made through an engineering design task such as obtaining and evaluating information about human tolerance levels for water contaminants to define criteria for public water systems, or analyzing data on the conditions needed to maintain healthy plants to define criteria for large-scale agriculture.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (HS-ETS1-1), developing and using models (HS-LS1-2 and HS-LS1-4), and planning and carrying out investigations (HS-LS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Systems and System Models (HS-LS1-4) and Stability and Change (HS-LS1-3). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	**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, stomate 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-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.** [Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.] **HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**
Example Phenomena	When I get cold, I shiver. When I get a cut, a scab grows and my skin heals itself.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Students could *ask questions that arise from examining models to seek additional information* [about how] ***cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism***. HS-LS1-4 **Developing and Using Models** • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. Students could *use multiple types of models to provide mechanistic accounts* [of how] ***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***. HS-LS1-3 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make directional hypotheses that specify what happens to* [one part of a body] ***system*** *when* [another part of the body] ***system changes***. HS-LS1-3

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data to make valid and reliable scientific claims* [about the idea that] ***feedback mechanisms can encourage or discourage what is going on inside the living system***. HS-LS1-3 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could use mathematical representations to support claims [that] ***the systems in multicellular organisms are hierarchical***. HS-LS1-2 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could apply scientific ideas and evidence to provide an explanation [for how] ***systems of tissues and organs work together to meet the needs of the whole organism***. HS-LS1-4 **Engaging in Argument from Evidence** • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). Students could evaluate competing design solutions [for how artificial systems could mimic] ***feedback mechanisms in maintaining a living system's internal conditions within certain limits***. HS-LS1-3 **Obtaining, Evaluating, and Communicating Information** • 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). Students could communicate scientific information in multiple formats [about how] ***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***. HS-LS1-3
Additional Crosscutting Concepts Building to the PEs	**Patterns** • 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. Students could identify *different patterns at each of the scales of an organism's* [body] *system and provide evidence for causality* [for] ***feedback mechanisms*** [between the] ***systems***. HS-LS1-2 and HS-LS1-3

Additional Crosscutting Concepts Building to the PEs (Continued)	**Cause and Effect** • 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. Students could *suggest and predict cause and effect relationships by examining what is known about smaller scale mechanisms* [for how] ***feedback mechanisms maintain a living system's internal conditions***. HS-LS1-3 **Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. Students could *examine the structures of different* ***system*** *components* [when] *investigating* [whether] ***multicellular organisms have a hierarchical structural organization***. HS-LS1-2
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence (SEP):** • Science disciplines share common rules of evidence used to evaluate explanations about natural systems. Students could construct an argument for how *science disciplines share common rules of evidence used to evaluate explanations,* [using as an example the explanation that] ***feedback mechanisms maintain a living system's internal conditions within certain limits***. HS-LS1-3 **Science Addresses Questions About the Natural and Material World (CCC):** • Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. Students could construct an argument for how s*cience and technology may raise ethical issues for which science, by itself, does not provide answers and solutions* [about how] ***feedback mechanisms maintain a living system's internal conditions within certain limits as external conditions change,*** [but only] ***within*** [certain] ***ranges***. HS-LS1-3

High School Conceptual Progressions Model Course II – Bundle 5
Inheritance of Genetic Variation

This is the fifth bundle of the High School Conceptual Progressions Model Course II. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 5 Question: This bundle is assembled to address the question "how can individuals of the same species have different characteristics?"

Summary

The bundle organizes performance expectations around helping students understand the role of DNA in living systems. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Systems of specialized cells within organisms help them perform the essential functions of life (LS1.A as in HS-LS1-1). These systems and their functions are controlled by the genetic information within all cells that forms DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells (LS1.A and HS-LS1-1 and HS-LS3-1). These ideas connect to the concepts that all cells in an organism have the same genetic content, but the genes expressed by the cell may be regulated in different ways, and that not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function (LS3.A as in HS-LS3-1).

The idea that there is variation and distribution of traits that depends on both genetic and environmental factors (LS3.B as in HS-LS3-2 and HS-LS3-3) connects to the idea although DNA replication is tightly regulated and remarkable accurate, errors do occur and result in mutations, which are also a source of variation. It also connects to the idea that environmental factors can cause mutations in genes (LS3.B as in HS-LS3-2) and hence affect the probability of occurrences of traits in a population (LS3.B as in HS-LS3-2 and HS-LS3-3).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions (HS-LS3-1), analyzing and interpreting data (HS-LS3-3), constructing explanations (HS-LS1-1), and engaging in argument (HS-LS3-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-LS3-1 and HS-LS3-2), Scale, Proportion, and Quantity (HS-LS3-3), and Structure and Function (HS-LS1-1). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	**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-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.** [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.] **HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.** [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.] **HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.** [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]
Example Phenomena	The DNA code only has four letters. DNA sequencing can be done from any part of a plant, even though the different parts all look very different.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation to clarify* [how] ***genetic and environmental factors both affect expression of traits***. HS-LS3-2 and HS-LS3-3 **Developing and Using Models** • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. Students could *evaluate merits and limitations of two different models* [of how] ***genetic and environmental factors both affect expression of traits, and hence affect the probability of occurrences of traits in a population*** *in order to select a model that best fits the evidence*. HS-LS3-2 and HS-LS3-3 **Planning and Carrying Out Investigations** • Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of supporting explanations for phenomena. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Students could *plan an investigation to produce data to serve as the basis for evidence* [for how] ***genetic and environmental factors both affect expression of traits***. HS-LS3-2 and HS-LS3-3

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data using mathematical models in order to make valid and reliable scientific claims* [about how] ***genetic and environmental factors both affect the probability of occurrences of traits in a population***. HS-LS3-2 and HS-LS3-3 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could *use computational representations of phenomena to describe* [that] ***each chromosome consists of a single very long DNA molecule, each gene on the chromosome is a particular segment of that DNA, and the instructions for forming species' characteristics are carried in DNA***. HS-LS3-1 **Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *assess the extent to which data support an explanation* [for how] ***genetic and environmental factors both affect expression of traits, and hence affect the probability of occurrences of traits in a population***. HS-LS3-2 and HS-LS3-3 **Engaging in Argument from Evidence** • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. Students could *respectfully provide critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions* [about how] ***all cells contain genetic information in the form of DNA molecules***. HS-LS1-1 **Obtaining, Evaluating, and Communicating Information** • Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Students could *compare and evaluate sources of information* [about how] ***not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function***. HS-LS3-1

Additional Crosscutting Concepts Building to the PEs	**Patterns** • 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. Students could identify *different patterns at each of the scales at which* [the effect of] ***DNA*** [on organisms and] ***populations*** *is studied*. HS-LS3-1, HS-LS3-2, and HS-LS3-3 **Scale, Proportion, and Quantity** • Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students could construct an argument for why [the effects of] ***DNA on trait expression*** *can be studied indirectly* [in the classroom because the effects of DNA are] *too small and too fast to observe directly*. HS-LS3-1 and HS-LS3-2 **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. Students could construct an argument for how *much of science deals with constructing explanations of how things change and how they remain stable,* [using as evidence] ***systems of specialized cells within organisms help them perform the essential functions of life.*** HS-LS1-1
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods (SEP):** • Science investigations use diverse methods and do not always use the same set of procedures to obtain data. Students could obtain, evaluate, and communicate information for how *science investigations* [about the role of] ***genes on chromosomes*** *use diverse methods and do not always use the same set of procedures to obtain data*. HS-LS1-1 and HS-LS3-1 **Science is a Way of Knowing (CCC):** • Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time. Students could construct an argument from evidence for how *science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time* [about the role of] ***DNA in coding for the formation of proteins***. HS-LS1-1 and HS-LS3-1

High School Conceptual Progressions Model III – Bundle 1
Evolution of Earth

This is the first bundle of the High School Conceptual Progressions Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "what evidence do we have that the Earth is different now than it used to be?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding about how the Earth has changed over time. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history (ESS1.C as in HS-ESS1-6).

Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet (PS4.A as in HS-ESS2-3). This evidence along with reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior (ESS2.A as in HS-ESS2-3). The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives this mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection (ESS2.B as in HS-ESS2-3) and plate tectonics is the unifying theory that explains the past and current movements of the rocks on Earth's surface and provides a framework for understanding its geologic history (ESS2.B as in HS-ESS1-5).

Because spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials (PS1.C as in HS-ESS1-6). For example, continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old (ESS1.C as in HS-ESS1-5). We can also use radiometric dating to gather information about the co-evolution of Earth's surface and the life that exists on it (ESS2.E as in HS-ESS2-7), including the gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen (ESS2.D as in HS-ESS2-7).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing models (HS-ESS2-3), constructing explanations (HS-ESS1-6), and engaging in argument (HS-ESS1-5 and HS-ESS2-7). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-ESS1-5), Energy and Matter (HS-ESS2-3), and Stability and Change (HS-ESS1-6 and HS-ESS2-7). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.	
Performance Expectations HS-ESS2-3 and HS-ESS2-7 are partially assessable	HS-ESS1-5. **Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.** [Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).] HS-ESS1-6. **Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.** [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.] HS-ESS2-3. **Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.] HS-ESS2-7. **Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.** [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.]
Example Phenomena	Ocean maps show that some parts of the ocean are much deeper than others. The moon appears to be pock-marked with many craters.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation to seek additional information* [about how] ***gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen***. HS-ESS2-7 **Developing and Using Models** • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. Students could *use multiple types of models to provide mechanistic accounts* [of why] ***continental rocks are generally much older than the rocks of the ocean floor,*** *and [choose different] model types based on merits and limitations*. HS-ESS1-5

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Students could *plan an investigation to serve as the basis for evidence* [that] ***plants capture carbon dioxide and release oxygen,*** [therefore causing] ***gradual atmospheric changes.*** HS-ESS2-7 **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data in order to make valid and reliable scientific claims* [about how] ***studying plate tectonics, erosion, lunar rocks, asteroids, and meteorites can provide information about Earth's formation and early history***. HS-ESS1-6 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could *use computational representations of phenomena to describe the explanation* [that] ***motions of the Earth's mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior***. HS-ESS2-3 **Constructing Explanations and Designing Solutions** • 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. Students could *construct an explanation based on valid and reliable evidence obtained from a variety of sources* [for how] ***gradual atmospheric changes were*** [caused by] ***plants and other organisms that captured carbon dioxide and released*** oxygen. HS-ESS2-7 **Engaging in Argument from Evidence** • Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. Students could *defend a claim based on evidence* [that] ***plate tectonics can be viewed as the surface expression of mantle convection***. HS-ESS2-3

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. Students could gather, read, and evaluate scientific information from multiple authoritative sources [about how] ***studying plate tectonics can provide information about Earth's formation and early history***. HS-ESS1-6
Additional Crosscutting Concepts Building to the PEs	**Patterns** • 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. Students could evaluate and communicate information about how *different patterns may be observed at different scales, and the patterns can provide evidence for causality* [about how] ***plate tectonics can be viewed as the surface expression of mantle convection***. HS-ESS2-3 **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Students could construct an argument for how *empirical evidence is required to differentiate between cause and correlation* [between] ***the evolution of Earth's surface and the evolution of the life that exists on it***. HE-ESS2-7 **Stability and Change** • Changes and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Students could construct an argument for how *changes and rates of change* [in] ***the movements of the rocks at Earth's surface*** *can be quantified and modeled over very short or very long periods of time*. HS-ESS1-5
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods** • Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge. Students could construct an argument for how *scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge* [about how] ***continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old***. HS-ESS1-5 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Students could construct an argument for how *scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future* [using as an example our knowledge about the] ***continual coevolution of Earth's surface and the life that exists on it.*** HS-ESS2-7

High School Conceptual Progressions Model III – Bundle 2
Evolution of Life

This is the second bundle of the High School Conceptual Progressions Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 2 Question: This bundle is assembled to address the question "why do such different organisms have similar characteristics?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how organisms evolved on Earth. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Ecosystems have carrying capacities; organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite limiting the abundance of species in any given ecosystem (LS2.A as in HS-LS2-1 and HS-LS2-2). A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant, but extreme fluctuations in conditions can challenge the functioning of ecosystems in terms of resources and habitat availability (LS2.C as in HS-LS2-2 and HS-LS2-6). Thus, changes in the physical environment, whether naturally occurring or human induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline of some species (LS4.C as in HS-LS4-5). Species become extinct because they can no longer survive and reproduce in their altered environment and if members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost (LS4.C as in HS-LS4-5).

Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically (LS4.C as in HS-LS4-3 and HS-LS4-4), behaviorally (LS2.D as in HS-LS2-8), and physiologically well suited to survive and reproduce in a specific environment (LS4.C as in HS-LS4-3 and HS-LS4-4). Adaptation also means that the distribution of traits in a population can change when conditions change (LS4.C as in HS-LS4-3). Therefore, natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information that leads to differences in performance among individuals (LS4.B as in HS-LS4-2 and HS-LS4-3). The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population (LS4.B as in HS-LS4-3).

Genetic information including similarities and differences in amino acid sequences as well as anatomical and embryological data provides evidence of evolution (LS4.A as in HS-LS4-1). Thus, evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment (LS4.C as in HS-LS4-2).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of using mathematics and computational thinking (HS-LS4-3, HS-LS2-1, and HS-LS2-2), constructing explanations (HS-LS4-2 and HS-LS4-4), engaging in argument (HS-LS2-6, HS-LS2-8, and HS-LS4-5), and communicating information (HS-LS4-1). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-LS4-1 and HS-LS4-3), Cause and Effect (HS-LS2-8, HS-LS4-2, HS-LS4-4, and HS-LS4-5), Scale, Proportion, and Quantity (HS-LS2-1 and HS-LS2-2), and Stability and Change (HS-LS2-6). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	HS-LS2-1. **Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.** [Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.] HS-LS2-2. **Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.** [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.] HS-LS2-6. **Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.** [Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and, extreme changes, such as volcanic eruption or sea level rise.] HS-LS2-8. **Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.** [Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.] HS-LS4-1. **Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.** [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.] HS-LS4-2. **Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.] HS-LS4-3. **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.** [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]

Performance Expectations (Continued)	HS-LS4-4. **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.] HS-LS4-5. **Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]
Example Phenomena	Doctors tell us to finish taking all of our antibiotic prescription, even after we feel better. The skeleton of a dinosaur looks a lot like the skeleton of a bird.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations. Students could *define a design problem that involves the development of a process* [related to how] ***changes in the physical environment have contributed to the expansion of some species***. HS-LS4-5 **Developing and Using Models** • Develop a complex model that allows for manipulation and testing of a proposed process or system. Students could *develop a complex model that allows for manipulation and testing of a proposed process* [for increasing the] ***carrying capacities of*** [an] ***ecosystem***. HS-LS2-1 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make directional hypotheses* [about how] ***extreme fluctuations in conditions can*** [affect] ***the functioning of ecosystems in terms of resources and habitat availability***. HS-LS2-2 **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data using tools and models to make valid and reliable scientific claims* [about how] ***changes in the physical environment have contributed to the decline—and sometimes the extinction—of some species***. HS-LS4-5 **Using Mathematical and Computational Thinking** • Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. Students could *revise a computational simulation* [of how] ***natural selection occurs if there is both variation in the genetic information between organisms in a population and variation in the expression of that genetic information that leads to differences in performance among individuals***. HS-LS4-2 and HS-LS4-3

Additional Practices Building to the PEs (Continued)	**Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *apply scientific reasoning and theory to link evidence to claims* [about how] ***the ongoing branching that produces multiple lines of*** [evolutionary] ***descent can be inferred by comparing the DNA sequences of different organisms***. HS-LS4-1 **Engaging in Argument from Evidence** • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. Students could *respectfully provide and receive critiques on scientific arguments* [about how] ***group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives***. HS-LS2-8 **Obtaining, Evaluating, and Communicating Information** • 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. Students could *critically read scientific literature to determine the central ideas or conclusions* [about how] ***group membership can increase the chances of survival for individuals and their genetic relatives***. HS-LS2-8
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Changes in systems may have various causes that may not have equal effects. Students could *obtain, evaluate, and communicate information about how changes in* ***ecosystems*** *may have various causes that may not have equal effects*, [and that] ***extreme fluctuations in conditions can challenge the functioning of ecosystems in terms of resources and habitat availability***. HS-LS2-2 and HS-LS2-6 **Scale, Proportion, and Quantity** • Patterns observable at one scale may not be observable or exist at other scales. Students could construct an argument for how *patterns observable at one scale may not be observable at other scales*, [describing observations on the scale of] ***the differential survival and reproduction of organisms in a population that have an advantageous heritable trait*** [to observations on the scale of the DNA itself]. HS-LS4-3 and HS-LS4-4

Additional Crosscutting Concepts Building to the PEs (Continued)	**Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Students could construct an argument for how *change and rates of change can be quantified over very short or very long periods of time* [related to how] ***evolution is a consequence of the interaction of (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment***. HS-LS4-2
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific explanations can be probabilistic. Students could construct an argument that *scientific explanations can be probabilistic,* [giving as evidence the explanation that] ***a complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions, modest biological or physical disturbances may return the ecosystem to its more or less original state, or extreme fluctuations in conditions can challenge the functioning of ecosystems in terms of resources and habitat availability***. HS-LS2-2 and HS-LS2-6 **Science is a Human Endeavor** • Science and engineering are influenced by society and society is influenced by science and engineering. Students could obtain, evaluate, and communicate information about how *science and engineering are influenced by society and society is influenced by science and engineering*, [describing examples related to] ***human induced changes in the physical environment*** [that have] ***contributed to the expansion of some species*** [and to our understanding of ecosystem dynamics]. HS-LS4-5

High School Conceptual Progressions Model III – Bundle 3
Human Influence on Earth

This is the third bundle of the High School Conceptual Progressions Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question "how could human activities change the Earth?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how human activities have changed the Earth over time. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Humans depend on the living world for the resources and other benefits provided by biodiversity, but human activity is affecting biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change (LS4.D as in HS-LS4-6, HS-LS2-7), and these anthropogenic changes can disrupt an ecosystem and threaten the survival of some species (LS2.C as in HS-LS2-7). Biodiversity is increased by the formation of new species and decreased by the loss of species (LS4.D as in HS-LS2-7) which can occur due to changes in the physical environment, whether naturally occurring or human induced (LS4.C as in HS-LS4-6). Additionally, the many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it (ESS2.E as in HS-ESS2-7) and includes the gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen (ESS2.D as in HS-ESS2-7).

Humans also depend upon the environment for energy, but all forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits (ESS3.A as in HS-ESS3-2). Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation (ESS3.C as in HS-ESS3-4) as we continue to make important discoveries about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities (ESS3.D as in HS-ESS3-6). Current models predict that average global temperatures will continue to rise, but this strongly depends on the amount of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere (ESS2.D as in HS-ESS3-6).

The engineering design idea that humanity faces many global challenges today that can be addressed through engineering, and that criteria and constraints include satisfying any requirements set by society and should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them (ETS1.A as in HS-ETS1-1), could connect to many different science concepts, including how human activity is having adverse impacts on biodiversity through overpopulation and how sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspiration value (LS4.D as in HS-LS4-6, HS-LS2-7). Connections could be made through engineering design tasks such as identifying and quantifying the criteria and constraints for minimizing the effects a new road has on local biodiversity, or in minimizing habitat disruption from a new recreational park.

The engineering design idea that when evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts (ETS1.B as in HS-ETS1-3) already connects to several science ideas in the bundle, but could also connect to other ideas, such as how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities (ESS3.D as in HS-ESS3-6). Connections could be made through an engineering design task such as evaluating a given solution for overfishing.

The engineering design idea that criteria may need to be broken down into smaller ones that can be approached systematically, and decisions about the priority of certain criteria over others may be needed (ETS1.C as in HS-ETS1-2) could connect to many different science ideas, including how all forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits (ESS3.A as in HS-ESS3-2) or how scientists and engineers are developing technologies that produce less pollution and waste and that preclude ecosystem degradation (ESS3.C as in HS-ESS3-4). Connections could be made through engineering design tasks such as prioritizing criteria and analyzing various methods of producing energy such as wind, water, coal, or solar, and evaluating the level of pollution that each of these methods produces.

The engineering design idea that both physical models and computers can be used in various ways to aid in the engineering design process (ETS1.B as in HS-ETS1-4) could connect to several science ideas, including how important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities (ESS3.D as in HS-ESS3-6) or to how scientists and engineers are developing technologies that produce less pollution and waste and that preclude ecosystem degradation (ESS3.C as in HS-ESS3-4). Connections could be made through engineering design tasks such as using computer-generated models to analyze data on how marinas or cruise ships can be designed or how landfills can be constructed to minimize waste and pollution to the ocean, atmosphere, and biosphere.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (HS-ETS1-1), using mathematics and computational thinking (HS-LS4-6, HS-ESS3-6, and HS-ETS1-4), designing solutions (HS-LS2-7, HS-ESS3-4, HS-ETS1-2, and HS-ETS1-3), and engaging in argument (HS-ESS2-7 and HS-ESS3-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-LS4-6), Systems and System Models (HS-ESS3-6 and HS-ETS1-4), and Stability and Change (HS-LS2-7, HS-ESS2-7, and HS-ESS3-4). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations HS-ESS2-7, HS-ETS1-1, HS-ETS1-2, and HS-ETS1-3 are partially assessable.	**HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*** [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.] **HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*** [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.] **HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.** [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.]

Performance Expectations (Continued)	**HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*** [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.] **HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).] **HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.** [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.] **HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** **HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** **HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.** **HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**
Example Phenomena	The bushes in the park died after English Ivy grew over them. The dust bowl affected the United States during the 1930s.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to clarify and refine a model, an explanation, or an engineering problem. Students could *ask questions to clarify and refine an engineering problem* [related to how] ***all forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits***. HS-ESS3-2 **Developing and Using Models** • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. Students could *evaluate merits and limitations of two different models in order to select the model that best fits the evidence* [for how] ***the ocean, atmosphere, and biosphere interact and are modified in response to human activities***. HS-ESS3-6

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. Students could *manipulate variables in a complex model,* [including] ***the ocean, atmosphere, biosphere, and human activities,*** *and collect data about* [how these] *variables* ***interact***. HS-ESS3-6 **Analyzing and Interpreting Data** • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. Students could *evaluate the impact of new data on a working model of a proposed* ***technology that produces less pollution and waste and that precludes ecosystem degradation***. HS-ESS3-4 **Using Mathematical and Computational Thinking** • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Students could *apply techniques of algebra and functions to represent problems* [related to how] ***human activity is having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change***. HS-LS4-6 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could *apply scientific ideas and evidence to provide an explanation* [for how] ***the ocean, atmosphere, and biosphere interact and are modified in response to human activities***. HS-ESS3-6 **Engaging in Argument from Evidence** • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. Students could *evaluate the claims and evidence behind the [relationship between]* ***climate model predictions and the amounts of human-generated greenhouse gases added to the atmosphere each year***. HS-ESS3-6 **Obtaining, Evaluating, and Communicating Information** • Compare, integrate, and evaluate sources of information presented in different media or formats (e.g, visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Students could *compare, integrate, and evaluate sources of information presented in different media or formats* [about how] ***anthropogenic changes in the environment such as habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change can disrupt an ecosystem and threaten the survival of some species***. HS-LS2-7

Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • 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. Students could *construct an argument about predicted complex cause and effect relationships by examining what is known about smaller scale mechanisms* [of how] ***the ocean, atmosphere, and biosphere interact and are modified in response to human activities***. HS-ESS3-6 **Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Students could obtain, evaluate, and communicate information about how *the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs*, [using as an example how] ***human activity is having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change***. HS-LS4-6 **Systems and System Models** • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. Students could construct an argument from evidence about how *models can be used to predict the behavior of a system, but these predictions have limited precision and reliability*, [using as an example models of how] ***feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it***. HS-ESS2-7
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. Students could obtain, evaluate, and communicate information about how a *scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed, and the science community validates each theory before it is accepted*, [using as an example that] ***feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it***. HS-ESS2-7 **Science Addresses Questions About the Natural and Material World** • Not all questions can be answered by science. Students could construct an argument for how ***when evaluating solutions, it is important to consider social, cultural, and environmental impacts of human activity on biodiversity*** and [for how] *not all* [of these] *questions can be answered by science*. HS-LS4-6 and HS-ETS1-3

High School Conceptual Progressions Model III – Bundle 4
Earth's Impact on Humans

This is the fourth bundle of the High School Conceptual Progressions Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 4 Question: This bundle is assembled to address the question "how do Earth's systems affect me?"	
Summary The bundle organizes performance expectations with a focus on helping students build understanding of the ways Earth systems affect human societies and vice versa. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations. **Connections between bundle DCIs** The availability of resources has guided the development of human society (ESS3.A as in HS-ESS3-1), and natural hazards and other geologic events have shaped the course of human history, significantly altering the sizes of human populations and driving human migrations (ESS3.B as in HS-ESS3-1). Our abilities to model, predict, and manage current and future impacts (ESS3.D as in HS-ESS3-5) from the environment have improved. However, the sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources (ESS3.C as in HS-ESS3-3). **Bundle Science and Engineering Practices** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of analyzing data (HS-ESS3-5), using mathematics and computational thinking (HS-ESS3-3), and constructing explanations (HS-ESS3-1). Many other practice elements can be used in instruction. **Bundle Crosscutting Concepts** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-ESS3-1) and Stability and Change (HS-ESS3-3 and HS-ESS3-5). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	**HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.** [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.] **HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.** [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]

Performance Expectations (Continued)	**HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.** [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]
Example Phenomena	Most major cities are located near large bodies of water. When the temperature increases in a region, people who live at higher altitudes can get malaria.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Evaluate a question to determine if it is testable and relevant Students could *evaluate questions* [about how] ***the sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources*** *to determine if the questions are testable and relevant*. HS-ESS3-3 **Developing and Using Models** • Design a test of a model to ascertain its reliability. Students could *design a test of a model* [of] ***the magnitudes of human impacts on*** [global climate] *to ascertain its reliability*. HS-ESS3-5 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make a directional hypothesis that specifies what happens to* ***biodiversity*** *when* ***management of natural resources*** [changes]. HS-ESS3-3 **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data to make valid and reliable scientific claims* [about how] ***natural hazards and other geologic events have shaped the course of human history***. HS-ESS3-1 **Using Mathematical and Computational Thinking** • Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model 'makes sense' by comparing the outcomes with what is known about the real world. Students could *use simple limit cases to test simulations* [of] ***the management of human impacts*** [on climate]. HS-ESS3-5 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could apply scientific ideas, principles, and evidence to provide an explanation [for how] ***the sustainability of human societies requires responsible management of natural resources***. HS-ESS3-3

Additional Practices Building to the PEs (Continued)	**Engaging in Argument from Evidence** • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required. Students could *respectfully provide and receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions* [about how] ***natural hazards and other geologic events have shaped the course of human history***. HS-ESS3-1 **Obtaining, Evaluating, and Communicating Information** • 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 Students could *communicate scientific information* [about how] ***the magnitudes of human impacts on*** [global climate] ***are greater than they have ever been***. HS-ESS3-5
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Changes in systems may have various causes that may not have equal effects. Students could construct an argument about how *changes in* [global climate] *may have various causes that may not have equal effects*, [including as evidence] ***the magnitude of human impacts*** [on climate]. HS-ESS3-5 **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Students could, *when describing* ***the sustainability of human societies and the biodiversity that supports them***, *define the boundaries and initial conditions of the system and analyze their inputs and outputs*. HS-ESS3-3 **Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. Students could develop a model for how *feedback can stabilize or destabilize a system*, [including a system of] ***responsible management of natural resources***. HS-ESS3-3
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific explanations can be probabilistic. Students could construct an argument about how *scientific explanations can be probabilistic*, [using as an example] ***explanations about the magnitudes of human impacts*** [on climate]. HS-ESS3-1 **Science Addresses Questions About the Natural and Material World** • Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. Students could construct an argument that many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues, [using as an example] ***human abilities to model, predict, and manage current and future impacts*** [on climate]. HS-ESS3-5

High School Conceptual Progressions Model Course III

Narrative and Rationale: This model course map is the third course in a three-year course sequence. It uses a customized version of the High School Conceptual Progressions model from NGSS Appendix K as the instructional year end goals. The PEs from Course 3 were then arranged into five different bundles of PEs based on a conceptual flow throughout the year.

Course 3 begins by expanding upon what was learned in Course 1 about ecosystems and heredity by taking a deeper look into the evolution of Earth systems and organisms. The course then focuses on how humans influence Earth systems and vice versa. It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations – additional practices and crosscutting concepts should be used throughout instruction in each bundle.

Bundle 1: Evolution of Earth ***~5 weeks***	**Bundle 2:** Evolution of Life ***~7 weeks***	**Bundle 3:** Human Influence on Earth ***~8 weeks***	**Bundle 4:** Earth's Impact on Humans ***~4 weeks***
HS-ESS1-5. Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. **HS-ESS1-6.** Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. **HS-ESS2-3.** Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.[1] **HS-ESS2-7.** Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth. [1]	**HS-LS2-1.** Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. **HS-LS2-2.** Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. **HS-LS2-6.** Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. **HS-LS2-8.** Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. **HS-LS4-1.** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. **HS-LS4-2.** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. **HS-LS4-3.** Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to	**HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* **HS-LS4-6.** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* **HS-ESS2-7.** Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth. **HS-ESS3-2.** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* **HS-ESS3-6.** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a	**HS-ESS3-1.** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. **HS-ESS3-3.** Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. **HS-ESS3-5.** Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

Bundle 1: Evolution of Earth ***~5 weeks***	**Bundle 2:** Evolution of Life ***~7 weeks***	**Bundle 3:** Human Influence on Earth ***~8 weeks***	**Bundle 4:** Earth's Impact on Humans ***~4 weeks***
	increase in proportion to organisms lacking this trait. **HS-LS4-4.** Construct an explanation based on evidence for how natural selection leads to adaptation of populations. **HS-LS4-5.** Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.	range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. **HS-ETS1-4.** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

High School Conceptual Progressions Course III Flowchart

Bundle 1

PS1.C as found in HS-ESS1-5 and HS-ESS1-6
- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other minerals.

ESS1.C as found in HS-ESS1-5
- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.

ESS1.C as found in HS-ESS1-6
- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

ESS2.A as found in HS-ESS2-3
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

ESS2.B as found in HS-ESS1-5
- Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history.

ESS2.B as found in HS-ESS2-3
- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

ESS2.D as found in HS-ESS2-7
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.

To LS4.C in Bundle 2

ESS2.E as found in HS-ESS2-7
- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it.

To LS4.C in Bundle 2

Bundle 2

To ESS3.A in Bundle 4

LS2.A as found in HS-LS2-1 and HS-LS2-2
- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

LS2.C as found in HS-LS2-2 and HS-LS2-6
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

LS2.D as found in HS-LS2-8
- Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.

LS4.A as found in HS-LS4-1
- Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

LS4.B as found in HS-LS4-2 and HS-LS4-3
- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information — that is, trait variation — that leads to differences in performance among individuals.

LS4.B as found in HS-LS4-3
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

LS4.C as found in HS-LS4-2
- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

LS4.C as found in HS-LS4-3 and HS-LS4-4
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

Bundle 3

LS2.C as found in HS-LS2-7
- Moreover, anthropogenic changes (induced by human activity) in the environment — including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change — can disrupt an ecosystem and threaten the survival of some species.

LS4.C as found in HS-LS4-6
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species.

LS4.D as found in HS-LS2-7
- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).

LS4.D as found in HS-LS2-7 and HS-LS4-6
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

ESS2.D as found in HS-ESS2-7
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.

ESS2.D as found in HS-ESS3-6
- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.

ESS2.E as found in HS-ESS2-7
- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it.

ESS3.A as found in HS-ESS3-2
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

ESS3.C as found in HS-ESS3-4
- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

ESS3.D as found in HS-ESS3-6
- Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

Bundle 4

ESS3.A as found in HS-ESS3-1
- Resource availability has guided the development of human society.

ESS3.B as found in HS-ESS3-1
- Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.

ESS3.C as found in HS-ESS3-3
- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

ESS3.D as found in HS-ESS3-5
- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.

LS4.C as found in HS-LS4-3
- Adaptation also means that the distribution of traits in a population can change when conditions change.

LS4.C as found in HS-LS4-5
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species.
- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.

To LS2.C and LS4.C in Bundle 3

ETS1.A as found in HS-ETS1-1
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

ETS1.B as found in HS-LS2-7, HS-LS4-6, HS-ESS3-2, HS-ESS3-4, and HS-ETS1-3
- When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

ETS1.B as found in HS-LS4-6 and HS-ETS1-4
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.

ETS1.C as found in HS-ETS1-2
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.

High School Science Domains Model Course 1-Chemistry-Bundle 1
Where do all the different elements come from?

This is the first bundle of the High School Domains Model Course 1-Chemistry. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question of "Where do all the different elements come from?"

Summary

The bundle organizes performance expectations around the theme of *elements are formed through nuclear processes*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. Also, each atom has a charged substructure (PS1.A as found in HS-PS1-1). These ideas connect ideas of atomic nuclei and nuclear processes including fission, fusion and radioactive decay (PS1.C as found in HS-PS1-8).

The idea of nuclear processes also connects (PS1.C as found in HS-PS1-8) to the concepts of nuclear fusion in the center of the sun (PS3.D as in HS-ESS1-1) and the idea that the sun is changing and will eventually burn out (ESS1.A as in HS-ESS1-1). The ideas of nuclear processes and nuclear fusion (PS3.D and ESS1.A as in HS-ESS1-1) connect to the concept that other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode (ESS1.A as in HS-ESS1-3).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models, and obtaining, evaluating, and communicating information. Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns, Energy and Matter, Scale, Proportion, and Quantity, and Energy and Matter. Many other CCC elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations HS-PS1-1 is partially assessable *(it is continued in Course 2: Physics)*	HS-PS1-1. **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [*Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*] HS-PS1-8. **Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [*Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*]

	HS-ESS1-1. **Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.** [Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [*Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.]* HS-ESS1-3. **Communicate scientific ideas about the way stars, over their life cycle, produce elements.** [Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [*Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.*]
Example Phenomena	When hydrogen gas is exposed to a lit match, it will explode. We can see the sun. When I get an x-ray, I cannot see the x-rays that are produced.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** ● Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Students could *examine the* **theories of how nuclear fusion processes in the center of the sun** *and can ask questions to seek additional information* [about the long term stability] **of the sun**. HS-ESS1-1 **Developing and Using Models** ● Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. Students could *use a computational model* [of] **radioactive decays of unstable nuclei** *to generate data to support explanations [of]* **nuclear processes**. HS-PS1-8 **Planning and Carrying Out Investigations** ● Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Students could *plan a* [hypothetical] *investigation* [that would] *produce data to serve as the basis for evidence* [that] **the composition of the nucleus of the atom changes during the processes of fission, fusion, and radioactive decay**. HS-PS1-8 **Analyzing and Interpreting Data** ● Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data using tools and technologies to make valid and reliable scientific claims* [about the way that] **nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation**. HS-ESS1-1

Additional Practices Building to the PEs (Continued)	**Using Mathematics and Computational Thinking** ● Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Students could *apply techniques of algebra and functions to represent and solve scientific problems* [related to the] **radioactive decays of unstable nuclei.** HS-PS1-8 **Constructing Explanations and Designing Solutions** ● Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could *apply scientific ideas [about the way that]* **the total number of neutrons plus protons does not change in any nuclear process** *[in order to] provide an explanation of phenomena, taking into account possible unanticipated effects*. HS-PS1-8 **Engaging in Argument from Evidence** ● Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. Students could *present an oral argument based on data and evidence [about the claim that]* **other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy**. HS-ESS1-3 **Obtaining, Evaluating, and Communicating Information** ● 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. Students could *critically read scientific literature adapted for classroom use to summarize complex evidence* [for the claim that] ***the star called the sun is changing and will burn out over a lifespan of approximately 10 billion years***,. HS-ESS1-1
Additional Crosscutting Concepts Building to the PEs	**Stability and Change** ● Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Students could describe *that some changes* [that involve] **nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei** *are irreversible*. HS-ESS1-8 **Energy and Matter** ● In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. Students could explain how *in nuclear processes,* **including fusion, fission, and radioactive decays of unstable nuclei**, *atoms are not conserved, but the total number of protons plus neutrons is conserved*. HS-PS1-8

Additional Crosscutting Concepts Building to the PEs (Continued)	**Scale, Proportion, and Quantity** ● The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Students could examine **radioactive decays of unstable nuclei, involving release or absorption of energy** [in order to determine] *the significance of a phenomenon* [based on its] *scale, proportion, and* [the] *quantity at which it occurs.* HS-PS1-8
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** ● Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. Students could consider the history of evidence supporting the concept that **stars' light spectra and brightness** [can be] **used to identify compositional elements of stars, their movements, and their distances from Earth** [to describe that] *most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence*. HS-ESS1-3 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ● Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Students could gather information about how scientists have formed the idea that **other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron** *based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future*. HS-ESS1-3

High School Science Domains Model Course 1-Chemistry-Bundle 2
Chemical Reactions

This is the second bundle of the High School Domains Model Course 1-Chemistry. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 2 Question: This bundle is assembled to address the question of "Why Do We Use Gasoline For Energy?"

Summary

The bundle organizes performance expectations with a focus of helping students understand how *the properties of an element determine the way its atoms will react with other atoms*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with the bundle performance expectations.

Connections between bundle DCIs

Elements have chemical properties (PS1.A as in HS-PS1-2) and the columns of the periodic table orders elements by these patterns (PS1.A as in HS-PS1-2). This idea connects to the concepts that knowledge of the chemical properties of the elements involved in a reaction can be used to describe and predict chemical reactions (PS1.B as in HS-PS1-7). The idea that atoms are conserved in these reactions (PS1.B as in HS-PS1-7) connects to the idea of energy through the concept that a stable molecule has less energy than the same set of atoms separated (PS1.A as in HS-PS1-4). This concept of energy in chemical reactions (PS1.A as in HS-PS1-4) also connects to the process of photosynthesis, and the idea that photosynthesis and cellular respiration are important components of the carbon cycle (LS2.B as in HS-LS2-5).

Concepts of the carbon cycle (LS2.B as in HS-LS2-5) connect to the ideas that gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen (ESS2.D as in HS-ESS2-6), human-generated greenhouse gases (ESS2.D as in HS-ESS3-6), the magnitude of human impacts on climate (ESS3.D as in HS-ESS3-5), and the complex set of interactions within an ecosystem (LS2.C as in HS-LS2-6).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of constructing explanations and designing solutions, developing and using models, using mathematics and computational thinking, engaging in argument from evidence, and analyzing and interpreting data. Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts Patterns, Energy and Matter, Systems and System Models, and Stability and Change. Many other CCC elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations HS-LS2-5 is partially assessable (it is continued in Course 3: Life Sciences)	HS-PS1-2. **Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*] HS-PS1-4. **Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and

	representations showing energy is conserved.] [*Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*] HS-PS1-7. **Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [*Assessment Boundary: Assessment does not include complex chemical reactions.*] HS-LS2-5. **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** [Clarification Statement: Examples of models could include simulations and mathematical models.] [*Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.*] HS-ESS2-6. **Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.** [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.] HS-ESS3-5. **Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.** [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [*Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.*] HS-ESS3-6. **Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.** [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [*Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*]
Example Phenomena	Wood burning in a campfire turns to ashes and smoke is formed. A metal fence appears to disintegrate as it rusts. Tillandsia ("air plants") don't need to be planted in soil in order to survive.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Students ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Students could *ask questions about how* **gradual atmospheric changes were due to plants and other organisms** *by examining models to clarify relationships between the* **atmosphere and organisms.** HS-ESS2-6

Additional Practices Building to the PEs (Continued)	**Developing and Using Models** • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. Students could *develop and use multiple types of models to provide mechanistic accounts of* **chemical processes, their rates, and whether or not energy is stored or released**. HS-PS1-4 **Planning and Carrying Out Investigations** ● Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. Students could *manipulate variables* [in] *a complex model of* **human impacts on global climate** *to improve* [hypothetical outcomes] *relative to criteria for success*. HS-ESS3-5 **Analyzing and Interpreting Data** ● Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. Students could *analyze and interpret data [related to]* **components of the carbon cycle** *[and in doing so] consider limitations of data analysis.* HS-LS2-5 **Using Mathematics and Computational Thinking:** ● Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.). Students could *apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems [related to]* **components of the carbon cycle** *involving quantities with derived or compound units.* HS-LS2-5 **Constructing Explanations and Designing Solutions:** ● Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could *apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena* [related to] **how the ocean, the atmosphere, and the biosphere interact.** HS-ESS3-6 **Engaging in Argument from Evidence:** ● Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. Students could *make and defend a claim based on evidence about* **how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities**. HS-ESS3-6

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information:** ● 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 (i.e., orally, graphically, textually, mathematically). Students could *communicate scientific and/or technical information or ideas about* **how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities** *in multiple formats (i.e., orally, graphically, textually, mathematically)*. HS-ESS3-6
Additional Crosscutting Concepts Building to the PEs	**Patterns** ● Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Students could examine **descriptions and predictions of chemical reactions** [and consider how] *classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced*. HS-PS1-2 **Energy and Matter** ● Energy drives the cycling of matter within and between systems. Students could describe *how energy drives the cycling of matter within and between systems* [in the] **carbon cycle**. HS-LS2-5 **Systems and Systems Models** ● Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. Students could *use models (e.g., physical, mathematical, computer models) to simulate* [that] **carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.** HS-LS2-5
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ● Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. Students could describe how models, [such as the] **periodic table,** [could] serve as a tool in the development of a scientific theory. HS-PS1-2 **Science is a Way of Knowing** ● Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review. Students could describe *the empirical standards* [necessary to understand] **chemical processes and their rates** , [and how these] *empirical standards* [are different from] *other ways of knowing*. HS-PS1-4

High School Science Domains Model Course 1-Chemistry-Bundle 3
The Flow of Energy

This is the third bundle of the High School Domains Model Course 1-Chemistry. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 3 Question: This bundle is assembled to address the question of "How can we get energy to flow from one place to another?"

Summary

The bundle organizes performance expectations with a focus on helping students understand *energy flows*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms (PS3.A as in HS-PS3-1). This idea of energy is expanded by the concept that at the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy (PS3.A as in HS-PS3-3). These ideas of energy and its forms then connect to ideas about the transfer of energy, which can occur through fields (PS2.B as in HS-PS2-5). Finally, the concept of energy connects to the idea of conservation of energy (PS3.B as in HS-PS3-4) and the conversion of energy in chemical reactions (PS3.D as in HS-PS3-4).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of planning and conducting investigations (HS-PS2-5 and HS-PS3-4), creating a computational model (HS-PS3-1), and designing, evaluating, and/or refining a solution (HS-PS3-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-PS2-5), Systems and System Models (HS-PS3-1 and HS-PS3-4), and Energy and Matter (HS-PS3-3). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	HS-PS2-5. **Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.** **[*Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.*]** HS-PS3-1. **Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** **[Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.]** **[*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]** HS-PS3-3. **Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** **[Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include**

	Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [*Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*] HS-PS3-4. **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]
Example Phenomena	Windmills can generate electricity. When the brakes are pressed in a hybrid car, the battery is recharged. To cool off the house on a hot day, I run the air conditioner. When my refrigerator is running, I feel warm air being blown on my feet.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** ● Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. Students could *define a design problem that involves the development of a process* [for the] **transfer of energy between systems.**. HS-PS3-1 **Developing and Using Models** ● Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Student could develop a model to illustrate the relationships between components in a system that **transports energy from one place to another**. HS-PS3-4 **Planning and Carrying Out Investigations** ● Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. Students could *manipulate variables and collect data about a complex model of a system* [in which] **energy is converted to less useful forms—for example, to thermal energy in the surrounding environment** [in order to] *to improve performance relative to criteria for success.* HS-PS3-3 **Analyzing and Interpreting Data** ● Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *collect and analyze data from a computational model of the* **energy in a system**, *in order to make valid and reliable scientific claims* [about how] **energy is continually transferred from one object to another and between its various possible forms.** HS-PS3-1

Additional Practices Building to the PEs (Continued)	**Using Mathematics and Computational Thinking** ● Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. Students could *compare the results of an algorithm of* [the amount of] **energy transferred from one object to another within a system** *to what is known about* **energy transfer** [in] *the real world*. HS-PS3-1 **Constructing Explanations and Designing Solutions** ● Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could *apply evidence about* [the amount of] **energy transferred from one object to another within a system** *to solve design problems*. HS-PS3-1 **Engaging in Argument from Evidence** ● Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). Considering competing design solutions, students could *evaluate the design solutions for their effectiveness using scientific knowledge* [of the] **transfer of thermal energy.** HS-PS3-4 **Obtaining, Evaluating, and Communicating Information** ● 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 (i.e., orally, graphically, textually, mathematically). Students could *communicate scientific information* [about the way that] **energy is transported from one place to another** *in multiple formats (i.e., orally, graphically, textually, mathematically)*. HS-PS3-4
Additional Crosscutting Concepts Building to the PEs	**Energy and Matter** ● Energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. When evaluating the **energy of a system**, students could describe how they take into account that *energy cannot be created or destroyed*. HS-PS3-1 and HS-PS3-3 **Patterns** ● Mathematical representations are needed to identify some patterns. Students could use *mathematical representations of* [data in order to identify] *patterns* [caused by] **forces** [acting] **at a distance.** HS-PS2-5 **Systems and Systems Models** ● When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Students could *define the boundaries and initial conditions of a system* [where] **energy is transported from one place to another** [and then] *analyze the inputs and outputs* [of that system] *using models*. HS-PS3-4

Additional Connections to Nature of Science	**Scientific Phenomena is Based on Empirical Evidence** ● Science knowledge is based on empirical evidence. Students could describe [the use of] *empirical evidence* [to make claims about how] **energy is transported from one place to another**. HS-PS3-4 **Science is a Human Endeavor** ● Technological advances have influenced the progress of science and science has influenced advances in technology. Students could investigate the development of devices made to **transport energy from one place to another** [to find information about how] *technological advances have influenced the progress of science and science has influenced advances in technology*. HS-PS3-4

High School Science Domains Model Course 1-Chemistry-Bundle 4
The Materials We Need

This is the fourth bundle of the High School Domains Model Course 1-Chemistry. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 4 Question: This bundle is assembled to address the question of "How and where do we get the materials we need?"

Summary

The bundle organizes performance expectations around the theme of *the materials we need*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors (ESS3.A as in HS-ESS3-2). Energy production and resource extraction connect to the ideas of water's capacity to absorb, store, and release large amounts of energy, and dissolve and transport materials (ESS2.C as in HS-ESS2-5) through the role of water in energy production and resource extraction.

The role of water in energy production and resource extraction has further connections chemical reactions through the idea that the collisions of molecules and the rearrangements of atoms into new molecules (PS1.B as in HS-PS1-5), which occur when water dissolves and transports materials (ESS2.C as in HS-ESS2-5). The ideas of chemical reactions (ESS2.C as in HS-ESS2-5) also connect to the concept that in many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present (PS1.B as in HS-PS1-6).

The ideas of energy production and resource extraction (ESS3.A as in HS-ESS3-2) have connections to the concept that when evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts (ETS1.B as in HS-ESS3-2). This could be accomplished through a student report reviewing methods of energy production and recommending methods based on an evaluation of their comparative costs, safety, or reliability. Alternatively, students could engage in a task that focuses on methods of mineral resource extraction, again through a student report reviewing methods and making recommendations based on an evaluation of their comparative costs, safety, or reliability.

The idea of a dynamic and condition-dependent balance between a reaction and the reverse reaction (PS1.B as in HS-PS1-6) connects to the idea that criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed (ETS1.C as in HS-PS1-6). This could be accomplished by having students engage in a task where they learn how engineers use principles of equilibrium and knowledge of chemical reactions to drive reactions to produce desired products or to increase the amount of product produced, and use this knowledge to recommend a manufacturing process that utilizes a recycled material that is reclaimed through a chemical reaction. Alternatively, students could engage in a task where they learn how engineers use principles of equilibrium and knowledge of chemical reactions to drive reactions to produce desired products or to increase the amount of product produced, and use this knowledge to recommend a manufacturing process that a material that is extracted through a chemical reaction.

The concept that criteria and constraints include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and that they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them (ETS1.A as in ETS1.1) could connect to the idea that energy production has associated economic, social, environmental, and geopolitical costs and risks as well as benefits (ESS3.A as in HS-ESS3-2). To explore this connection, students could engage in a task where they analyze a form of energy production in order to quantify the economic, social, environmental, and geopolitical risks associated with that resource. Students could propose a change to an energy production process that would meet criteria that would mitigate risks. Alternatively, students could engage in a similar task focusing on one form of energy production and on quantifying the risks associated with one risk category-either economic, social, environmental, or geopolitical. Students could propose a design change to a specific technology associated with that form of energy production based upon criteria that would mitigate risks in the identified category.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of constructing explanations and designing solutions (HS-PS1-5 and HS-PS1-6), planning and conducting an investigations (HS-ESS2-5), engaging in argument (HS-ESS3-2), and defining problems (HS-ETS1-1). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-PS1-5), Stability and Change (HS-PS1-6), Structure and Function (HS-ESS2-5), and Connections to Engineering, Technology, and Applications of Science (HS-ESS3-2 and HS-ETS1-1). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations HS-ESS2-5 is partially assessable (continued in Course 2: Physics).	HS-PS1-5. **Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** **[Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [*Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*]** HS-PS1-6. **Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* [Clarification Statement: Emphasis is on the application of Le Hotelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [*Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.*]**

Performance Expectations (Continued)	HS-ESS2-5. **Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]** HS-ESS3-2. **Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. * [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]** HS-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**
Example Phenomena	Bread rises faster in a warm room than in a cold room. Salt dissolves more easily in warm water than cold water. Some types of batteries can be recharged but other types of batteries cannot.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** ● Ask questions to clarify and refine a model, an explanation, or an engineering problem. Students could *ask questions to clarify* **environmental and societal constraints related to the management, utilization, and/or use of energy and mineral resources.** HS-ESS3-2 **Developing and Using Models** ● Develop a complex model that allows for manipulation and testing of a proposed process or system. Students could *create a model of a* **dynamic and condition-dependent balance between a reaction and the reverse reaction** in order to investigate the way that reaction would change under different conditions. HS-PS1-6 **Planning and Carrying Out Investigations** ● Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. Students could *plan and conduct an investigation to collect evidence for how* **temperature affects reaction rates.** HS-PS1-5

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** ● Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. After investigating **chemical reaction rates**, students could *compare* [their data to their classmates' data or another source of data to evaluate] *the consistency of relationships observed*. HS-PS1-5 **Using Mathematics and Computational Thinking** ● Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. [Students could *use an algorithmic representation of a* **chemical process** to describe [a method for increasing a desired product from a chemical system]. HS-PS1-6 **Constructing Explanations and Designing Solutions** ● 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. Students could use their understanding of how the **properties of water are central to the planet's dynamics** *to explain* [how processes in the] *natural world operate today as they did in the past*. HS-PS1-6 and HS-ESS2-5 **Engaging in Argument from Evidence** ● Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. Students could use their *evidence of* **the structure and properties of water** *in order to make and defend a claim about the* **roles of water in Earth's surface processes.** HS-ESS2-5 **Obtaining, Evaluating, and Communicating Information** ● 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. Students could *critically read scientific literature* [related to] **forms of energy production and other resource extraction** *to determine central ideas or conclusions* [about the] **associated economic, social, environmental, and geopolitical costs and risks and benefits**. HS-ESS3-2

Additional Crosscutting Concepts Building to the PEs	**Scale, Proportion, and Quantity** ● Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. Students could *use orders of magnitude to understand how models of the* **reaction and the reverse reaction in a chemical system** *at one scale relates to a model at another scale*. HS-PS1-6 **Systems and Systems Models** ● Models (e.g., physical, mathematical, computer models) can be used to simulate the flow of energy, matter, and interactions within and between systems at different scales. Students could *use models (e.g., physical, mathematical, computer models) to simulate the* **reaction and the reverse reaction in a chemical system** *at different scales*. HS-PS1-6 **Stability and Change** ● Changes and rates of change can be quantified and modeled over very short or very long periods of time. Students could *quantify* **change in the rates of chemical reactions** *over very short or very long periods of time*. HS-PS1-5
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ● Scientists often use hypotheses to develop and test theories and explanations. Students could describe *hypotheses* [that have] *tested theories about* **the balance between a reaction and the reverse reaction.** HS-PS1-6 **Science is a Human Endeavor** ● Technological advances have influenced the progress of science and science has influenced advances in technology. Students could gather information about *how science has influenced advances in* **mineral resources** *technology*. HS-ESS3-2

High School Domains Model Course 1 – Chemistry

Narrative and Rationale: This Chemistry model course map is the first in a three-year course sequence that uses a customized version of the Modified High School Domains Model from NGSS Appendix K as the instructional year end goals. The four bundles in this model are characterized by the overarching ideas that materials gained from natural resources are composed of atoms with characteristic chemical and physical properties, and that those properties affect the way that natural resources are formed and used. Using phenomena related to the formation of elements and materials as a way to connect bundles allows for students not only to master PEs, but also to develop a deeper understanding of the crosscutting concepts (CCCs) that they built throughout their K-8 experiences in science.

This course model is written with the assumption that it will come first in a high school sequence of Chemistry, Physics, and Biology courses, each with Earth and Space Sciences and Engineering Design integrated into the courses. This Chemistry course model is intended to lay the foundation for all other high school courses, and assumes that students enter high school with proficiency in the middle school DCIs, Science and Engineering Practices, and crosscutting concepts from the NGSS.

This model gives students the opportunity to deepen their understanding and use of the Science and Engineering Practices (SEPs). It places special emphasis on developing and using models, planning and carrying out investigations, and constructing explanations and designing solutions. The SEPs emphasized here contribute to students' understanding of both the CCCs and DCIs they explore. Students continue to grow in their capabilities with science and engineering practices over the course of the year and the level of sophistication at which they are able to engage in them, over time.

The bundles in this domains model guide students through the use of the SEPs, CCCs, and DCIs to answer the essential questions for each unit listed in the bundles below. It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional practices and crosscutting concepts should be used throughout instruction toward each bundle.

Bundle 1: Where do all the different elements come from? **~5 weeks**	**Bundle 2:** Why do we use gasoline for energy? **~5 weeks**	**Bundle 3:** How can we get energy to flow from one place to another? **~5 weeks**	**Bundle 4:** How and where do we get the materials we need? **~5 weeks**
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.[1] **HS-PS1-8.** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. **HS-ESS1-1**. Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. **HS-ESS1-3**. Communicate scientific ideas about the way stars, over their life cycle, produce elements.	**HS-PS1-2** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. **HS-PS1-4**. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. **HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. **HS-LS2-5.** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.[1] **HS-ESS2-6.** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	**HS-PS2-5.** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. **HS-PS3-1.** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. **HS-PS3-3.** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* **HS-PS3-4.** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within	**HS-PS1-5.** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. **HS-PS1-6.** Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* **HS-ESS2-5.** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.[1] **HS-ESS3-2**. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*

Bundle 1: Where do all the different elements come from? **~5 weeks**	**Bundle 2:** Why do we use gasoline for energy? **~5 weeks**	**Bundle 3:** How can we get energy to flow from one place to another? **~5 weeks**	**Bundle 4:** How and where do we get the materials we need? **~5 weeks**
	HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. **HS-ESS3-6.** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	**HS-ETS1-1**. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

High School Domains Model Course 1 (Chemistry) Flowchart

Bundle 1

PS1.A as found in HS-PS1-1
•Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
•The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

PS1.C as found in HS-PS1-8
•Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.

PS3.D as found in HS-ESS1-1
•Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.

ESS1.A as found in HS-ESS1-1
•The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

ESS1.A as found in HS-ESS1-3
•The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
•Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

Bundle 2

PS1.A as found in HS-PS1-2
•The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

PS1.A as found in HS-PS1-4
•A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

PS1.B as found in HS-PS1-2 and HS-PS1-7
•The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

PS1.B as found in HS-PS1-4
•Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

PS3.D as in HS-LS2-5
•The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.

LS2.B as found in HS-LS2-5
•Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

ESS2.D as found in HS-ESS2-6
• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
• Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

ESS2.D as found in HS-ESS3-6
•Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.

ESS3.D as found in HS-ESS3-5
• Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.

ESS3.D as found in HS-ESS3-6
• Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

Bundle 3

PS2.B as found in HS-PS2-5
•Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
•Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS3.A as found in HS-PS2-5
•"Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.

PS3.A as found in HS-PS3-1
•Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.A as found in HS-PS3-3
•At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

PS3.B as found in HS-PS3-1
•Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
•Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
•Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
•The availability of energy limits what can occur in any system.

PS3.B as found in HS-PS3-4
•Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
•Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

PS3.D as found in HS-PS3-3 and HS-PS3-4
•Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ETS1.A as found in HS-PS3-3
•Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

Bundle 4

PS1.B as found in HS-PS1-5
•Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

PS1.B as found in HS-PS1-6
•In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.

ESS2.C as found in HS-ESS2-5
•The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

ESS3.A as found in HS-ESS3-2
•All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

ETS1.A as found in HS-ETS1-1
•Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
•Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

ETS1.B as found in HS-ESS3-2
•When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

ETS1.C as found in HS-PS1-6
•Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

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High School Modified Domains Model Course II - Physics
Bundle 1: Why don't we fall through the floor?

This is the first bundle of the High School Domains Model Course II - Physics. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "why don't we fall through the floor?"

Summary

The bundle organizes performance expectations with a focus on helping students understand how forces arise from the interactions between fields. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Every atom has a substructure consisting of a nucleus, which is made of positively-charged protons and neutral neutrons, surrounded by negatively-charged electrons (PS1.A as in HS-PS1-1). This concept connects to the idea that the structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms (PS1.A as in HS-PS1-3), as well as the idea that attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformation of matter, as well as the contact forces between material objects (PS2.B as in HS-PS2-6).

These ideas about how the interactions between charged particles at the atomic level relate to observations of matter also connect to the concepts about how forces and energy relate to the interaction of objects at a variety of scales. This includes the idea that forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space, including between two atoms (PS2.B as in HS-PS2-4). The idea that the presence of fields explains energy transfer and forces between distant objects connects to the idea that when two objects interacting through a field change relative position, the energy stored in the field is changed (PS3.B as in HS-PS3-5).

These concepts about relationships between forces, energy transfer, and observations of matter at multiple scales all connect to quantitative concepts about the nature and transfer of energy. These include the idea that energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system, and that the existence of a single quantity called 'energy' (as opposed to multiple independent kinds of energy) is because a system's total energy is conserved, even as within the system, energy is continually transferred from one object to another and between its various possible forms (PS3.A as in HS-PS3-2). These concepts about the transfer and conservation of a single quantity 'energy' through various forms within systems are connected to the concepts of interactions of matter at the microscopic scale (e.g., particles, atoms), at which scale all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with their configuration, including cases in which the relative position energy can be thought of as stored in fields. This last concept includes radiation, a phenomenon in which energy stored in fields moves across space (PS3.A as in HS-PS3-2).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (HS-PS1-1, HS-PS3-2, and HS-PS3-5), planning and carrying out investigations (HS-PS1-3), using mathematical thinking (HS-PS2-4), and communicating information (HS-PS2-6). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-PS1-3 and HS-PS2-4), Cause and Effect (HS-PS3-5), Energy and Matter (HS-PS3-2), and Structure and Function (HS-PS2-6). Many other crosscutting elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	HS-PS1-1. **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.] HS-PS1-3. **Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.] HS-PS2-4. **Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.] HS-PS2-6. **Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.] HS-PS3-2. **Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).** [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.] HS-PS3-5. **Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]
Example Phenomena	When I use a compass close to a wire, the compass doesn't point to magnetic north. I can walk on a frozen lake but not on the same lake in the summer.

Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables. Students could *ask questions to determine relationships between the* ***relative positions*** [of] ***two objects interacting through a field*** [and] ***the energy stored in the field.*** HS-PS3-5 **Developing and Using Models** • Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. Students could *use* ***Coulomb's law*** [as] *a model to generate data to predict* ***the effects of electrostatic forces between distant objects***. HS-PS2-4 **Planning and Carrying Out Investigations** • Select appropriate tools to collect, record, analyze, and evaluate data. Students could *select appropriate tools to analyze data* [on the relationship between the] ***attraction and repulsion between electric charges at the atomic scale*** [and] ***the properties of matter***. HS-PS2-6 **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data using tools, technologies, and/or models in order to make valid and reliable science claims* [about how] ***when two objects interacting through a field change relative position, the energy stored in the field is changed***. HS-PS3-5 **Using Mathematical and Computational Thinking** • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Students could *apply techniques of algebra and functions to represent* [that] ***when two objects interacting through a field change relative position, the energy stored in the field is changed***. HS-PS3-5 **Constructing Explanations and Designing Solutions** • Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. Students could *make a qualitative claim regarding the relationships between* ***the structure of matter at the bulk scale*** [and the] ***electrical forces within and between atoms***. HS-PS1-3 **Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. Students could *construct a written argument based on data and evidence* [for how] ***the structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms***. HS-PS1-3

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. Students could *evaluate the validity and reliability of multiple claims* [about how] ***attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects***. HS-PS2-6
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Students could construct an argument for [how the concept that] ***attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects*** [relates to the concept that] *explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced*. HS-PS2-6 **Energy and Matter** • The total amount of energy and matter in closed systems is conserved. Students could develop a model for how ***when two objects interacting through a field change relative position, the energy stored in the field is changed,*** [but] *the total amount of energy in closed system is conserved*. HS-PS3-5 **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. Students could construct an argument for how *the functions and properties of natural and designed objects can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials,* [which] ***are determined by electrical forces within and between atoms***. HS-PS1-3
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence:** • Science knowledge is based on empirical evidence. Students could construct an argument [that our] *knowledge* [about how] ***forces at a distance are explained by fields permeating space that can transfer energy through space***, *is based on empirical evidence*. HS-PS2-4 **Science Addresses Questions About the Natural and Material World:** • Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. Students could evaluate design solutions [that make use of the scientific ideas about] ***field permeating space that can transfer energy***, [taking into account that] *many decisions rely on social and cultural contexts to resolve issues* [about the use of the design solution]. HS-PS2-4

High School Modified Domains Model Course II - Physics
Bundle 2: How Do We Protect Ourselves From Collisions?

This is the second bundle of the High School Domains Model Course II - Physics. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 2 Question: This bundle is assembled to address the question "how do we protect ourselves from collisions?"

Summary

The bundle organizes performance expectations with a focus on helping students understand forces and collisions at the macroscopic scale. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object relative to the reference frame (PS2.A as in HS-PS2-2). While momentum within a system is conserved, the total momentum of a system can change if a system interacts with objects outside itself; however, these changes are balanced by changes in the momentum of objects outside the system (PS2.A as in HS-PS2-2 and HS-PS2-3). These ideas connect to the concepts about the motion objects, including that Newton's second law accurately predicts changes in the motion of macroscopic objects (PS2.A as in HS-PS2-1) while Kepler's laws describe common features of the motions of orbiting objects (ESS1.B as in HS-ESS1-4).

The concepts about momentum changes in systems and about Kepler's laws connect to ideas about the motion of objects within and outside of our solar system at different scales. In addition to the common features of the motions of orbiting objects described by Kepler's laws, the motion of objects outside our solar system, such as the motions of other solar systems and galaxies, can be understood through the Big Bang theory. The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation that still fills the universe (ESS1.A as in HS-ESS1-2). These ideas about the kinds of observations that provide astronomical evidence for the Big Bang theory connect to the concept that studying the light spectra and brightness of stars aids in the identification of compositional elements of stars, their movements, and their distances from Earth (ESS1.A as in HS-ESS1-2), and to the idea that atoms of each element emit and absorb characteristic frequencies of light which allow identification of the presence of an element, even in microscopic quantities (PS4.B as in HS-ESS1-2).

The engineering design concept that criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them (ETS1.A as in HS-ETS1-1) could be applied to a variety of science concepts, such as definitions of momentum as the mass times the velocity of the object (PS2.A as in HS-PS2-2) and balance of momentum changes within a given system by changes in the momentum of interacting objects outside the system (PS2.A as in HS-PS2-2, HS-PS2-3). Connections could be made through engineering design tasks such as identifying the criteria and constraints for designing safer vehicles or developing more energy efficient modes of transportation.

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts (ETS1.B as in HS-ETS1-3). This engineering design concept connects to other engineering concepts about criteria and constraints (ETS1.A as in HS-ETS1-1) and could also be applied to a variety of science concepts, including that momentum is the mass times the velocity of the object (PS2.A as in HS-PS2-2) or that if a system interacts with objects outside itself, any change in the system is balanced by changes in the momentum of objects outside the system (PS2.A as in HS-PS2-2, HS-PS2-3). Connections could be made through engineering design tasks such as taking into account a range of constraints for the development of energy production technologies such as generators, wind turbines, or small motors, or for the design of amusement park rides such as roller coasters, water rides, or merry-go-rounds.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (HS-ETS1-1), analyzing data (HS-PS2-1), using mathematical and computational representations (HS-PS2-2 and HS-ESS1-4), and constructing explanations and designing solutions (HS-PS2-3, HS-ESS1-2, and HS-ETS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-PS2-1 and HS-PS2-3), Scale, Proportion, and Quantity (HS-ESS1-4), Systems and System Models (HS-PS2-2), and Energy and Matter (HS-ESS1-2). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	HS-PS2-1. **Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.** [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one dimensional motion and to macroscopic objects moving at non-relativistic speeds.] HS-PS2-2. **Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.** [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.] HS-PS2-3. **Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*** [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.] HS-ESS1-2. **Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).] HS-ESS1-4. **Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.] HS-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**

Performance Expectations (Continued)	HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.**
Example Phenomena	Fewer people die in car accidents when they have airbags versus those who don't have airbags. When one billiard ball strikes another billiard ball, the first ball might stop while the second ball starts moving.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to clarify and refine a model, an explanation, or an engineering problem. Students could *ask questions to clarify and refine an explanation* [for how] ***if a system interacts with objects outside itself, the total momentum of the system can change***. HS-PS2-2 and HS-PS2-3 **Developing and Using Models** • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Students could *use a model based on evidence to predict relationships* [of distance between our galaxy and] ***distant galaxies*** [based on] ***the Big Bang theory***. HS-ESS1-2 **Planning and Carrying Out Investigations** • Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Students could *plan an investigation to produce data to serve as the basis for evidence* [that] ***momentum is the mass times the velocity of an object***. HS-PS2-2 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. Students could *consider limitations of data analysis when analyzing and interpreting data* [on how] ***orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system***. HS-ESS1-4 **Using Mathematical and Computational Thinking** • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Students could *apply techniques of algebra and functions to represent and solve engineering problems* [related to how] ***orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system***. HS-ESS1-4

Additional Practices Building to the PEs (Continued)	**Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *apply scientific reasoning and models to assess the extent to which the reasoning and data support the explanation* [that] ***orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system***. HS-ESS1-4 **Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. Students could *construct and present an oral written argument based on data and evidence* [that] ***momentum is the mass times the velocity of the object***. HS-PS2-2 **Obtaining, Evaluating, and Communicating Information** • 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). Students could *communicate scientific information* [about how] ***observations of the maps of spectra of the primordial radiation that fills the universe support the Big Bang theory***. HS-ESS1-2
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Empirical evidence is needed to identify patterns. Students could describe why *empirical evidence to identify* [the] *pattern* [that] ***Newton's second law accurately predicts changes in the motion of macroscopic objects***. HS-PS2-1 **Cause and Effect** • 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. Students could *suggest cause and effect relationships of* ***the total momentum of a system*** [during a collision with an] ***object outside itself*** *by examining what is known about smaller scale mechanisms within the system*. HS-PS2-2 and HS-PS2-3 **Systems and System Models** • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. Students could construct an argument for how *models can be used to predict the behavior of* ***orbits*** [of] ***objects in the solar system****, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models* [for how] ***orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system***. HS-ESS1-4

Additional Connections to Nature of Science	**Scientific Investigations use a Variety of Methods (SEP):** • New technologies advance scientific knowledge. Students could construct an argument for how *new technologies* [have] *advanced scientific knowledge*, [including how] ***Kepler's laws describe common features of orbiting objects***. HS-ESS1-4 **Science is a Human Endeavor (CCC):** • Science and engineering are influenced by society and society is influenced by science and engineering. Students could construct an argument for how *engineering is influenced by society and society is influenced by engineering* [for issues related to] ***risk mitigation*** [during collisions]. HS-PS2-3

High School Modified Domains Model Course II - Physics
Bundle 3: What Happens When Energy Moves from One Place to Another?

This is the third bundle of the High School Domains Model Course II - Physics. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question "what happens when energy moves from one place to another?"

Summary

The bundle organizes performance expectations with a focus on helping students understand forces and energy transfer when objects interact. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as within the system, energy is continually transferred from one object to another, and between its various possible forms (PS3.A as in HS-PS3-1). These ideas connect to the concept that energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems (PS3.B as in HS-PS3-1 and HS-PS3-4). This also connects to the idea that at the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy (PS3.A as in HS-PS3-3) and although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment (PS3.D as in HS-PS3-3 and HS-PS3-4), and also to the idea that mathematical expressions, which quantify how the stored energy in a system depends on its configuration and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior (PS3.B as in HS-PS3-1). The availability of energy limits what can occur in any system and uncontrolled systems always evolve toward more stable states (PS3.B as in HS-PS3-4).

These ideas about energy and systems connect to the ideas about Earth's systems and their transfer of energy, including that the foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space (ESS2.D as in HS-ESS2-2 and HS-ESS2-4); the abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics (ESS2.C as in HS-ESS2-5); Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes (ESS2.A as in HS-ESS2-1 and HS-ESS2-2); the radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of heat that drives mantle convection (ESS2.B as in HS-ESS2-3); motions of the Earth's mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy form Earth's interior and gravitational movement of denser materials toward the interior (ESS2.A as in HS-ESS2-3); the geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities (ESS2.A as in HS-ESS2-4); and that changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate (ESS2.D as in HS-ESS2-4).

The engineering design concepts that criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others may be needed (ETS1.C as in HS-ETS1-2) could be applied to many different science ideas, including how the foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space (ESS2.D as in HS-ESS2-2 and HS-ESS2-4) or how changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate (ESS2.D as in HS-ESS2-4). Connections could be made through an engineering design task such as breaking criteria down into simpler ones to develop systems of transportation that emit less carbon, or designing artificial climate control systems for a greenhouse or school.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (HS-ESS2-1, HS-ESS2-3, and HS-ESS2-4), planning and conducting investigations (HS-PS3-4 and HS-ESS2-5), analyzing data (HS-ESS2-2), using mathematics and computational thinking (HS-PS3-1), and constructing explanations and designing solutions (HS-PS3-3 and HS-ETS1-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-ESS2-4); Systems and System Models (HS-PS3-4 and HS-PS3-1); Energy and Matter (HS-PS3-3 and HS-ESS2-3); Structure and Function (HS-ESS2-5); and Stability and Change (HS-ESS2-1 and HS-ESS2-2). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	HS-PS3-1. **Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.] HS-PS3-3. **Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.] HS-PS3-4. **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.] HS-ESS2-1. **Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.]

Performance Expectations (Continued)	HS-ESS2-2. **Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.** [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.] HS-ESS2-3. **Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.] HS-ESS2-4. **Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.** [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.] HS-ESS2-5. **Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).] HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**
Example Phenomena	A solar oven can get hot enough to cook food. When hot and cold water are mixed together, they reach a final temperature that is between each of the original temperatures.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. Students could *evaluate questions that challenge the premise(s) of an argument* [about how] ***interactions among changes in the Earth's orbit and ocean circulation change global and regional climate***. HS-ESS2-4 **Developing and Using Models** • Design a test of a model to ascertain its reliability. Students could *design a test of a model* [of how] ***energy can be converted to less useful forms*** *to ascertain its reliability*. HS-PS3-3

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively to produce data to serve as the basis for evidence as part of supporting explanations for phenomena. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Students could *plan an investigation to produce data* [that could] *serve as the basis for evidence* [for the claim that] ***the foundation for Earth's global climate systems is the electromagnetic radiation from the sun***. HS-ESS2-2 and HS-ESS2-4 **Analyzing and Interpreting Data** • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. Students could *apply concepts of statistics and probability* [to analyze whether] ***Earth's systems cause feedback effects***. HS-ESS2-2 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could *use mathematical representations to describe and support the claim* [that] ***in a system the total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms***. HS-PS3-1 **Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *apply scientific reasoning and models to assess the extent to which the reasoning and data support an explanation* [for how] ***Earth's systems cause feedback effects***. HS-ESS2-2 **Engaging in Argument from Evidence** • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. Students could *evaluate the evidence, and reasoning behind currently accepted explanations* [for how] ***evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust***. HS-ESS2-3 **Obtaining, Evaluating, and Communicating Information** • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Students could *evaluate sources of information presented in different formats* [about how] ***the total change of energy in any system is always equal to the total energy transferred into or out of the system***. HS-PS3-1

Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • 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. Students could construct an argument from evidence for how *cause and effect relationships can be suggested and predicted* [for the relationship between] ***human activity*** [and] ***increased carbon dioxide concentrations***. HS-ESS2-4 **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. Students could describe *models that simulate systems and interactions within and between systems at different scales*, [including the interactions between the Earth's] ***mantle convection and the radioactive decay of unstable isotopes within Earth's crust and mantle***. HS-ESS2-3 **Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of and within that system. Students could develop a model of *energy and matter flows into, out of and within a system* [to describe that] ***energy cannot be created or destroyed, but it can be transported form one place to another and transferred between systems***. HS-PS3-1 and HS-PS3-4
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Laws are statements or descriptions of the relationships among observable phenomena. Students could construct an argument for how *laws are statements or descriptions of the relationships among observable phenomena*, [including how] ***the total change of energy in any system is always equal to the total energy transferred into or out of the system***. HS-PS3-1 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Students could construct an argument for how *scientific knowledge, [such as the causes of]* ***global and regional climate****, is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future*. HS-ESS2-4

High School Modified Domains Model Course II - Physics
Bundle 4: How Do We Use Energy to Communicate with Each Other?

This is the fourth bundle of the High School Domains Model Course II - Physics. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 4 Question: This bundle is assembled to address the question "how do we use energy to communicate with each other?"

Summary

The bundle organizes performance expectations around the theme of *how energy is used to communicate.* Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing (PS4.A as in HS-PS4-1). These features of waves and their interactions with matter connect to concepts about electromagnetic radiation, including that electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields. The wave model is useful for explaining many features of electromagnetic radiation, while the particle model explains other features (PS4.B as in HS-PS4-3).

Understanding how different kinds of waves influence the interaction between energy and matter connects to the idea that multiple technologies are based on an understanding of waves and their interactions with matter (PS4.C as in HS-PS4-5). This includes concepts like photoelectric materials emitting electrons when they absorb light of a high-enough frequency (PS4.B as in HS-PS4-5), and that when light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy, and that shorter wavelength electromagnetic radiation can ionize atoms and cause damage to living cells (PS4.B as in HS-PS4-4). Technologies built on concepts of waves and interactions with matter connect to the idea that information can be digitized, and in this form can be stored reliably and sent over long distances in a series of wave pulses (PS4.A as in HS-PS4-2 and HS-PS4-5). These technologies are part of everyday experiences in the modern world and in scientific research. They are essential tools for producing, transmitting, and capturing signals for storing, and interpreting the information contained in them (PS4.C as in HS-PS4-5).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions (HS-PS4-2), using mathematical thinking (HS-PS4-1), engaging in argument (HS-PS4-3), and obtaining, evaluating, and communicating information (HS-PS4-4 and HS-PS4-5). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-PS4-1, HS-PS4-4, and HS-PS4-5), Systems and System Models (HS-PS4-3), and Stability and Change (HS-PS4-2). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	HS-PS4-1. **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.] HS-PS4-2. **Evaluate questions about the advantages of using a digital transmission and storage of information.** [Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.] HS-PS4-3. **Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.** [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include using quantum theory.] HS-PS4-4. **Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.** [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.] HS-PS4-5. **Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*** [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]
Example Phenomena	We can communicate using Bluetooth. Lab technicians use MRIs to collect information about their patients.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Students could *ask questions that arise from examining models to clarify* [how] ***the wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features***. HS-PS4-3 **Developing and Using Models** • Design a test of a model to ascertain its reliability. Students could *design a test of a model* [of how] ***photoelectric materials emit electrons when they absorb light of a high-enough frequency*** *to ascertain its reliability*. HS-PS4-5 **Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively to produce data as part of testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Students could *plan an investigation to produce data to test solutions to a problem* [related to the fact that] ***photoelectric materials emit electrons when they absorb light of a high-enough frequency***. HS-PS4-5

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims* [about how] ***the wavelength and frequency of a wave are related to one another by the speed of travel of the wave***. HS-PS4-1 **Using Mathematical and Computational Thinking** • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Students could *apply techniques of algebra and functions to represent problems* [related to] ***the storage of information,*** [comparing the reliability of] ***digital storage*** [to other types of storage]. HS-PS4-2 **Constructing Explanations and Designing Solutions** • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. Students could *evaluate a solution to a complex real-world problem* [related to how] ***photoelectric materials emit electrons when they absorb light of a high-enough frequency***. HS-PS4-5 **Engaging in Argument from Evidence** • Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. Students could *compare and evaluate competing arguments in light of limitations, constraints, and ethical issues* [related to how] ***electromagnetic radiation can ionize atoms and cause damage to living cells***. HS-PS4-4 **Obtaining, Evaluating, and Communicating Information** • 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. Students could *critically read scientific literature to obtain and summarize technical information* [about how] ***information can be digitized, stored reliably in computer memory and sent over long distances as a series of wave pulses***. HS-PS4-2
Additional Crosscutting Concepts Building to the PEs	**Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g. linear growth vs. exponential growth). Students could describe how *algebraic thinking could be used to examine scientific data and predict the effect of a change in one variable on another* [related to how] ***the wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing***. HS-PS4-1

Additional Crosscutting Concepts Building to the PEs (Continued)	**Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. Students could describe the necessity of *examining the structures and connections of different components* [in order to] *reveal their function* [related to how] ***information can be digitized and sent over long distances as a series of wave pulses***. HS-PS4-2 **Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. Students could obtain and communicate information about how *feedback can stabilize or destabilize a system* ***of waves traveling in various media***. HS-PS4-1
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena (SEP):** • Scientists often use hypotheses to develop and test theories and explanations. Students could obtain and communicate information about how *scientists often use hypotheses to develop and test theories and explanations*, [including that] ***the wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features***. HS-PS4-3 **Science is a Human Endeavor (CCC):** • Science and engineering are influenced by society and society is influenced by science and engineering. Students could construct an argument for how *science and engineering are influenced by society and society is influenced by science and engineering*, [using as an example how] ***multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world and in scientific research***. HS-PS4-5

High School Science Domains Model Course III – Life Sciences
Bundle 1: Changes to Earth

This is the first bundle of the High School Domains Model Course III – Life Sciences. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the question "why does Earth look so different than it used to?"	
Summary The bundle organizes performance expectations with a focus on helping students build understanding of the changes to Earth over time. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations. **Connections between bundle DCIs** Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history (ESS1.C as in HS-ESS1-6). Additional information about Earth's history can be provided by radiometric dating, which can be used to determine the ages of rocks and other materials. Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old (ESS1.C as in HS-ESS1-5). Over time, gradual atmospheric changes occurred due to plants and other organisms that captured carbon dioxide and released oxygen. This lead to many dynamic and delicate feedbacks between the biosphere and other Earth systems causing a continual co-evolution of Earth's surface and the life that exists on it (ESS2.E as in HS-ESS2-7). **Bundle Science and Engineering Practices** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of constructing explanations and designing solutions (HS-ESS1-6) and engaging in argument from evidence (HS-ESS1-5 and HS-ESS2-7). Many other practice elements can be used in instruction. **Bundle Crosscutting Concepts** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-ESS1-5) and Stability and Change (HS-ESS1-6 and HS-ESS2-7). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	**HS-ESS1-5. Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.** [Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).] **HS-ESS1-6. Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.** [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

Performance Expectations (Continued)	**HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.** [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.]
Example Phenomena	Pictures of Mars appear to show canyons similar to those on Earth. Compost helps plants grow.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation of* ***radiometric dating from continental rocks and rocks on the ocean floor*** *to seek additional information* [about the cause of the results]. HS-ESS1-5 **Developing and Using Models** • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Students could *use a model to predict the relationships between* ***the biosphere and other Earth systems,*** [including the feedbacks that] ***cause a continual co-evolution of Earth's surface and the life that exists on it***. HS-ESS2-7 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make directional hypotheses that specify what happens to* ***the rock record on Earth*** *when* ***active geologic processes*** [occur]. HS-ESS1-6 **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims* [that] ***objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years***. HS-ESS1-6 **Using Mathematical and Computational Thinking** • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Students could *apply techniques of algebra and functions to represent* [the] ***characteristic exponential decay law of spontaneous radioactive decays***. HS-ESS1-5 and HS-ESS1-6

Additional Practices Building to the PEs (Continued)	**Constructing Explanations and Designing Solutions** • 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. Students could *construct an explanation based on valid and reliable evidence obtained from a variety of sources* [about how] ***the many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it***. HS-ESS2-7 **Engaging in Argument from Evidence** • Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. Students could *make and defend a claim based on evidence* [that] ***active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth***. HS-ESS1-6 **Obtaining, Evaluating, and Communicating Information** • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. Students could *gather, read, and evaluate scientific and/or technical information from multiple authoritative sources [about how]* ***gradual atmospheric changes were due to plants and other organisms capturing carbon dioxide and releasing oxygen****, assessing the evidence and usefulness of each source***.** HS-ESS2-7
Additional Crosscutting Concepts Building to the PEs	**Patterns** • 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. Students could identify and describe *different patterns at each of the scales at which* ***the continual co-evolution of Earth's surface and the life that exists on it*** *is studied*. HS-ESS2-7 **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Students could *provide critiques of arguments* [about how] ***gradual atmospheric changes were related to plants and other organisms,*** [including in their critiques the principle that] *empirical evidence is required to differentiate between cause and correlation*. HS-ESS1-5 **Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Students could construct an argument [for why] *some system changes are irreversible*, [using as evidence that] ***spontaneous radioactive decays follow a characteristic exponential decay law***. HS-ESS1-5 and HS-ESS1-6

Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods** • Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge. Students could obtain and communicate information [about the idea that] *scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge,* [including knowledge about how] ***the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it***. HS-ESS2-7 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Students could construct an argument [for why the principle that] *scientific knowledge is based on the assumption that natural laws operate today as they did in the past and that they will continue to do so in the future* [helps us understand that] ***plate tectonics provides a framework for understanding Earth's geologic history.*** HS-ESS1-5

High School Modified Domains Model Course III – Life Sciences
Bundle 2: How Organisms Use Matter and Energy

This is the second bundle of the High School Domains Model Course III – Life Sciences. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 2 Question: This bundle is assembled to address the question "how do our bodies function?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how organisms obtain and use the matter and energy they need to live and grow. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle concepts

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 as in HS-LS1-2). As matter and energy flow through these different organizational levels of living systems, chemical elements are recombined in different ways to form different products (LS1.C as in HS-LS1-6, HS-LS1-7). The complex chemical processes of photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy [and matter] for life processes (LS2.B as in HS-LS2-3) on Earth. The main way that solar energy is captured and stored is through photosynthesis (PS3.D as in HS-LS2-5), which converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen (LS1.C as in HS-LS1-5). Conversely, in cellular respiration, the bonds of sugars or food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles (LS1.C as in HS-LS1-7).

As a result of these chemical reactions, energy is transferred form one system of interacting molecules to another and is released to the surrounding environment, including to maintain body temperature (LS1.C as in HS-LS1-7). All of these processes work together using feedback mechanisms to 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 or discourage what is going on inside the living system (LS1.A as in HS-LS1-3).

The engineering design idea that criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them (ETS1.A as in HS-ETS1-1) could connect to many different science ideas, such as how the process of photosynthesis converts light energy to stored chemical energy (LS1.C as in HS-LS1-6) or how photosynthesis and cellular respiration are important components of the carbon cycle (LS2.B as in HS-LS2-5). Connections could be made through engineering design tasks, for example, where students analyze the criteria and constraints for developing more efficient solar energy collection using a model of photosynthesis, or for decreasing atmospheric carbon dioxide levels by manipulating photosynthesis.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions and defining problems (HS-ETS1-1), developing and using models (HS-LS1-2, HS-LS1-5, HS-LS1-7, and HS-LS2-5), planning and carrying out investigations (HS-LS1-3), and constructing explanations and designing solutions (HS-LS1-6 and HS-LS2-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the concepts of Systems and System Models (HS-LS1-2 and HS-LS2-5), Energy and Matter (HS-LS1-6, HS-LS1-7, and HS-LS2-3), and Stability and Change (HS-LS1-3). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	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, stomate 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-LS1-5. **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.] HS-LS1-6. **Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.** [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.] HS-LS1-7. **Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.** [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.] 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.] HS-LS2-5. **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** [Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.] HS-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**
Example Phenomena	We get sweaty when we exercise. Some bread dough rises if you leave it in a cool, dark place.

Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Students could *ask questions that arise from examining models of the* ***structural organization of multicellular organisms*** *to clarify relationships* [between body systems]. HS-LS1-2 **Developing and Using Models** • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. Students could *evaluate the merits and limitations of two different models [for how]* ***photosynthesis and cellular respiration provide most of the energy for life processes*** *to select a model that best fits the evidence*. HS-LS2-3 **Planning and Carrying Out Investigations** • Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Students could *plan a [hypothetical] investigation to produce data to serve as the basis for evidence* [that] ***photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen***. HS-LS1-5 **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims* [that] ***carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes***. HS-LS2-5 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could *use mathematical representations of phenomena to describe and/or support claims* [that] ***feedback mechanisms maintain living system's internal conditions within certain limits even as external conditions change within some range***. HS-LS1-3

Additional Practices Building to the PEs (Continued)	**Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *apply scientific reasoning to assess the extent to which the reasoning and data support the explanation* [that] ***carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.*** HS-LS2-5 **Engaging in Argument from Evidence** • Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. Students could *make and defend a claim based on evidence* [of how] ***feedback mechanisms allow*** [an organism] ***to remain alive and functional even as external conditions change within some range***. HS-LS1-3 **Obtaining, Evaluating, and Communicating Information** • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Students could *compare, integrate and evaluate sources of information presented in different media or formats* [for how] ***cellular respiration releases energy to maintain body temperature***. HS-LS1-7
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • 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. Students could suggest cause and effect relationships [for how] ***feedback mechanisms maintain a living system's internal conditions***. HS-LS1-3 **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Students could define the boundaries, initial conditions, the inputs, and outputs of the system model [of] ***the process of photosynthesis***. HS-LS1-5 **Energy and Matter** • The total amount of energy and matter in closed systems is conserved. Students could use mathematical representations [to show that] ***carbon*** *is conserved* ***[as it] is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes***. HS-LS2-5

Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence** • Science disciplines share common rules of evidence used to evaluate explanations about natural systems. Students could communicate information [about why] *science disciplines share common rules of evidence when evaluating explanations*, [and how these common rules of evidence have affected our understanding of how] ***chemical elements are recombined in different ways to form different products.*** HS-LS1-6 and HS-LS1-7 **Science is a Way of Knowing** • Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review. Students could communicate [how] *science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review*, [and how this way of knowing led to our understanding that] ***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***. HS-LS1-2

High School Modified Domains Model Course III – Life Sciences
Bundle 3: Genetic Information Affects the Diversity of Life

This is the third bundle of the High School Domains Model Course III – Life Sciences. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question "how are there so many different kinds of organisms?"

Summary
The bundle organizes performance expectations with a focus on helping students build understanding of how genes affect traits and the evolution of populations. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
In multicellular organisms, individual cells grow and then divide via a process called mitosis, with each parent cell passing identical genetic material to both daughter cells. Cellular division and differentiation produce and maintain a complex organism (LS1.B as in HS-LS1-4) with systems of specialized cells that help them perform the essential functions of life (LS1.A as in HS-LS1-1). Genes are regions in the DNA that contain the instructions that code for the formation of proteins (LS1.A as in HS-LS1-1 and HS-LS3-1). In addition to protein formation, some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function (LS3.A as in HS-LS3-1).

Unlike mitosis, in sexual reproduction during the process of meiosis, chromosomes can sometimes swap sections, thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation (LS3.B as in HS-LS3-2). Environmental factors also affect expression of traits, thus the variation and distribution of traits observed in a population depends on both genetic and environmental factors (LS3.B as in HS-LS3-2 and HS-LS3-3).

If there is both variation in the genetic information between organisms in a population and variation in the expression of that genetic information that leads to differences in performance among individuals, then natural selection can occur (LS4.B as in HS-LS4-2), which can lead to evolution. Evolution can occur if a species has the potential to increase in number, there is genetic variation among individuals in the species due to mutation and sexual reproduction, there is competition for resources, and there is a proliferation of those organisms that are better able to survive and reproduce in that environment (LS4.C as in HS-LS4-2). Genetic information helps to provide evidence of evolution. Overlapping DNA sequences as well as similarities and differences in amino acid sequences, anatomy, and embryological development all serve as evidence (LS4.A as in HS-LS4-1).

The engineering design idea that criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them (ETS1.A as in HS-ETS1-1) could connect to several different science ideas, such as how the genes expressed by a cell may be regulated in different ways and some segments of DNA are involved in regulatory functions (LS3.A as in HS-LS3-1) and how cellular division and differentiation produce and maintain a complex organism (LS1.B as in HS-LS1-4). Connections could be made through engineering design tasks, such having students analyze the criteria and constraints for manipulating gene expression or the process of cell division to prevent or cure various genetic diseases.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions and defining problems (HS-LS3-

1 and HS-ETS1-1), developing and using models (HS-LS1-4), analyzing and interpreting data (HS-LS3-3), constructing explanations and designing solutions (HS-LS1-1 and HS-LS4-2), engaging in argument from evidence (HS-LS3-2), and obtaining, evaluating, and communicating information (HS-LS4-1). Many other crosscutting concept elements can be used in instruction. **Bundle Crosscutting Concepts** Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-LS4-1), Cause and Effect (HS-LS3-1, HS-LS3-2, and HS-LS4-2), Scale, Proportion, and Quantity (HS-LS3-3), Systems and System Models (HS-LS1-4), and Structure and Function (HS-LS1-1). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	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-LS1-4. **Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.** [Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.] HS-LS3-1**. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.** [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.] HS-LS3-2. **Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.** [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.] HS-LS3-3. **Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.** [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.] HS-LS4-1. **Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.** [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.] HS-LS4-2. **Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.] HS-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**

Example Phenomena	Babies started out as a single cell, and then grow until adulthood, when they stop growing. Bloodhounds have long floppy ears, whereas other dogs look quite different.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation of phenomena to seek additional information* [about how] ***cellular differentiation produce a complex organism, composed of systems of tissues and organs***. HS-LS1-4 **Developing and Using Models** • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanisms, or system in order to select or revise a model that best fits the evidence or design criteria. Students could *evaluate the merits and limitations of two different models of the* ***process of meiosis*** *in order to select or revise a model that best fits the evidence* [for how] ***chromosomes can sometimes swap sections, thereby creating new genetic combinations and thus more genetic variation***. HS-LS3-2 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make directional hypotheses that specify what happens to the* ***expression of traits*** *when* ***environmental factors change***. HS-LS3-2 **Analyzing and Interpreting Data** • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. Students could *evaluate the impact of new data on a working model* [of] ***the ongoing branching that produces multiple lines of*** [evolutionary] ***descent***. HS-LS4-1 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could *use mathematical, representations of phenomena to support claims* that ***environmental factors affect expression of traits, and hence affect the probability of occurrences of traits in a population.*** HS-LS3-2 and HS-LS3-3 **Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *apply scientific reasoning to link evidence to the claims* that ***genetic information such as similarities and differences in amino acid sequences provide evidence of evolution***. HS-LS4-1

Additional Practices Building to the PEs (Continued)	**Engaging in Argument from Evidence** • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations to determine the merits of arguments. Students could *evaluate the evidence behind currently accepted explanations [that]* ***genes are regions in the DNA that contain the instructions that code for the formation of proteins***. HS-LS1-1 **Obtaining, Evaluating, and Communicating Information** • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. Students could *gather, read, and evaluate scientific information from multiple authoritative sources* [about how] ***the genes expressed by different cells*** [within the same organism] ***may be regulated in different ways***. HS-LS3-1
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Mathematical representations are needed to identify some patterns. Students could use *mathematical representations to represent patterns* [of how] ***the variation and distribution of traits observed depends on both genetic and environmental factors***. HS-LS3-3 **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. Students could synthesize and communicate information about the *functions and properties of* ***DNA*** *including the shape and molecular substructure of its various parts* and communicate [why] ***not all DNA codes for proteins; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function***. HS-LS3-1 **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. Students could *construct an explanation* [for how] *DNA replication is tightly regulated and remarkably accurate* [allowing for] *stability*, ***yet errors do occur and result in mutations, which are also a source of genetic variation*** or *change*. HS-LS3-2
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods** • Science investigations use diverse methods and do not always use the same set of procedures to obtain data. Students could obtain and evaluate information about *the diverse methods and procedures that science investigations use*, [including investigations of how] ***the genes expressed by the cell may be regulated in different ways***. HS-LS3-1 **Science is a Way of Knowing** • Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time. Students could obtain, evaluate, and communicate information about *the refinement of science knowledge over time* [about how] ***some segments of DNA are involved in regulatory or structural functions***. HS-LS3-1

High School Modified Domains Model Course III – Life Sciences
Bundle 4: Life Diversifies Over Time

This is the fourth bundle of the High School Domains Model Course III – Life Sciences. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 4 Question: This bundle is assembled to address the question "how can populations change over time?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how genetic variation among organisms affects survival and reproduction. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment (LS4.C as in HS-LS4-2).

Evolution can be a result of natural selection, which occurs only if there is both variation in the genetic information between organisms in a population and variation in the expression of that genetic information that leads to differences in performance among individuals (LS4.B as in HS-LS4-2 and HS-LS4-3). Natural selection leads to adaptation, in other words, to the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not (LS4.C as in HS-LS4-3 and HS-LS4-4). Adaptation also means that the distribution of traits in a population can change when conditions change (LS4.C as in HS-LS4-3). Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species (LS4.C as in HS-LS4-5).

The engineering design idea that when evaluating solutions, it is important to take into account a range of constraints, including cost safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts (ETS1.B as in HS-ETS1-3) could connect to many different science ideas, including how species become extinct because they can no longer survive and reproduce in their altered environment (LS4.C as in HS-LS4-5). Connections could be made through engineering design tasks such as evaluating solutions for how to stop the extinction of a local endangered organism by minimizing the negative effects of roads, housing construction, or pollution.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of analyzing and interpreting data (HS-LS4-3), constructing explanations and designing solutions (HS-LS4-2, HS-LS4-4, and HS-ETS1-3), and engaging in argument from evidence (HS-LS4-5). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-LS4-3) and Cause and Effect (HS-LS4-2, HS-LS4-4, and HS-LS4-5). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.	
Performance Expectations HS-LS4-3 and HS-LS4-5 are partially assessable.	HS-LS4-2. **Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.] HS-LS4-3. **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait**. [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.] HS-LS4-4. **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.] HS-LS4-5. **Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.] HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.**
Example Phenomena	The fly orchid looks a lot like an insect. The golden toad was last seen in 1989, and is now extinct.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. Students could *define a design problem* [related to] ***the extinction of species*** [when] ***they can no longer survive and reproduce in their altered environment***. HS-LS4-5 **Developing and Using Models** • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Students could *develop, revise, and/or use a model based on evidence to illustrate* [how] ***natural selection occurs only if there is both variation in the genetic information between organisms in a population and variation in the expression of that genetic information***. HS-LS4-2 and HS-LS4-3

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Select appropriate tools to collect, record, analyze, and evaluate data. Students could *select appropriate tools to record, analyze, and evaluate data on* ***variation in traits that leads to differences in performance among individuals***. HS-LS4-2 **Analyzing and Interpreting Data** • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. Students could *evaluate the impact of new data on a working model* [of how] ***competition for an environment's limited supply of resources*** [contributes to] ***evolution***. HS-LS4-2 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could *use computational representations of phenomena to support claims* [for how] ***natural selection leads to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment***. HS-LS4-3 and HS-LS4-4 **Constructing Explanations and Designing Solutions** • Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. Students could *make a qualitative claim regarding the relationship between* ***the changes in the physical environment and the expansion of some species***. HS-LS4-5 **Engaging in Argument from Evidence** • Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. Students could *compare and evaluate competing arguments* [about how] ***natural selection leads to adaptation***. HS-LS4-3 and HS-LS4-4 **Obtaining, Evaluating, and Communicating Information** • 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. Students could *critically read scientific literature* [about how] ***evolution is a consequence of the interaction of four factors*** *to determine the conclusions and paraphrase them in simpler but still accurate terms*. HS-LS4-5

Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • 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. Students could *predict cause and effect relationships between* ***traits that positively affect survival and traits that are common in populations*** *by examining what is known about smaller scale mechanisms within the system*. HS-LS4-3 **Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Students could evaluate information about how the *significance of an* ***advantageous heritable trait*** *depends on* [its] *scale, proportion, and quantity* ***in a population***. HS-LS4-3 and HS-LS4-4 **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. Students could communicate how *science deals with constructing explanations of how things change*, [using as an example explanations of] ***changes in the physical environment contributing to the expansion of some species, the emergence of new distinct species, or the decline or extinction of some species***. HS-LS4-5
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods** • Science investigations use diverse methods and do not always use the same set of procedures to obtain data. Students could communicate how *science investigations use diverse methods and procedures to obtain data*, [including data on how] ***changes in the physical environment have contributed to the expansion of some species, the emergence of new distinct species, or the decline or extinction of some species***. HS-LS4-5 **Science Addresses Questions About the Natural and Material World** • Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. Students could construct an argument that *science knowledge indicates what can happen in natural systems and not what should happen* [when] ***evaluating solutions*** [for the] ***extinction of some species***. HS-LS4-5 and HS-ETS1-3

High School Modified Domains Model Course III – Life Sciences
Bundle 5: Ecosystems and Biodiversity

This is the fifth bundle of the High School Domains Model Course III – Life Sciences. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 5 Question: This bundle is assembled to address the question "how does biodiversity affect us?"
Summary The bundle organizes performance expectations with a focus on helping students build understanding of how the environment influences populations of organisms over multiple generations. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations. **Connections between bundle DCIs** At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways (LS2.B as in HS-LS2-4). Matter and energy are conserved at each step in a food web (LS2.B as in HS-LS2-4), limiting the amount of resources in the environment. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources have carrying capacities. This fundamental tension affects the abundance of species in any given ecosystem (LS2.A as in HS-LS2-1 and HS-LS2-2). Because of the fundamental tension between population size and carrying capacity, a complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, the system may return to its more or less original status while extreme fluctuations in conditions can challenge the functioning of ecosystems in terms of resources and habitat availability (LS2.C as in HS-LS2-2 and HS-LS2-6). Additionally, group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives (LS2.D as in LS2-8) in a given ecosystem. Since resources are finite (LS2.A as in HS-LS2-1), changes in the physical environment, whether naturally occurring or human induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline-and sometimes the extinction—of some species (LS4.C as in HS-LS4-5). Natural selection leads to the differential survival and reproduction of organisms in a population that have an advantageous heritable trait which leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not (LS4.C as in HS-LS4-3). However, natural selection occurs only if there is both variation in the genetic information between organisms in a population and variation in the expression of that genetic information that leads to differences in performance among individuals (LS4.B as in HS-LS4-2 and HS-LS4-3). The engineering design idea that criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them (ETS1.A as in HS-ETS1-1) could connect to many different science ideas, including how environments including living and nonliving resources are finite and thus limit population sizes (LS2.A as in HS-LS2-1 and HS-LS2-2). Connections could be made through engineering design tasks such as evaluating the criteria and constraints related to influencing local hunting practices of overpopulated animals or to expanding the habitats of endangered animals.

Bundle Science and Engineering Practices
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions and defining problems (HS-ETS1-1), analyzing and interpreting data (HS-LS4-3), using mathematics and computational thinking (HS-LS2-1, HS-LS2-2, and HS-LS2-4), and engaging in argument from evidence (HS-LS2-8 and HS-LS4-5). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts
Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-LS4-3), Cause and Effect (HS-LS2-8 and HS-LS4-5), Scale, Proportion, and Quantity (HS-LS2-1 and HS-LS2-2), Energy and Matter (HS-LS2-4), and Stability and Change (HS-LS2-6). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	HS-LS2-1. **Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.** [Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.] HS-LS2-2. **Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.** [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.] HS-LS2-4. **Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.** [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.] HS-LS2-6. **Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.** [Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and, extreme changes, such as volcanic eruption or sea level rise.] HS-LS2-8. **Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.** [Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.] HS-LS4-3. **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait**. [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]

Performance Expectations (Continued)	HS-LS4-5. **Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.] HS-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**
Example Phenomena	Large numbers of deer are hit by cars each year. There are 10 times as many calories in a pound of cheese as there are in a pound of green beans.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. Students could *ask questions* [about] ***the resilience of ecosystems*** *that can be investigated within the scope of the school laboratory*. HS-LS2-2 and HS-LS2-6 **Developing and Using Models** • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Students could *develop a model based on evidence to predict the relationships between* ***ecosystem carrying capacities and the availability of living and nonliving resources***. HS-LS2-1 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make directional hypotheses that specify what happens to* ***the numbers and types of organisms when an ecosystem*** [experiences] ***extreme fluctuations in conditions in terms of resources and habitat availability***. HS-LS2-6 **Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims* [that] ***at each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level***. HS-LS2-4 **Using Mathematical and Computational Thinking** • Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. Students could *revise a computational simulation of* ***natural selection*** *to represent* [that] ***natural selection occurs only if there is both variation in the genetic information between organisms in a population and variation in the expression of that genetic information that leads to differences in performance among individuals***. HS-LS4-3

Additional Practices Building to the PEs (Continued)	**Constructing Explanations and Designing Solutions** • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. Students could *design, evaluate, and/or refine a solution*, ***including satisfying criteria and constraints set forth by society,*** [to the problem that] ***changes in the physical environment have contributed to the decline or extinction of some species***. HS-LS4-5 and HS-ETS1-1 **Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. Students could construct, use, and/or present an oral and written argument or counter-argument based on data and evidence [that] ***predation, competition, and disease*** [affect] ***ecosystem carrying capacities***. HS-LS2-1 **Obtaining, Evaluating, and Communicating Information** • 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. Students could *critically read scientific literature to obtain scientific information* [about how] ***group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives***. HS-LS2-8
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Changes in systems may have various causes that may not have equal effects. Students could communicate that *changes in systems may have various causes that may not have equal effects*, [including that] ***living and nonliving resources, predation, competition, and disease*** [all affect] ***ecosystem carrying capacity*** [to different degrees]. HS-LS2-1 **Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. Students could describe the *use of a model to simulate* ***ecosystems*** *and interactions within* ***ecosystems,*** [including the] ***conservation of matter and energy at each link in an ecosystem***. HS-LS2-4 **Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes can be irreversible. Students could analyze [how] *change and rates of change can be quantified and modeled over very short or very long periods of time* [for] ***ecosystems carrying capacities that change over time due to predation***. HS-LS2-1

Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific explanations can be probabilistic. Students could analyze data [to determine if] *probability can be* [used] *to explain* [that] ***organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite***. HS-LS2-1 **Science is a Human Endeavor** • Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. Students could obtain, evaluate, and communicate information *from other nations and cultures that have contributed to science* [understanding of how] ***modest biological or physical disturbances to an ecosystem may return the ecosystem to its more or less original status***. HS-LS2-2 and HS-LS2-6

High School Modified Domains Model Course III – Life Sciences
Bundle 6: Humans Affect the Lives of Other Organisms

This is the sixth bundle of the High School Domains Model Course III – Life Sciences. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 6 Question: This bundle is assembled to address the question "how can we make a positive impact on Earth and organisms?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how to sustain human populations while increasing the positive effects of human activities on the environment and biodiversity. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Humans depend on the living world (LS4.D as in HS-LS4-6), creating a need for responsible management of natural resources to sustain human societies and the biodiversity that supports them (ESS3.C as in HS-ESS3-3). Resource availability has guided the development of human society (ESS3.A as in HS-ESS3-1) and natural hazards and other geologic events have shaped the course of human history (ESS3.B as in HS-ESS3-1). Conversely, human activity can disrupt an ecosystem and threaten the survival of some species (LS2.C as in HS-LS2-) through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change (LS4.D as in HS-LS4-6).Changes in the physical environment have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline or extinction of some species (LS4.C as in HS-LS4-6).

Three engineering design core ideas are integrated in this bundle. The first two are 1) that it is important to take into account a range of constraints, including cost safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts when evaluating solutions (ETS1.B as in HS-ETS1-3) and 2) that criteria can be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed (ETS1.C as in HS-ETS1-2). These core ideas could connect to several different science concepts, including the importance of responsibly managing natural resources to sustain human societies and biodiversity (ESS3.C as in HS-ESS3-3). Connections could be made through engineering design tasks, such as designing methods of producing more food with fewer resources or designing housing subdivisions to minimize negative effects on biodiversity (ESS3.C as in HS-ESS3-3).

The third engineering core idea integrated in this bundle is that both physical models and computers can be used in running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs (ETS1.B as in HS-ETS1-4). This core idea could connect to many different science ideas, including that scientists and engineers can develop technologies that produce less pollution and waste and that preclude ecosystem degradation (ESS3.C as in HS-ESS3-4) or that anthropogenic changes can disrupt an ecosystem and threaten the survival of some species (LS2.C as in HS-LS2-7). Connections could be made by developing presentations for community members about new systems for minimizing disruption of local habitats or minimizing the introduction of invasive species.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of using mathematics and computational thinking (HS-LS4-6, HS-ESS3-3, and HS-ETS1-4) and constructing explanations and designing solutions (HS-LS2-7, HS-ESS3-1, HS-ESS3-4, HS-ETS1-2, and HS-ETS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (HS-LS4-6 and HS-ESS3-1), Systems and System Models (HS-ETS1-4), and Stability and Change (HS-LS2-7, HS-ESS3-3, and HS-ESS3-4). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	HS-LS2-7. **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*** [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.] HS-LS4-6. **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*** [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.] HS-ESS3-1. **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.** [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.] HS-ESS3-3. **Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.** [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.] HS-ESS3-4. **Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).] HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.** HS-ETS1-4. **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**
Example Phenomenon	When we travel out of state to go camping, we are not allowed to bring our own firewood. There are “ghost towns” in the west part of the country.

Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Evaluate a question to determine if it is testable and relevant. Students could *evaluate questions* [about how] ***management of natural resources*** [affects] ***the sustainability of human societies*** *to determine if the questions are testable and relevant.* HS-ESS3-3 **Developing and Using Models** • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Students could *use a model based on evidence to predict the relationships between* ***anthropogenic changes in the environment and the survival of some species***. HS-LS2-7 **Planning and Carrying Out Investigations** • Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. Students could *plan a safe and ethical test* [of] ***a technology that produces less pollution and waste***. HS-ESS3-4 **Analyzing and Interpreting Data** • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. Students could *evaluate the impact of new data on a model of a proposed* ***technology that produces less pollution and waste and that preclude ecosystem degradation***. HS-ESS3-4 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could *use mathematical representations of phenomena to support claims* [that] ***natural hazards have significantly altered the sizes of human populations***. HS-ESS3-1 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could *apply scientific ideas, principles, and evidence to solve design problems* [related to] ***responsible management of natural resources***. HS-ESS3-3 **Engaging in Argument from Evidence** • Respectfully provide critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, and responding thoughtfully to diverse perspectives. Students could *respectfully provide critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions* [about how] ***natural hazards and other geologic events have shaped the course of human history***. HS-ESS3-1

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Students could *compare, integrate, and evaluate sources of information presented in different media or formats to solve a problem* [related to how] ***anthropogenic changes in the environment can disrupt an ecosystem and threaten the survival of some species, and*** [in doing so,] ***consider social, cultural, and environmental impacts*** [of the solution]. HS-LS2-7 and HS-ETS1-3
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • 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. Students could *predict cause and effect relationships for* [for how] ***anthropogenic changes in the environment can disrupt an ecosystem*** *by examining what is known about smaller scale mechanisms within the system*. HS-LS2-7 **Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Students could construct an argument from evidence for how *the significance of* ***an ecosystem disruption*** *is dependent on the scale, proportion, and quantity at which it occurs*. HS-LS2-7 **Systems and System Models** • Models can be used predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. Students could evaluate the merits and limitations of using two different models of how ***resource availability has driven human migrations*** *to predict* [future human migrations, describing that] *these predictions have limited precision and reliability*. HS-ESS3-1
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. Students could obtain, evaluate, and communicate how a scientific theory is a substantiated explanation based on a body that facts that has been repeatedly confirmed and has been validated by the scientific community, [using as an example the body of facts supporting the idea that] anthropogenic changes in the environment can disrupt an ecosystem and threaten the survival of some species. HS-LS2-7 **Science Addresses Questions About the Natural and Material World** • Many decisions are **not** made using science alone, but rely on social and cultural contexts to solve issues. Students could obtain, evaluate, and communicate information [about how] ***scientists and engineers can make contributions by developing technologies that produce less pollution and waste*** [while also] *relying on social and cultural contexts to solve issues* [by] ***considering social, cultural, and environmental impacts*** [of the technologies]. HS-ESS3-4 and HS-ETS1-3

High School Domains Model Course III – Life Sciences

Narrative and Rationale: This Life Sciences model course map is the last in a three-year course sequence that uses a customized version of the Modified High School Domains Model from NGSS Appendix K as the instructional year end goals. This course model assumes that students are grounded in the basics of chemistry and physics and have previously spent two years in high school developing their proficiency in the NGSS Science and Engineering Practices and Crosscutting Concepts.

The conceptual flow of this biology course model begins building to the understanding that life on Earth today reflects a deep history. This course model includes performance expectations from Life Sciences, Earth/Space Sciences, and Engineering Design that allow students to develop a natural flow of understanding of how and why the abiotic and biotic realms are interwoven and interdependent, why living organisms share so many commonalities of structure and function, and the mechanisms that allow a rich diversity of life to exist within a wide variety of ecosystems. Students also can consider the human species' place in, and effects on, Earth's living systems.

The bundles in this domains model guide students through the use of the SEPs, CCCs, and DCIs to answer the essential questions for each unit listed in the bundles below. It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional practices and crosscutting concepts should be used throughout instruction toward each bundle.

Bundle 1: Why does Earth look so different than it used to? **~3 weeks**	**Bundle 2:** How do our bodies function? **~5 weeks**	**Bundle 3:** How are there so many different kinds of organisms? **~6 weeks**	**Bundle 4:** How can populations change over time? **~3 weeks**	**Bundle 5:** How does biodiversity affect us? **~3 weeks**	**Bundle 6:** How can we make a positive impact on Earth and organisms? **~4 weeks**
HS-ESS1-5. Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. **HS-ESS1-6.** Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. **HS-ESS2-7.** Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.	**HS-LS1-2.** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. **HS-LS1-3.** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. **HS-LS1-5.** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. **HS-LS1-6.** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. **HS-LS1-7.** Use a model to illustrate that cellular respiration is a chemical process whereby	**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. **HS-LS1-4.** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. **HS-LS3-1.** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. **HS-LS3-2.** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during	**HS-LS4-2.** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. **HS-LS4-3.** Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in	**HS-LS2-1.** Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. **HS-LS2-2.** Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. **HS-LS2-4.** Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. **HS-LS2-6.** Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing	**HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* **HS-LS4-6.** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* **HS-ESS3-1.** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. **HS-ESS3-3.** Create a computational simulation to illustrate the relationships among management of natural resources, the

Bundle 1: Why does Earth look so different than it used to? **~3 weeks**	**Bundle 2:** How do our bodies function? **~5 weeks**	**Bundle 3:** How are there so many different kinds of organisms? **~6 weeks**	**Bundle 4:** How can populations change over time? **~3 weeks**	**Bundle 5:** How does biodiversity affect us? **~3 weeks**	**Bundle 6:** How can we make a positive impact on Earth and organisms? **~4 weeks**
	the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. **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. **HS-LS2-5.** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	replication, and/or (3) mutations caused by environmental factors. **HS-LS3-3.** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. **HS-LS4-1.** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. **HS-LS4-2.** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	proportion to organisms lacking this trait. [1] **HS-LS4-4.** Construct an explanation based on evidence for how natural selection leads to adaptation of populations. **HS-LS4-5.** Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.[1] **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.	conditions may result in a new ecosystem. **HS-LS2-8.** Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. **HS-LS4-3.** Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. **HS-LS4-5.** Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	sustainability of human populations, and biodiversity. **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. **HS-ETS1-4.** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

High School Domains Model Course 3: Life Sciences Flowchart

Bundle 1

PS1.C as found in HS-ESS1-5 and HS-ESS1-6
- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.

ESS1.C as found in HS-ESS1-5
- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.

ESS1.C as found in HS-ESS1-
- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

ESS2.B as found in HS-ESS1-5
- Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history.

ESS2.D as found in HS-ESS2-7
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.

to LS2.B in Bundle 2

ESS2.E as found in HS-ESS2-7
- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it.

to LS4.C in Bundle 3

Bundle 2

PS3.D as found in HS-LS2-5
- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.

LS1.A as found in HS-LS1-2
- 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 as found in HS-LS1-3
- 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.

LS1.C as found in HS-LS1-5
- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.

LS1.C as found in HS-LS1-6
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.

LS1.C as found in HS-LS1-6 and HS-LS1-7
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

to LS2.B in Bundle 5

LS1.C as found in HS-LS1-7
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.

to LS2.B in Bundle 5

LS2.B as found in HS-LS2-3
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.

to LS2.B in Bundle 5

Bundle 3

LS1.A as found in HS-LS1-1
- Systems of specialized cells within organisms help them perform the essential functions of life.

LS1.A as found in HS-LS1-1 and HS-LS3-1
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.

LS1.B as found in HS-LS1-4
- In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.

LS3.A as found in HS-LS3-1
- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

LS3.B as found in HS-LS3-2
- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.

LS3.B as found in HS-LS3-2 and HS-LS3-3
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.

Bundle 4

LS4.B as found in HS-LS4-2 and HS-LS4-3
- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information — that is, trait variation — that leads to differences in performance among individuals.

LS4.B as found in HS-LS4-3
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

LS4.C as found in HS-LS4-2
- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

LS4.C as found in HS-LS4-3 and HS-LS4-4
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

LS4.C as found in HS-LS4-3
- Adaptation also means that the distribution of traits in a population can change when conditions change.

LS4.C as found in HS-LS4-5
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species.
- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.

Bundle 5

LS2.A as found in HS-LS2-1 and HS-LS2-2
- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

LS2.B as found in HS-LS2-4
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.

LS2.C as found in HS-LS2-2 and HS-LS2-6
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

LS2.D as found in HS-LS2-8
- Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.

Bundle 6

LS2.C as found in HS-LS2-7
- Moreover, anthropogenic changes (induced by human activity) in the environment — including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change — can disrupt an ecosystem and threaten the survival of some species.

LS4.C as found in HS-LS4-6
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species.

LS4.D as found in HS-LS2-7
- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).

LS4.D as found in HS-LS2-7 and HS-LS4-6
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

ESS3.A as found in HS-ESS3-1
- Resource availability has guided the development of human society.

ESS3.B as found in HS-ESS3-1
- Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.

ESS3.C as found in HS-ESS3-3
- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

ESS3.C as found in HS-ESS3-4
- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

LS2.B as found in HS-LS2-5
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

ETS1.A as found in HS-ETS1-1
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

LS4.A as found in HS-LS4-1
- Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

LS4.B as found in HS-LS4-2
- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information — that is, trait variation — that leads to differences in performance among individuals.

LS4.C as found in HS-LS4-2
- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

to LS4.B in Bundle 4

ETS1.A as found in HS-ETS1-1
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

ETS1.B as found in HS-ETS1-3
- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

LS4.B as found in HS-LS4-3
- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information — that is, trait variation — that leads to differences in performance among individuals.

LS4.B as found in HS-LS4-3
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

to LS4.D in Bundle 6

LS4.C as found in HS-LS4-3
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

LS4.C as found in HS-LS4-3
- Adaptation also means that the distribution of traits in a population can change when conditions change.

to LS2.C in Bundle 6

LS4.C as found in HS-LS4-5
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species.
- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.

ETS1.A as found in HS-ETS1-1
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

ETS1.B as found in HS-LS2-7, HS-LS4-6, HS-ESS3-4, and HS-ETS1-3
- When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

ETS1.B as found in HS-LS4-6 and HS-ETS1-4
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.

ETS1.C as found in HS-ETS1-2
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.

High School Domains Model Course II - Physics

Narrative and Rationale: This Physics model course map is the second in a three-year course sequence that uses a customized version of the Modified High School Domains Model from NGSS Appendix K as the instructional year end goals. This course model assumes that students are grounded in the basics of chemistry and have previously spent one year in high school developing their proficiency in the NGSS Science and Engineering Practices and crosscutting concepts.

The first bundle in this course continues the study of structure and properties of matter that began in chemistry the previous year, and extends to a focus on how forces arise from the interactions between fields. The second bundle continues a focus on forces, but shifts to a study of collisions at the macroscopic scale. The third bundle focuses on forces and energy transfer when objects interact, and the fourth bundle ends the course by focusing on harnessing energy transfer for communication purposes. Throughout the course, relevant Earth and Space Sciences and Engineering Design PEs are integrated.

The bundles in this domains model guide students through the use of the SEPs, CCCs, and DCIs to answer the essential questions for each unit listed in the bundles below. It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional practices and crosscutting concepts should be used throughout instruction toward each bundle.

Bundle 1: Why Don't We Fall Through the Floor? **~6 weeks**	**Bundle 2:** How Do We Protect Ourselves From Collisions? **~6 weeks**	**Bundle 3:** What Happens When Energy Moves From One Place to Another? **~8 weeks**	**Bundle 4:** How Do We Use Energy to Communicate With Each Other? **~4 weeks**
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.[1] **HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. **HS-PS2-4.** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. **HS-PS2-6.** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* **HS-PS3-2.** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). **HS-PS3-5.** Develop and use a model of two objects interacting through electric or	**HS-PS2-1.** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. **HS-PS2-2.** Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. **HS-PS2-3.** Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* **HS-ESS1-2.** Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. **HS-ESS1-4.** Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.[1] **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints,	**HS-PS3-1.** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. **HS-PS3-3.** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* **HS-PS3-4.** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). **HS-ESS2-1**. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. **HS-ESS2-2**. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. **HS-ESS2-3.** Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	**HS-PS4-1.** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. **HS-PS4-2.** Evaluate questions about the advantages of using a digital transmission and storage of information. **HS-PS4-3.** Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. **HS-PS4-4.** Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. **HS-PS4-5**. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*

Bundle 1: Why Don't We Fall Through the Floor? **~6 weeks**	**Bundle 2:** How Do We Protect Ourselves From Collisions? **~6 weeks**	**Bundle 3:** What Happens When Energy Moves From One Place to Another? **~8 weeks**	**Bundle 4:** How Do We Use Energy to Communicate With Each Other? **~4 weeks**
magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.[1]	**HS-ESS2-4.** Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. **HS-ESS2-5.** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

High School Domains Model Course II (Physics) Flowchart

Bundle 1

PS1.A as found in HS-PS1-1
- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

To PS4.B in Bundle 4

PS1.A as found in HS-PS1-3
- The structure and interactions of matter at the bulk scale are determined by the electrical forces within and between atoms.

PS2.B as found in HS-PS2-4
- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS2.B as found in HS-PS2-6
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

PS3.A as found in HS-PS3-2
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

PS3.C as found in HS-PS3-5
- When two objects interacting through a field change relative position, the energy stored in the field is changed.

Bundle 2

PS2.A as found in HS-PS2-1
- Newton's second law accurately predicts changes in the motion of macroscopic objects.

PS2.A as found in HS-PS2-2
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.

PS2.A as found in HS-PS2-2 and HS-PS2-3
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

PS4.B as found in HS-ESS1-2
- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.

ESS1.A as found in HS-ESS1-2
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

To ESS2.D in Bundle 3 and PS3.D in Bundle 4

ESS1.B as found in HS-ESS1-4
- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

ETS1.A as found in HS-PS2-3 and HS-ETS1-1
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

ETS1.A as found in HS-ETS1-1
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

ETS1.B as found in HS-ETS1-3
- When evaluating solution, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Bundle 3

PS3.A as found in HS-PS3-1
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.A as found in HS-PS3-3
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

PS3.B as found in HS-PS3-1
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

PS3.B as found in HS-PS3-4
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

PS3.D as found in HS-PS3-3 and HS-PS3-4
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ESS1.B as found in HS-ESS2-4
- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.

ESS2.A as found in HS-ESS2-1 and HS-ESS2-2
- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.A as found in HS-ESS2-3
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

ESS2.A as found in HS-ESS2-4
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

Bundle 4

PS3.D as found in HS-PS4-5
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.

PS4.A as found in HS-PS4-1
- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

PS4.A as found in HS-PS4-2 and HS-PS4-5
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

PS4.A as found in HS-PS4-3
- [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)

PS4.B as found in HS-PS4-3
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.

PS4.B as found in HS-PS4-4
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.

PS4.B as found in HS-PS4-5
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

PS4.C as found in HS-PS4-5
- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

ETS1.C as found in HS-PS2-3
•Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

ESS2.B as found in HS-ESS2-1
• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.

ESS2.B as found in HS-ESS2-3
• The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

ESS2.C as found in HS-ESS2-5
• The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

ESS2.D as found in HS-ESS2-2 and HS-ESS2-4
• The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.

To PS4.B in Bundle 4

ETS1.A as found in HS-PS3-3
•Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

ETS1.C as found in HS-ETS1-2
•Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.