Oklahoma Academic Standards

SCIENCE

OKLAHOMA
Education

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Introduction

The 2020 Oklahoma Academic Standards for Science are the result of the contributions of hundreds of science educators, representatives of higher education, and community members. This document reflects the collaborative work of all members of the Draft Oklahoma Academic Standards for Science Writing and Draft Committees.

The standards specify what students should know and be able to do as learners of science at the end of each grade level or science course. The order of the standards at any grade level is not meant to imply a sequence of topics and should be considered flexible for the organization of any course. The Oklahoma Academic Standards describe the specific areas of student learning that are considered the most important for proficiency in the discipline at a particular level and provide a basis for the development of local curricula and statewide assessments.

The standards are not a curriculum and they do not represent a scope, sequence, or curriculum guide. They provide a framework for schools and teachers to develop an aligned science curriculum. They are also designed as coherent progressions of learning in grades PreK-12, intended to be used as a whole, ensuring all students are provided opportunities to experience science at each grade K-8 and various courses at high school. Although instruction may go beyond standards, using only a portion of the standards will leave gaps in the scientific understanding and practices of students.

The 2020 Oklahoma Academic Standards for Science were informed by the 2014 Oklahoma Academic Standards for Science, The Framework for K-12 Science Education (National Academies of Science, 2010), the Next Generation Science Standards (Achieve, Inc., 2012), and other states' standards documents.

Science is a way of knowing, a process of using observations and investigations to gain knowledge and understanding of the physical and natural world. The PreK-12 Oklahoma Academic Standards for Science place an emphasis on students being active learners. They showcase that it is not enough for students to read about science; they must do science. Students must engage in planning and carrying out investigations, making observations, asking questions, analyzing data, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information to gain the science knowledge and skills to be college, career, and citizen ready upon graduation from high school.

Science Strands Overview

The Oklahoma Academic Standards for Science, K-12, are three-dimensional performance expectations representing the things students should know, understand, and be able to do to be proficient in science and engineering. Performance expectations are considered standards and include a science and engineering practice (everyday skills of scientists and engineers), disciplinary core ideas (science ideas used by scientists and engineers), and crosscutting concepts (ways of thinking like scientists and engineers).

The PreK standards emphasize one dimension, the science and engineering practices. This provides early learners with ample time for exploratory play and background experiences that will inform learning experiences K-12.

Performance Expectation:

Each Performance Expectation is built upon recommendations in *A Framework for K-12 Science Education* and the three dimensions of science.

1. Science and Engineering Practices
2. Disciplinary Core Ideas
3. Crosscutting Concepts (NRC, 2012, p. 2)

The following additional components in the standard documents serve as support for instructors in providing clarity and further guidance for each Performance Expectation.

Clarification Statement:

Where needed, a Clarification Statement accompanies a Performance Expectation. The aim of a Clarification Statement is to provide further explanation or examples to better support educators in understanding the aim of the Performance Expectation.

Assessment Boundary:

Where applicable, an Assessment Boundary accompanies a Performance Expectation in order to provide additional support for educators in understanding the intent of the Performance Expectation and its relation to other Performance Expectations in the learning progression. Teachers should utilize the Assessment Boundaries as tools for developing curriculum and local assessments. For 5th grade, 8th grade, Biology, and Physical Science(s) the Assessement Boundaries will be utilized to inform the development of the state summative academic achievement assessments.

Dimension 1: Science and Engineering Practices

The Science and Engineering Practices describe the major practices that scientists employ as they investigate and build models and theories about the world, and a key set of engineering practices that engineers use as they design and build systems. Performance Expectations that emphasize engineering are designated with an asterisk *. The eight science and engineering practices are:

Asking Questions and Defining Problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works. Engineering questions clarify problems to determine criteria for successful solutions.

Developing and Using Models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.

Planning and Carrying Out Investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed in order to derive meaning, and engineering investigations include analysis of data collected in the tests of designs.

Using Mathematics and Computational Thinking

In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for constructing simulations, solving equations exactly or approximately, and recognizing, expressing, and applying quantitative relationships.

Constructing Explanations and Designing Solutions

End products of science are explanations, and end products of engineering are solutions. The construction of theories provides explanatory accounts of the world, and scientific knowledge is utilized in the development of solution to problems.

Engaging in Scientific Argument from Evidence

Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem.

Obtaining, Evaluating, and Communicating Information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate.
Critiquing and communicating ideas individually and in groups is a critical professional activity.

Dimension 2: Disciplinary Core Ideas

Disciplinary Core Ideas represent a set of science and engineering ideas for K-12 science education that have broad importance across multiple sciences or engineering disciplines; provide a key tool for understanding or investigating more complex ideas and solving problems; relate to the interests and life experiences of students; and are teachable and learnable over multiple grades at increasing levels of sophistication. (NRC, 2012, p. 31) Disciplinary Core Ideas are grouped into four domains:

Domain 1: Physical Science (PS)
Most systems or processes depend at some level on physical and chemical subprocesses, whether the system is a star, Earth's atmosphere, a river, a bicycle, or a living cell. To understand the physical and chemical basis of a system, students must understand the structure of matter, the forces between objects, the related energy transfers, and their consequences. In this way, the underlying principles of physical science, chemistry, and physics allow students to understand all natural and human-created phenomena.

Domain 2: Life Science (LS)
The life sciences focus on patterns, processes, and relationships of living organisms. The study of life ranges over scales from single molecules, organisms and ecosystems, to the entire biosphere. A core principle of the life sciences is that organisms are related through common ancestry and that processes of natural selection have led to the tremendous diversity of the biosphere. Through courses like Biology and Environmental Science, students explore all aspects of living things and the environments they live in.

Domain 3: Earth and Space Science (ESS)
Through Earth and Space Sciences (ESS), students investigate processes that operate on Earth and also address Earth's place in the solar system and the galaxy. ESS involve phenomena that range in scale from unimaginably large to invisibly small and provide students opportunities to understand how the atmosphere, geosphere, and biosphere are connected.

Domain 4: Engineering, Technology, and Applications of Science (ETS)
The applications of science knowledge and practices to engineering have contributed to the technologies and the systems that serve people today. Insights gained from scientific discovery have altered the ways in which buildings, bridges, and cities are constructed; changed the operations of factories; led to new methods of generating and distributing energy; and created new modes of travel and communication. An overarching goal of ETS is for students to explore links among engineering, technology, science, and society throughout the physical, life, and Earth and space sciences.

Dimension 3: Crosscutting Concepts

The Crosscutting Concepts represent common threads or themes that span across science disciplines (biology, chemistry, physics, environmental science, Earth/space science) and have value to both scientists and engineers because they identify universal properties and processes found in all disciplines. These Crosscutting Concepts are:

Patterns
Observed patterns of forms and events guide organization and classification. Patterns prompt questions about the factors that influence cause and effect relationships. Patterns are useful as evidence to support explanations and arguments.

Cause and Effect
Events have causes, sometimes simple, sometimes multifaceted and complex. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Scale, Proportion, Quantity
In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

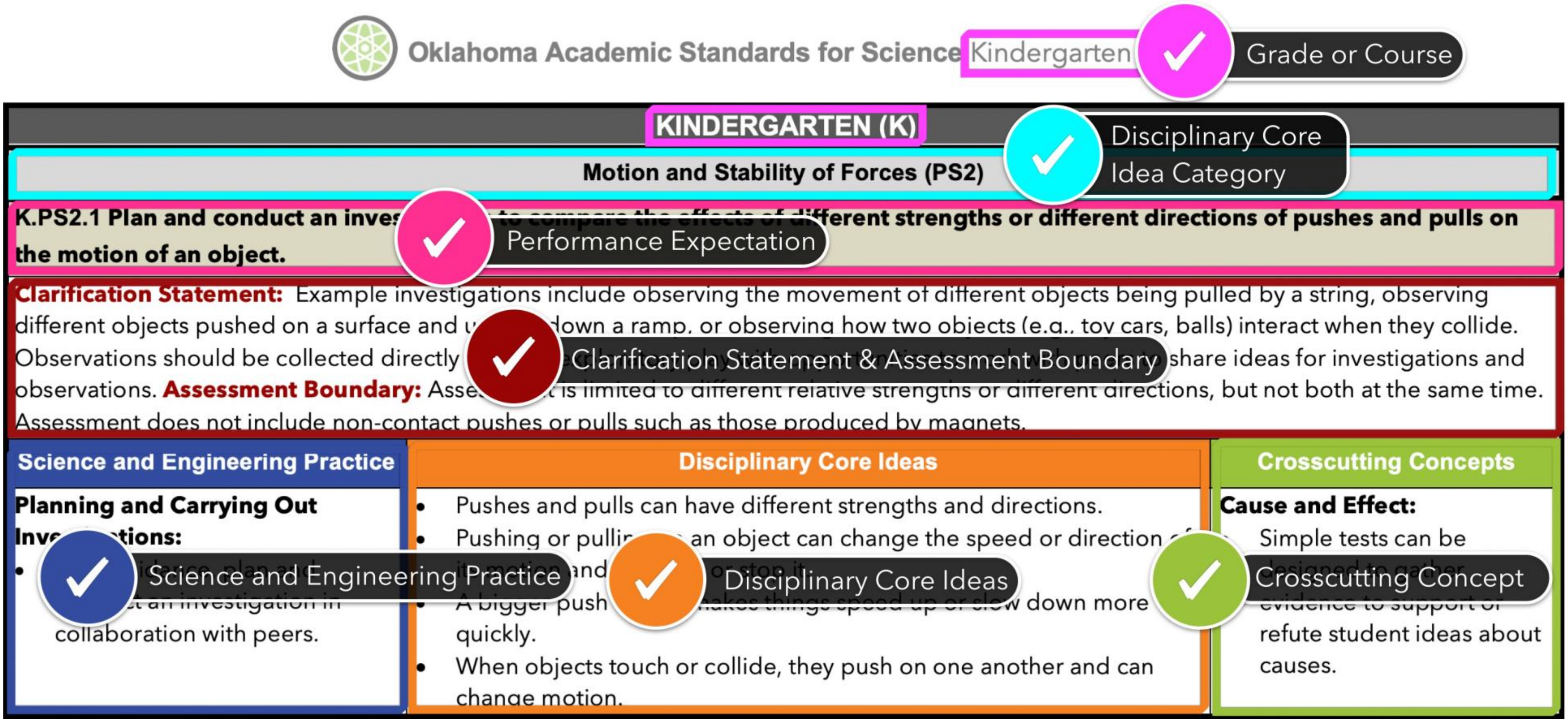
Systems and System Models
Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

Energy and Matter
Tracking fluxes of energy and matter into, out of, and within systems helps one understand the system's possibilities and limitations.

Structure and Function
An object's structure and shape determine many of its properties and functions. The structures, shapes, and substructures of living organisms determine how the organism functions to meet its needs within an environment.

Stability and Change
For natural and built systems alike, conditions of stability and rates of change provide the focus for understanding how the system operates and causes for changes in systems.

Reading the Oklahoma Academic Standards for Science



PREKINDERGARTEN (PK)	
Science Exploration (S)	
PK.S.1 Engage in play to explore the physical and natural world.	**Clarification Statement:** Exploration-based play should include playing inside the classroom (e.g., building towers with blocks, interacting with a balloon, mixing water colors, placing different objects in water) and outside the classroom (e.g., swinging at different speeds, kicking a ball in different ways, rolling round objects down a hill, digging in the dirt). Emphasis is on basic play as a means of exploration.
PK.S.2 Make observations of the physical and natural world.	**Clarification Statement:** Observations should focus on what things look, feel, hear, or smell like, how they might operate or function, and similarities and differences among things inside classroom (e.g., pencils, markers, and highlighters make different marks on paper) and outside a classroom (e.g., leaves look different at different times of year, sticks in different areas of the school yard are different shapes and sizes, it is cooler in the morning than at lunch). Explanations for why things inside and outside the classroom look, feel, or smell the way they do are not expected.
PK.S.3 Notice and describe similarities and differences among plants, animals, and objects.	**Clarification Statement:** Similarities and differences might include grouping like plants, animals, or objects based on observations. Descriptions of groupings might be based on how plants, animals, or objects look, feel, or smell.
PK.S.4 Share noticings and wonderings about the physical and natural world.	**Clarification Statement:** Sharing could include drawing, writing, building models, or other creative expressions, such as drama or creative movement. Sharing could include retelling, verbal descriptions, or talking with others. Wonderings might include "why," "how," and "what if" statements. Respect for the noticings and wondering of others should be emphasized, but explanations for noticings and wonderings are not emphasized or expected.
PK.S.5 Ask questions based on curiosity about the physical and natural world.	**Clarification Statement:** Questions may arise through observations, play, interests, events in the classroom, text, media, or other experiences of the natural and physical world.
PK.S.6 Engage in investigations based on curiosity and wondering about the physical and natural world.	**Clarification Statement:** Opportunities for investigation or further investigation could arise from opportunities to engage in play inside and outside the classroom, curiosities and wonderings of the student from school or out of school experiences. Emphasis is on providing opportunities for investigations to arise from student curiosities, wonderings, or questions.

KINDERGARTEN (K)

Motion and Stability of Forces (PS2)

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: Example investigations include observing the movement of different objects being pulled by a string, observing different objects pushed on a surface and up and down a ramp, or observing how two objects (e.g., toy cars, balls) interact when they collide. Observations should be collected directly through exploratory play with opportunities to work with peers to share ideas for investigations and observations. **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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • With guidance, plan and conduct an investigation in collaboration with peers.	• Pushes and pulls can have different strengths and directions. • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. • A bigger push or pull makes things speed up or slow down more quickly. • When objects touch or collide, they push on one another and can change motion.	**Cause and Effect:** • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

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 pull.*

Clarification Statement: Data should be limited to observational data collected through exploration-based play of simple design solutions to address problems. Example problems include having an object (e.g., toy car or ball) move a certain distance, follow a particular path, or knock down other objects. Designed solutions could include using or building a ramp to increase the speed of the object, using objects that would cause an object like a toy car or ball to follow a particular path. Emphasis is on basic play as a means to develop a designed solution and test that design. **Assessment Boundary:** Assessment does not include friction as a mechanism for change in speed.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing Data: • Analyze data from tests of an object or tool to determine if it works as intended.	• Pushes and pulls can have different strengths and directions. • Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. • A situation that people want to change or create can be approached as a problem to be solved through engineering. • Such problems may have many acceptable solutions.	**Cause and Effect:** • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

Energy (PS3)

K.PS3.1 Make observations to determine the effect of sunlight on Earth's surface.

Clarification Statement: Making observations should include opportunities to directly observe surfaces (e.g. sand, soil, rocks, or playground equipment) in direct sunlight, partial sunlight and shade with opportunities to explore and discuss observed patterns of the Sun's impact on those surfaces. Opportunities to share noticings and wonderings should be encouraged. **Assessment Boundary:** Assessment of temperature is limited to relative measures such as warmer/cooler.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • Make observations (firsthand or from media) to collect data that can be used to make comparisons.	• Sunlight warms the Earth's surface.	**Cause and Effect:** • Events have causes that generate observable patterns.

K.PS3.2 Use tools and materials to design and build a structure that will reduce the warming effect of sunlight on an area.*

Clarification Statement: Examples of structures could include forms of umbrellas, canopies, and tents developed through exploratory play with a variety of materials allowing opportunities to build and test how designed structures might minimize the warming effect of the Sun.
Effectiveness can be determined by placing rocks or sand under the structure and observing the warmth or coolness of the object. **Assessment Boundary:** Assessment of temperature is limited to relative measures such as warmer/cooler.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Designing Solutions: • Use tools and materials provided to design and build a device that solves a specific problem or a solution to a specific problem.	• Sunlight warms the Earth's surface.	**Cause and Effect:** • Events have causes that generate observable patterns.

From Molecules to Organisms: Structure and Function (LS1)

K.LS1.1 Use observations to describe patterns of what plants and animals (including humans) need to survive.

Clarification Statement: Examples of observable patterns could include that animals need to take in food but plants do not; the different kinds of food needed by different types of animals; the requirement of plants to have light; and that all living things need water. Observations could be collected through nature walks around the playground and videos. Patterns of similarities and differences among different animals or between plants and animals should be discussed.
Assessment Boundary: Assessment is limited to observations and not how plants use light (photosynthesis).

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data: • Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions.	• All animals need food in order to live and grow. • Animals obtain their food from plants or from other animals. • Plants need water and light to live and grow.	**Patterns:** • Patterns in the natural and human designed world can be observed and used as evidence.

Earth Systems (ESS2)

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 temperature is limited to whole numbers for patterns, and relative measures such as warmer/cooler for temperatures.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data: • Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions.	• Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. • People measure these conditions to describe and record the weather and to notice patterns over time.	**Patterns:** • Patterns in the natural world can be observed, used to describe phenomena, and used as evidence.

Earth Systems (ESS2)

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

Clarification Statement: Arguments center on sharing examples of how plants and animals change their environments and discussing ideas as to why those changes meet a need of plants and animals (e.g., shelter, food, room to grow). Examples of arguments could include squirrels digging in the ground to hide food, tree roots breaking sidewalks, birds building a nest to protect their young.
Assessment Boundary: Arguments should be based on qualitative not quantitative evidence.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Construct an argument with evidence to support a claim.	• Plants and animals can change their environment. • Things that people do to live comfortably can affect the world around them.	**Systems and System Models:** • Systems in the natural and designed world have parts that work together.

Earth and Human Activity (ESS3)

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

Clarification Statement: Models could include drawings, physical replicas, or dramatizations that show relationships between plants or animals and their surroundings. Examples of relationships could include that squirrels eat nuts and seeds, and therefore, they usually live near trees; and grasses need sunlight, so they often grow in meadows with no or few trees. Opportunities to share noticings and wondering should be encouraged. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Use a model to represent relationships in the natural world.	• Living things need water, air, and resources from the land, and they live in places that have the things they need. • Humans use natural resources for everything they do.	**Systems and System Models:** • Systems in the natural and designed world have parts that work together.

Earth and Human Activity (ESS3)		
K.ESS3.2 Ask questions to understand the purpose of weather forecasting to prepare for and respond to severe weather.*		
Clarification Statement: Questions may arise or be encouraged through observations, interests, text, or media. Emphasis is on weather forecasting of local weather and how weather forecasting can help people plan for, and respond to, specific types of local weather (e.g., staying indoors during severe weather, going to cool places during heat waves). **Assessment Boundary:** Assessment does not include causes for severe weather.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Asking Questions: • Asking questions, making observations, and gathering information are helpful in thinking about problems.	• Some kinds of severe weather are more likely than others in a given region. • Weather scientists forecast severe weather so that the communities can prepare for and respond to these events. • People depend on various technologies in their lives; human life would be very different without technology. • People encounter questions about the natural world every day.	**Cause and Effects:** • Events have causes that generate observable patterns.

1st Grade (1)

Waves and Their Applications in Technologies for Information Transfer (PS4)

1.PS4.1 Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.

Clarification Statement: Examples of vibrating materials that make sound could include tuning forks, kazoos, plucking a stretched string or rubber band, and stringed instruments. Examples of sound making matter vibrate could include holding a piece of paper near a speaker making sound, placing hand on personal larynx or mouth while humming, and holding an object near a vibrating tuning fork. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • Plan and conduct investigations collaboratively to produce data to serve as the basis for evidence to answer a question.	• Sound can make matter vibrate, and vibrating matter can make sound.	**Cause and Effect:** • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

1.PS4.2 Make observations to construct an evidence-based account that objects can be seen only when illuminated.

Clarification Statement: Examples of observations could include those made in a completely dark room or those made in a dark room with the door opened slightly. Illumination could be from an external light source or an object giving off its own light. This can be explored with string lights, mirrors, projectors, and flashlights. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Make observations (firsthand or from media) to construct an evidence- based account for natural phenomena.	• Objects can be seen if light is available to illuminate them or if they give off their own light.	**Cause and Effect:** • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
1.PS4.3 Plan and conduct an investigation to determine the effect of placing objects made with different materials in the path of a beam of light.		
Clarification Statement: Examples of materials could include those that are transparent (such as clear plastic), translucent (such as wax paper), opaque (such as cardboard), and reflective (such as a mirror). **Assessment Boundary:** Assessment does not include the speed of light or assessment of descriptive words like transparent, translucent, opaque, or reflective.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Planning and Carrying Out Investigations: • Plan and conduct investigations collaboratively to produce data to serve as the basis for evidence to answer a question.	• Some materials allow light to pass through them, others allow only some light through, and others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. • Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.)	**Cause and Effect:** • Simple tests can be designed to gather evidence to support or refute student ideas about causes.
1.PS4.4 Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.*		
Clarification Statement: Examples of devices could include a light source to send signals, paper cup and string "telephones," and a pattern of drum beats. **Assessment Boundary:** Assessment does not include technological details for how communication devices work.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Designing Solutions: • Use tools and materials provided to design a device that solves a specific problem.	• People also use a variety of devices to communicate (send and receive information) over long distances. • People depend on various technologies in their lives; human life would be very different without technology.	**Structure and Function:** • The shape and stability of structures of natural and designed objects are related to their functions.

From Molecules to Organisms: Structure and Function (LS1)		
1.LS1.1 Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.*		
Clarification Statement: Examples of human problems that can be solved by mimicking plant or animal solutions could include designing clothing or equipment to protect bicyclists by mimicking turtle shells, acorn shells, and animal scales; stabilizing structures by mimicking animal tails and roots on plants; keeping out intruders by mimicking thorns on branches and animal quills; and detecting intruders by mimicking eyes and ears. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Designing Solutions: • Use tools and materials provided to design a device that solves a problem.	• All organisms have external parts. • Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water, and air. • Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow. • Animals have body parts that capture and convey different kinds of information needed for growth and survival. • Plants also respond to some external inputs. • Every human-made product is designed by applying some knowledge of the natural world and is built using materials derived from the natural world.	**Structure and Function:** • The shape and stability of structures of natural and designed objects are related to their functions.

From Molecules to Organisms: Structure and Function (LS1)

1.LS1.2 Obtain information from media and/or text to determine patterns in the behavior of parents and offspring that help offspring survive.

Clarification Statement: Examples of patterns of behaviors could include the signals that offspring make (such as crying, cheeping, and other vocalizations) and the responses of the parents (such as feeding, comforting, and protecting the offspring). Information may be obtained through observations, media, and/or text. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information: • Read grade-appropriate texts and use media to obtain scientific information to determine patterns in the natural world.	• Adult plants and animals can have young. • In many kinds of animals, parents and the offspring themselves engage in behaviors that help the offspring to survive.	**Patterns:** • Patterns in the natural world can be observed, used to describe phenomena, and used as evidence.

Heredity: Inheritance and Variation of Traits (LS3)

1.LS3.1 Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.

Clarification Statement: Examples of patterns could include features plants or animals share. Examples of observations could include that leaves from the same kind of plant are the same shape but can differ in size; and that particular breed of dog looks like its parents but is not exactly the same. **Assessment Boundary:** Assessment does not include inheritance, animals that undergo metamorphosis or hybrids.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena.	• Young animals are very much, but not exactly like, their parents. • Plants also are very much, but not exactly, like their parents. • Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways.	**Patterns:** • Patterns in the natural world can be observed, used to describe phenomena, and used as evidence.

Earth's Place in the Universe (ESS1)

1.ESS1.1 Use observations of the Sun, Moon, and stars to describe patterns that can be predicted.

Clarification Statement: Examples of patterns could include that the Sun and Moon appear to rise in one part of the sky, move across the sky, and set; and stars other than our Sun are visible at night but not during the day. **Assessment Boundary:** Assessment of star patterns is limited to stars being seen at night and not during the day.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data: • Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions.	• Patterns of the motion of the Sun, Moon, and stars in the sky can be observed, described, and predicted.	**Patterns:** • Patterns in the natural world can be observed, used to describe phenomena, and used as evidence.

1.ESS1.2 Make observations at different times of year to relate the amount of daylight and relative temperature to the time of year.

Clarification Statement: Emphasis is on relative comparisons of the amount of daylight and temperature in the winter to the amount in the spring, fall, or summer. **Assessment Boundary:** Assessment is limited to relative amounts of daylight, not quantifying the hours or time of daylight.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • Make observations (firsthand or from media) to collect data that can be used to make comparisons.	• Seasonal patterns of sunrise and sunset can be observed, described, and predicted.	**Patterns:** • Patterns in the natural world can be observed, used to describe phenomena, and used as evidence.

Earth and Human Activity (ESS3)		
1.ESS3.1 Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.*		
Clarification Statement: Examples of human impact on the land could include cutting trees to produce paper and using resources to produce bottles. Examples of solutions could include reusing paper and recycling cans and bottles. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Obtaining, Evaluating and Communicating Information: • Communicate solutions with others in oral and/or written forms using models and/or drawings that provide detail about scientific ideas.	• Things that people do to live comfortably can affect the world around them. But, they can make choices that reduce their impacts on the land, water, air, and other living things. • Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people.	**Cause and Effect:** • Events have causes that generate observable patterns.

2nd GRADE (2)

Matter and Its Interactions (PS1)

2.PS1.1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

Clarification Statement: Observations could include color, texture, hardness, and flexibility. Patterns could include the similar properties that different materials share. Investigations could include ice and snow melting or frozen objects thawing. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.	• Different kinds of matter exist and many of them can be either solid or liquid, depending on temperature. • Matter can be described and classified by its observable properties. • Different properties are suited to different purposes.	**Patterns:** • Patterns in the natural and human-designed world can be observed.

2.PS1.2 Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for the intended purpose.*

Clarification Statement: Examples of properties could include strength, flexibility, hardness, texture, and absorbency (e.g. paper towels could be utilized to measure absorbency and strength). **Assessment Boundary:** Assessment of quantitative measurements is limited to length.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data: • Analyze data from tests of an object or tool to determine if it works as intended.	• Different properties are suited to different purposes. • Every human-made product is designed by applying some knowledge of the natural world and is built using materials derived from the natural world.	**Cause and Effect:** • Simple tests can be designed to gather evidence to support or refute student ideas about causes.

Matter and Its Interactions (PS1)		
2.PS1.3 Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object.		
Clarification Statement: Examples of pieces could include building blocks, or other assorted small objects. Provide students with the same number of pieces to create a different object. **Assessment Boundary:** Do not introduce terminology associated with the Law of Conservation of Matter just concepts. Chemical change is outside of this performance expectation.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena.	• A great variety of objects can be built up from a small set of pieces. • Different properties are suited to different purposes.	**Energy and Matter:** • Objects may break into smaller pieces and be put together into larger pieces, or change shapes.
2.PS1.4 Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.		
Clarification Statement: Demonstrations of reversible changes could include materials such as water, butter, or crayons at different temperatures. Demonstrations of irreversible changes could include cooking an egg, freezing a plant leaf, or heating paper. Arguments center on using first-hand observations as evidence to support a claim that a material can change and go back to its original form through heating and cooling. **Assessment Boundary:** Students should not be expected to identify or explain physical and chemical changes.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Construct an argument with evidence to support a claim.	• Heating or cooling a substance may cause changes that can be observed. • Sometimes these changes are reversible, and sometimes they are not.	**Cause and Effect:** • Events have causes that generate observable patterns.

Ecosystems: Interactions, Energy and Dynamics (LS2)		
2.LS2.1 Plan and conduct an investigation to determine if plants need sunlight and water to grow.		
Clarification Statement: Investigations should be limited to testing one variable at a time. **Assessment Boundary:** Assessment is limited to testing one variable at a time, although students are not expected to understand the term variable at this time.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Planning and Carrying Out Investigations: • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.	• Plants depend on water and light to grow.	**Cause and Effect:** • Events have causes that generate observable patterns.
2.LS2.2 Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants.*		
Clarification Statement: Examples include: placing socks on the outside of students' shoes and walking outside allows socks to gather seeds, plant sock(s) to see what grows, use a pipe cleaner to move powder (like flour) from one place to another emulating flowers being pollinated by bees or other insects. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a simple model based on evidence to represent a proposed object or tool.	• Plants depend on animals for pollination or to move their seeds around. • Designs can be conveyed through sketches, drawings, or physical models. • These representations are useful in communicating ideas for a problem's solutions to other people.	**Structure and Function:** • The shape and stability of structures of natural and designed objects are related to their function(s).

Biological Unity and Diversity (LS4)

2.LS4.1 Make observations of plants and animals to compare the diversity of life in different habitats.

Clarification Statement: Emphasis is on the diversity of living things in each of a variety of different habitats. Students could explore different habitats such as a neighborhood park, ponds, and the school playground. **Assessment Boundary:** Assessment does not include specific animal and plant names in specific habitats.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • Make observations (firsthand or from media) to collect data which can be used to make comparisons.	• There are many different kinds of living things in any area, and they exist in different places on land and in water.	**Systems and System Models:** • A system is an organized group of related objects or components.

Earth's Place in the Universe (ESS1)

2.ESS1.1 Use information from several sources to provide evidence that Earth events can occur quickly or slowly.

Clarification Statement: Examples of events and timescales could include volcanic explosions and earthquakes, which happen quickly, and erosion of rocks, which occurs slowly. **Assessment Boundary:** Assessment does not include quantitative measurements of timescales.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Make observations from several sources to construct an evidence-based account for natural phenomena.	• Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe.	**Stability and Change:** • Things may change slowly or rapidly.

Earth's Systems (ESS2)

2.ESS2.1 Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.*

Clarification Statement: Examples of solutions could include different designs of dikes and windbreaks to hold back wind and water, and different designs for using shrubs, grass, and trees to hold back the land. Students could explore these ideas with sand tables or soil and water in large containers. **Assessment Boundary:** N/A.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Designing Solutions: • Compare multiple solutions to a problem.	• Wind and water can change the shape of the land. • Because there is always more than one possible solution to a problem, it is useful to compare and test designs. • Developing and using technology has impacts on the natural world.	**Stability and Change:** • Things may change slowly or rapidly.

2.ESS2.2 Develop a model to represent the shapes and kind of land and bodies of water in an area.

Clarification Statement: Examples could include a diagram, drawing, physical replica, or three-dimensional diorama. Models can be based on photographs, virtual images, or in-person observations. **Assessment Boundary:** Assessment does not include quantitative scaling in models.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop a model to represent patterns in the natural world.	• Maps show where things are located. • One can map the shapes and kinds of land and water in any area.	**Patterns:** • Patterns in the natural world can be observed.

2.ESS2.3 Obtain information to identify where water is found on Earth and that it can be solid or liquid.

Clarification Statement: Information can be obtained through text, media, or in-person observations. Patterns can be observed through identifying where solid water (ice) is found and where liquid water can be located. **Assessment Boundary:** N/A.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information: • Obtain information using various texts and media.	• Water is found in the ocean, rivers, lakes, and ponds. • Water exists as solid ice and in liquid form.	**Patterns:** • Patterns in the natural world can be observed.

3RD GRADE (3)

Motion and Stability: Forces and Interactions (PS2)

3.PS2.1 Plan and conduct investigations on the effects of balanced and unbalanced forces on the motion of an object.

Clarification Statement: Examples could include that an unbalanced force on one side of a ball can make it start moving and balanced forces pushing on a box from opposite 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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • 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.	• 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 quantitative addition of forces is not used at this level.) • Objects in contact exert forces on each other.	**Cause and Effect:** • Cause and effect relationships are routinely identified.

3.PS2.2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing (pendulum), object rolling down a ramp from different heights, a ball rolling back and forth in a bowl, and two children on a see-saw. **Assessment Boundary:** Assessment does not include technical terms such as period and frequency.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon.	• The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed).	**Patterns:** • Patterns of change can be used to make predictions.

Motion and Stability: Forces and Interactions (PS2)

3.PS2.3 Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force. **Assessment Boundary:** Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions: • Ask questions that can be investigated based on patterns such as cause and effect relationships.	• Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.	**Cause and Effect:** • Cause and effect relationships are routinely identified, tested, and used to explain change.

3.PS2.4 Define a simple design problem that can be solved by applying scientific ideas about magnets.*

Clarification Statement: Examples of problems could include a door that will not stay closed or two objects that keep colliding. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Define Problems: • Define a simple problem that can be solved through the development of a new or improved object or tool.	• Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. • Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process.	**Cause and Effect:** • Cause and effect relationships are routinely identified, tested, and used to explain change. *Other crosscutting concepts may be more appropriate depending on the problem chosen.*

From Molecules to Organisms: Structure and Function (LS1)		
3.LS1.1 Develop and use models to describe that organisms have unique and diverse life cycles but all have a common pattern of birth, growth, reproduction, and death.		
Clarification Statement: Changes different organisms go through during their life form a pattern. Organism life cycles that can be studied include mealworms, dandelions, lima beans, dogs, and butterflies. **Assessment Boundary:** Assessment includes animal and plant life cycles. Plant life cycles are limited to those of flowering plants. Assessment does not include details of human reproduction or microscopic organisms.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop models to describe phenomena.	• Reproduction is essential to the continued existence of every kind of organism. • Plants and animals have unique and diverse life cycles.	**Patterns:** • Patterns of change can be used to make predictions.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
3.LS2.1 Construct an argument that some animals form groups that help members survive.		
Clarification Statement: Arguments could include examples of group behavior such as division of labor in a bee colony, flocks of birds staying together to confuse or intimidate predators, or wolves hunting in packs to more efficiently catch and kill prey. When animals are no longer part of their group, they may not survive as well. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engage in Argument from Evidence: • Construct an argument from evidence, data, and/or a model.	• Being part of a group helps animals obtain food, defend themselves, and cope with changes. • Groups may serve different functions and vary dramatically in size.	**Cause and Effect:** • Cause and effect relationships are routinely used to explain change.

Heredity: Inheritance and Variation of Traits (LS3)

3.LS3.1 Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.

Clarification Statement: Patterns are the similarities and differences in traits shared between offspring and their parents, or among siblings. Emphasis is on organisms other than humans. **Assessment Boundary:** Assessment does not include genetic mechanisms of inheritance and prediction of traits. Assessment is limited to non-human examples.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data: • Analyze and interpret data to make sense of phenomena using logical reasoning.	• Many characteristics of organisms are inherited from their parents. • Different organisms vary in how they look and function because they have different inherited information.	**Patterns:** • Similarities and differences in patterns can be used to sort and classify natural phenomenon.

3.LS3.2 Use evidence to support the explanation that traits can be influenced by the environment.

Clarification Statement: Examples of the environment affecting a trait could include that normally tall plants grown with insufficient water are stunted; a pet dog that is given too much food and little exercise may become overweight; and animals who teach their offspring skills like hunting. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Use evidence (e.g., observations, patterns) to support an explanation.	• Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. • The environment also affects the traits that an organism develops.	**Cause and Effect:** • Cause and effect relationships are routinely identified and used to explain changes.

Biological Unity and Diversity (LS4)

3.LS4.1 Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.

Clarification Statement: Examples of data could include type, size, and distribution of fossil organisms. Examples of fossils and environments could include marine fossils found on dry land, tropical plant fossils found in Arctic areas, and fossils of extinct organisms. **Assessment Boundary:** Assessment does not include identification of specific fossils or present plants and animals. Assessment is limited to major fossil types and relative ages.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data: • Analyze and interpret data to make sense of phenomena using logical reasoning.	• Some kinds of plants and animals that once lived on Earth are no longer found anywhere. • Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments.	**Scale, Proportion, and Quantity:** • Observable phenomena exist from very short to very long time periods.

3.LS4.2 Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving and reproducing.

Clarification Statement: Examples of cause and effect relationships could be plants that have larger thorns than other plants may be less likely to be eaten by predators; and animals that have better camouflage coloration than other animals may be more likely to survive and therefore more likely to leave offspring. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Use evidence (e.g., observations, patterns) to construct an explanation.	• Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing.	**Cause and Effect:** • Cause and effect relationships are routinely identified, tested, or used to explain change.

Biological Unity and Diversity (LS4)

3.LS4.3 Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

Clarification Statement: Examples of evidence could include needs and characteristics of the organisms and habitats involved. The organisms and their habitat make up a system in which the parts depend on each other. At no time should animals be put in danger to collect evidence.
Assessment Boundary: N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Construct an argument with evidence.	• For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. • Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful.	**Cause and Effect:** • Cause and effect relationships are routinely identified and used to explain change.

3.LS4.4 Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.*

Clarification Statement: Examples of environmental changes could include changes in land characteristics, water distribution, temperature, food, and other organisms. **Assessment Boundary:** Assessment is limited to a single environmental change. Assessment does not include the greenhouse effect or climate change.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.	• When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. • Populations live in a variety of habitats, and change in those habitats affects the organisms living there. • Knolwedge of relevant scientific concepts and research findings is important in engineering.	**Systems and System Models:** • A system can be described in terms of its components and their interactions.

Earth's Systems (ESS2)		
3.ESS2.1 Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.		
Clarification Statement: Examples of data at this grade level could include average temperature, precipitation, and wind direction. **Assessment Boundary:** Assessment of graphical displays is limited to frequency tables, line plots, pictographs, and single bar graphs. Students are not expected to calculate averages but simply to represent them in graphical form.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyzing and Interpreting Data: • Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships.	• Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next.	**Patterns:** • Patterns of change can be used to make predictions.

Earth's Systems (ESS2)		
3.ESS2.2 Obtain and combine information to describe climates in different regions of the world.		
Clarification Statement: Information could include hours of daylight, amount of precipitation, temperature, seasons, and wind. Descriptions could include the use of frequency tables, line plots, pictographs, and single bar graphs. Climate data should include weather conditions over multiple years. **Assessment Boundary:** Assessments do not include causes of seasons.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information: • Obtain and combine information from books and other reliable media to explain phenomena.	• Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years to centuries.	**Patterns:** • Patterns of change can be used to make predictions.

Earth and Human Activity (ESS3)		
3.ESS3.1 Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.*		
Clarification Statement: Examples of design solutions to weather-related hazards could include barriers to prevent flooding, wind/hail resistant roofs/windows, textured walking surfaces for ice, tornado shelters, and lighting rods. While earthquakes, volcanoes, and tsunamis are natural hazards they are not caused by weather phenomenon. **Assessment Boundary:** Assessments are limited to weather-related hazards only.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.	• A variety of natural hazards result from natural processes. • Humans cannot eliminate natural hazards but can take steps to reduce their impact. • Engineers improve existing technologies or develop new ones to increase their benefits (e.g., better artificial limbs), decrease known risks (e.g., seatbelts in cars), and meet societal demands (e.g., cell phones).	**Cause and Effect:** • Cause and effect relationships are routinely identified, tested, and used to explain change.

4TH GRADE (4)		
Energy (PS3)		
4.PS3.1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.		
Clarification Statement: Energy can be moved from place to place by moving objects (e.g. wind moving a sail then moving a boat, throwing a ball, or paddling a boat). As objects increase in speed they possess more energy (e.g. ball rolling down a ramp). **Assessment Boundary:** Assessment does not include quantitative measures of changes in the speed of an object (acceleration) or on any precise, quantitative, or complete definition of energy.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Use evidence (e.g., measurements, observations, patterns) to construct an explanation.	• The faster a given object is moving, the more energy it possesses.	**Patterns:** • Patterns can be used as evidence to support an explanation.

Energy (PS3)		
4.PS3.2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.		
Clarification Statement: Light, heat, sound, and electric currents transfer energy. Examples of this can include sound from a radio, light from a flashlight, the Sun heating a window pane, and currents to electronic devices. When energy is transferred it can stay in the same form or change forms. **Assessment Boundary:** Assessment does not include quantitative measurements of energy or the difference between transferring and transforming energy.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Planning and Carrying Out Investigations: • Make observations to produce data to serve as the basis for evidence for an explanation of a phenomena or test a design solutions.	• Energy can be moved from place to place by moving objects or through sound, light, or electric currents. • Energy is present whenever there are moving objects, sound, light, or heat. • When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. • Light also transfers energy from place to place. • Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light.	**Energy and Matter:** • Energy can be transferred in various ways and between objects.

<table>
<tr><th colspan="3">Energy (PS3)</th></tr>
<tr><td colspan="3">4.PS3.3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.</td></tr>
<tr><td colspan="3">Clarification Statement: Collisions include any interactions between objects when they come in contact with one another and transfer energy. Emphasis is on the change in energy due to the change in speed, not forces, as objects interact. Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object (acceleration) or quantitative measurements of energy.</td></tr>
<tr><th>Science and Engineering Practice</th><th>Disciplinary Core Ideas</th><th>Crosscutting Concepts</th></tr>
<tr><td>Asking Questions:
• Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.</td><td>• Energy can be moved from place to place by moving objects or through sound, light, or electric currents.
• Energy is present whenever there are moving objects, sound, light, or heat.
• When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
• When objects collide, the contact forces transfer energy so as to change the objects' motions.</td><td>Energy and Matter:
• Energy can be transferred in various ways and between objects.</td></tr>
</table>

Energy (PS3)		
4.PS3.4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*		
Clarification Statement: Examples of devices could include mousetrap cars; rubber band-powered vehicles; electric circuits that convert electrical energy into light, sound, or motion energy of a vehicle; and a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Designing Solutions: • Apply scientific ideas to solve design problems.	• Energy can be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. • The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use. • Possible solutions to a problem are limited by available materials and resources (constraints).Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. • The success of a designed solution is determined by considering the desired features of a solution (criteria). • Engineers improve existing technologies or develop new ones.	**Energy and Matter:** • Energy can be transferred in various ways and between objects.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
4.PS4.1 Develop and use a model of waves to describe patterns in terms of amplitude and wavelength, and to show that waves can cause objects to move.		
Clarification Statement: Examples of models could include diagrams, analogies, and physical models using items like stringed beads, rubber bands, or yarn to illustrate wavelength and amplitude of waves. Examples of wave patterns that cause objects to move up and down or side to side could include the vibrating patterns associated with sound, the vibrating patterns of seismic waves produced by earthquakes. **Assessment Boundary:** Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model using an analogy, example, or abstract representation to describe a scientific principle.	• Waves, which are regular patterns of motion, can be made in water by disturbing the surface. • When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. • Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks).	**Patterns:** • Similarities and differences in patterns can be used to sort and classify designed products.
4.PS4.2 Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.		
Clarification Statement: Models would identify components such as the source of the light, objects that are seen, the path of the light, and the eye. Models could be used to investigate what happens when one of the components changes (Example: Close the eyes, block the light, or change the light path). **Assessment Boundary:** Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model to describe phenomena.	• An object can be seen when light reflected from its surface enters the eyes.	**Cause and Effect:** • Cause and effect relationships are routinely identified.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
4.PS4.3 Generate and compare multiple solutions that use patterns to transfer information.*		
Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1's and 0's representing black and white to send information about a picture, QR codes, barcodes, and using Morse code to send text. **Assessment Boundary:** Assessment does not include creating or writing digital code.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Designing Solutions: • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.	• Digitized information can be transmitted over long distances without significant degradation. • High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	**Patterns:** • Similarities and differences in patterns can be used to sort and classify designed products.

From Molecules to Organisms: Structure and Processes (LS1)		
4.LS1.1 Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.		
Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin. **Assessment Boundary:** Assessment is limited to macroscopic structures within plant and animal systems.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Construct an argument with evidence, data, and/or a model.	• Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.	**Structure and Function:** • Substructures have shapes and parts that serve functions.

From Molecules to Organisms: Structure and Processes (LS1)

4.LS1.2 Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.

Clarification Statement: Emphasis is on systems of information transfer. Examples of response to stimuli include a dog is hot and lies in the shade, a rabbit hears a noise and runs away, and a person is cold so they put on a jacket. **Assessment Boundary:** Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Use a model to test interactions concerning the functioning of a natural system.	• Different sense receptors are specialized for particular kinds of information, which may be then processed by the animal's brain. • Animals are able to use their perceptions and memories to guide their actions.	**Systems and System Models:** • A system can be described in terms of its components and their interactions.

Earth's Place in the Universe (ESS1)

4.ESS1.1 Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.

Clarification Statement: Examples of evidence from patterns could include rock layers with marine shell fossils above rock layers with plant fossils and no shells, indicating a change from land to water over time; and a canyon with different rock layers in the walls and a river in the bottom, indicating that over time a river cut through the rock. **Assessment Boundary:** Assessment does not include specific knowledge or memorization of specific rock formation and layers. Assessment is limited to relative time.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Identify the evidence that supports particular points in an explanation.	• Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. • The presence and location of certain fossil types indicate the order in which rock layers were formed.	**Patterns:** • Patterns can be used as evidence to support an explanation.

Earth's Systems (ESS2)		
4.ESS2.1 Plan and conduct investigations on the effects of water, ice, wind, and vegetation on the relative rate of weathering and erosion.		
Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow. **Assessment Boundary:** Assessment is limited to a single form of weathering or erosion.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Planning and Carrying Out Investigations: • With guidance, plan and conduct an investigation with peers.	• Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around.	**Cause and Effect:** • Cause and effect relationships are routinely identified, tested, and used to explain change.
4.ESS2.2 Analyze and interpret data from maps to describe patterns of Earth's features.		
Clarification Statement: Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyzing and Interpreting Data: • Analyze and interpret data to make sense of phenomena using logical reasoning.	• The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. • Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. • Major mountain chains form inside continents or near their edges. • Maps can help locate the different land and water features where people live and in other areas of Earth.	**Patterns:** • Patterns can be used as evidence to support an explanation.

Earth and Human Activity (ESS3)		
4.ESS3.1 Obtain and combine information to describe that energy and fuels are derived from renewable and non-renewable resources and how their uses affect the environment.		
Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information: • Obtain and combine information from books and other reliable media to explain phenomena.	• Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. • Some resources are renewable over time, and others are not.	**Cause and Effect:** • Cause and effect relationships are routinely identified, tested, and used to explain change.
4.ESS3.2 Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.*		
Clarification Statement: Examples of solutions could include designing an earthquake resistant building, improving monitoring of volcanic activity, and constructing waterways for flood waters. **Assessment Boundary:** Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Designing Solutions: • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.	• A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). • Humans cannot eliminate the hazards but can take steps to reduce their impacts. • Testing a solution involves investigating how well it performs under a range of likely conditions. • Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands.	**Cause and Effect:** • Cause and effect relationships are routinely identified and used to explain change.

5TH GRADE (5)		
Matter and Its Interactions (PS1)		
5.PS1.1 Develop a model to describe that matter is made of particles too small to be seen.		
Clarification Statement: Examples of evidence that could be utilized in building models include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water. **Assessment Boundary:** Assessment does not include atomic scale mechanism of evaporation and condensation or defining the unseen particles.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model to describe phenomena.	• Matter of any type can be subdivided into particles that are too small to see, but even then, the matter still exists and can be detected by other means. • A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects.	**Scale, Proportion, and Quantity:** • Natural objects exist from the very small to the immensely large.
5.PS1.2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.		
Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that forms new substances. Measurements can be organized in tables, charts, and graphs and can be used as evidence that weight is conserved. **Assessment Boundary:** Assessment does not include distinguishing between mass and weight.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Use Mathematics and Computational Thinking: • Represent data in graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.	• The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. • No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level).	**Scale, Proportion, and Quantity:** • Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

Matter and Its Interactions (PS1)

5.PS1.3 Make observations and measurements to identify materials based on their properties.

Clarification Statement: Observations can be based on direct experiences with materials and comparisons of materials. Examples of materials to be identified could include powders (e.g. baking soda, cornstarch, sugar), metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property. **Assessment Boundary:** Assessment does not include density or distinguishing mass and weight. At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon.	• Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.)	**Scale, Proportion, and Quantity:** • Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

5.PS1.4 Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

Clarification Statement: Examples of interactions forming new substances can include mixing baking soda and vinegar. Examples of interactions not forming new substances can include mixing baking soda and water. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • 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.	• When two or more different substances are mixed, a new substance with different properties may be formed.	**Cause and Effect:** • Cause and effect relationships are routinely identified, tested, and used to explain change.

Motion and Stability: Forces and Interactions (PS2)

5.PS2.1 Support an argument, with evidence, that Earth's gravitational force pulls objects downward toward the center of the earth.

Clarification Statement: "Downward" is a local description of the direction that points toward the center of the spherical earth. Earth causes objects to have a force on them that point toward the center of the Earth, "downward". Evidence could be drawn from diagrams, models, and data that are provided. **Assessment Boundary:** Mathematical representation of gravitational force is not assessed.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Construct and/or support an argument with evidence, data, and/or a model.	• The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	**Cause and Effect:** • Cause and effect relationships are routinely identified, tested, and used to explain change.

Energy (PS3)

5.PS3.1 Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the Sun.

Clarification Statement: Examples of models could include diagrams and flow-charts. **Assessment Boundary:** Assessment does not include cellular mechanisms of digestive absorption.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Use models to describe phenomena.	• The energy released from food was once energy from the Sun that was captured by plants in the chemical process that forms plant matter (from air and water). • Food provides animals with the materials they need for body repair and growth, energy they need to maintain body warmth and for motion.	**Energy and Matter:** • Energy can be transferred in various ways and between objects.

From Molecules to Organisms: Structure and Processes (LS1)		
5.LS1.1 Support an argument that plants get the materials they need for growth chiefly from air and water.		
Clarification Statement: While energy for plant growth comes from the Sun, material for plant growth comes chiefly from air and water, not from the soil. Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil. **Assessment Boundary:** Does not include molecular explanations of photosynthesis.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Support an argument with evidence, data, or a model.	• The energy released from food was once energy from the Sun that was captured by plants in the chemical process that forms plant matter (from air and water). • Plants acquire their material for growth chiefly from air and water.	**Energy and Matter:** • Matter is transported into, out of, and within systems.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
5.LS2.1 Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.		
Clarification Statement: Emphasis is on the idea that matter in systems cycles among living and nonliving things (air, water, decomposed materials in soil). Examples of systems could include organisms, ecosystems, and the Earth. **Assessment Boundary:** Assessment does not include photosynthesis or molecular explanations.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model to describe phenomena.	• The food of almost any kind of animal can be traced back to plants. • Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. • Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." • Decomposition eventually restores (recycles) some materials back to the soil. • Organisms can survive only in environments in which their particular needs are met. • A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. • Newly introduced species can damage the balance of an ecosystem. • Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. • Organisms obtain gases and water from the environment, and release waste matter (gas, liquid, or solid) back into the environment.	**Systems and System Models:** • A system can be described in terms of its components and their interactions.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
5.LS2.2 Use models to explain factors that upset the stability to local ecosystems.		
Clarification Statement: Explanatory models can include representations of relationships between and among organisms, or simulations can be used to predict how factors might impact an ecosystem. Factors that upset an ecosystem's stability includes invasive species, drought, human development, and removal of predators. **Assessment Boundary:** Does not include molecular explanations.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model to describe phenomena.	• Organisms can survive only in environments in which their particular needs are met. • A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. • Newly introduced species can damage the balance of an ecosystem.	**Systems and System Models:** • A system can be described in terms of its components and their interactions.

Earth's Place in the Universe (ESS1)		
5.ESS1.1 Support an argument with evidence that differences in the apparent brightness of the Sun compared to other stars is due to their relative distances from Earth.		
Clarification Statement: Examples of scale could include relative distance of specific stars to Earth. Evidence to support arguments could come from data or models. Examples of stars include Polaris, Sirius, and Betelgeuse. **Assessment Boundary:** Assessment is limited to relative distances, not size of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage).		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Arguments from Evidence: • Support an argument with evidence, data, or a model.	• The Sun is a star that appears brighter than other stars because it is closer to Earth. • The Sun is a star that appears larger than other stars because it is closer to Earth. • Stars range greatly in their distance from Earth.	**Scale, Proportion, and Quantity:** • Natural objects exist from the very small to the immensely large.

Earth's Place in the Universe (ESS1)		
5.ESS1.2 Represent data in graphical displays to reveal patterns of daily changes in the length and direction of shadows, in addition to different positions of the Sun, Moon, and stars at different times of the day, month, and year.		
Clarification Statement: Examples of patterns could include the position and motion of Earth with respect to the Sun, and selected stars that are visible only in particular months or the position of the Moon with respect to the Sun and Earth. **Assessment Boundary:** Assessment does not include causes of seasons or labeling specific phases of the Moon.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyzing and Interpreting Data: • Represent data in graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.	• The orbits of Earth around the Sun and of the Moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include: day and night; daily changes in the length and direction of shadows; and different positions of the Sun, Moon, and stars at different times of the day, month, and year.	**Patterns:** • Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena.

Earth's Systems (ESS2)		
5.ESS2.1 Develop a model to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.		
Clarification Statement: The geosphere, hydrosphere, atmosphere, and biosphere are each a system. Examples of system interactions could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. **Assessment Boundary:** Assessment is limited to the interactions of two systems at a time.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model using an example to describe phenomena.	• Earth's major systems are the geosphere, hydrosphere, atmosphere, and biosphere. • These systems interact in multiple ways to affect Earth's surface materials and processes. • The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. • Winds and clouds in the atmosphere interact with landforms to determine patterns of weather.	**System and System Models:** • A system can be described in terms of its components and their interactions.

Earth's Systems (ESS2)		
5.ESS2.2 Describe and graph amounts of saltwater and freshwater in various reservoirs to provide evidence about the distribution of water on Earth.		
Clarification Statement: Descriptions could include comparisons using graphs, charts, and tables. Quantities could include percentages, total volume, and amounts. Emphasis is on using amounts or percentages of water to make comparisons. No attempt to calculate percentages should be made. **Assessment Boundary:** Assessment is limited to oceans, lakes, rivers, glaciers, groundwater, and polar ice caps, and does not include the atmosphere. Only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. Assessment should not include circle charts (pie charts) or calculation of percentages.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking: • Describe and graph quantities such as area and volume to address scientific questions.	• Nearly all of Earth's available water is in the ocean. • Most freshwater is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.	**Scale, Proportion, and Quantity:** • Standard units are used to measure and describe physical quantities such as weight and volume.

Earth and Human Activity (ESS3)		
5.ESS3.1 Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environments.		
Clarification Statement: Examples of information might include the use of natural fertilizers or biological pest control by farmers, replanting trees after cutting them by the logging industry, and the institution of recycling programs in cities. **Assessment Boundary:** Assessment is limited to one human interaction at a time.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information: • Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.	• Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.	**System and System Models:** • A system can be described in terms of its components and their interactions.

6TH GRADE (6)		
Matter and Its Interactions (PS1)		
6.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. **Assessment Boundary:** The use of mathematical formulas is not intended		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model to predict and/or describe phenomena.	• 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. • 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.	**Cause and Effect:** • Cause and effect relationships are routinely identified, tested, and used to explain change.

Energy (PS3)		
6.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. Care should be taken with devices that concentrate significant amounts of energy, e.g. conduction, convection, and/or radiation. **Assessment Boundary:** Assessment does not include calculating the total amount of thermal energy.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Designing Solutions: • Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process, or system.	• 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. • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. • 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. • 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.	**Energy and Matter:** • The transfer of energy can be tracked as energy flows through a designed or natural system.

Energy (PS3)		
6.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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• 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. • 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.	**Scale, Proportion, and Quantity:** • Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
6.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 of light waves through a prism, mechanical waves through gas vs. liquids vs. solids, or sound waves through different mediums. **Assessment Boundary:** Assessment is limited to qualitative applications pertaining to electromagnetic and mechanical waves.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop and use a model to describe phenomena.	• A sound wave needs a medium through which it is transmitted. • 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 can travel 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.	**Structure and Function:** • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

From Molecules to Organisms: Structure and Processes (LS1)

6.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 things, and understanding that living things may be made of one cell or many and varied cells. **Assessment Boundary:** Assessment does not include identification of specific cell types and should emphasize the use of evidence from investigations.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of an investigation.	• 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).	**Scale, Proportion, and Quantity:** • Phenomena that can be observed at one scale may not be observable at another scale.

6.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. Other organelles can be introduced while covering this concept.

Assessment Boundary: Assessment of organelle structure/function relationships limited to cell wall and cell membrane. Assessment of other organelles is limited to their relationship to the whole cell. Assessment does not include biochemical functions of cell or cell parts.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop and use a model to describe phenomena.	• Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.	**Structure and Function:** • Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts.

From Molecules to Organisms: Structure and Processes(LS1)		
6.LS1.3 Use an 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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.	• 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.	**Systems and System Models:** • Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
6.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.		
Clarification Statement: Examples include receptors in the eye that respond to light intensity and color; receptors in hair cells of the inner ear that detect vibrations conducted from the eardrum; taste buds that detect chemical qualities of foods including sweetness, bitterness, sourness, saltiness, and umami (savory taste); and receptors in the skin that respond to variations in pressure. **Assessment Boundary:** The assessment should provide evidence of students' abilities to provide a basic and conceptual explanation of the process. Assessment does not include mechanisms for the transmission of this information.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information: • Read and comprehend grade appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas.	• 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.	**Cause and Effect:** • Cause and effect relationships may be used to predict phenomena in natural systems.

Earth's Place in the Universe (ESS1)

6.ESS1.4 Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's geologic history.

Clarification Statement: Emphasis is on analyses of rock formations and fossils they contain to establish relative ages of major events in Earth's history. Scientific explanations can include models to study the geologic time scale. **Assessment Boundary:** Assessment does not include recalling the names of specific periods or epochs and events within them.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Construct 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.	• 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. • Major events could include the formation of mountain chains and ocean basins, adaptation and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and the development of watersheds and rivers through glaciation and water erosion.	**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.

Earth's Systems (ESS2)		
6.ESS2.1 Develop a model to describe the cycling of Earth's materials and the flow of energy that drives these processes within and among Earth's systems.		
Clarification Statement: Emphasis is on how energy from the Sun and Earth's hot interior drive processes that cause physical and chemical changes to materials within and between the geosphere, hydrosphere, atmosphere, and biosphere. Examples of processes could include melting, crystallization, weathering, deformation, and sedimentation, which act together to form and change rocks and minerals through the rock cycle. **Assessment Boundary:** Assessment does not include the identification or naming of minerals.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop and use a model to describe phenomena.	• 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 produces chemical and physical changes in Earth's materials.	**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.

Earth's Systems (ESS2)		
6.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 usually behave gradually but are punctuated by catastrophic events (such as earthquakes, volcanoes, and meteor impacts). 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. **Assessment Boundary:** Assessment does not include identification or naming of specific events.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Construct 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.	• The planet's systems interact over scales that range from microscopic to global in size; these interactions have shaped Earth's history and will determine its future. • Water's movements, both on the land and underground, cause weathering and erosion, which change the land's surface features and create underground formations.	**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.

Earth's Systems (ESS2)		
6.ESS2.3 Analyze and interpret data on the patterns of distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.		
Clarification Statement: Examples could include identifying patterns on maps of earthquakes and volcanoes relative to plate boundaries, the shapes of the continents, the locations of ocean structures (including mountains, volcanoes, faults, and trenches), or similarities of rock and fossil types on different continents. **Assessment Boundary:** Paleomagnetic anomalies in oceanic and continental crust are not assessed.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyze and Interpret Data: • Analyze and interpret data to determine similarities and differences in findings.	• Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. • 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.	**Patterns:** • Patterns in rate of change and other numerical relationships can provide information about natural and human-designed systems.

Earth's Systems (ESS2)

6.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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop a model to describe unobservable mechanisms.	• 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.	**Energy and Matter:** • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

6.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 interact. 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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• 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. • Because these patterns are so complex, weather can be predicted only probabilistically.	**Cause and Effect:** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Earth's Systems (ESS2)		
6.ESS2.6 Develop and use a model to describe how unequal heating and rotation of the Earth causes 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 (e.g., Gulf Stream, North Pacific Drift, California Current) is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Interactions between the atmosphere and oceans can affect the ocean's surface temperature (El Nino/La Nina). Examples of models can be diagrams, maps and globes, or digital representations. **Assessment Boundary:** Assessment should not be focused on specific weather events, but on the patterns that drive Earth's climate systems.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop and use a model to describe phenomena.	• Variations in density due to variations in temperature and salinity drive a global pattern on interconnected ocean currents. • 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, and globally redistributing it through ocean currents.	**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 the systems.

Earth and Human Activity (ESS3)		
6.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). **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyzing and Interpreting Data: • Analyze and interpret data to provide evidence for phenomena.	• 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.	**Patterns:** • Graphs, charts, and images can be used to identify patterns in data.

7TH GRADE (7)

Matter and Its Interactions (PS1)

7.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/or 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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Use a model to predict the relationships between systems or between components of a system.	• 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).	**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.

7.PS1.2 Analyze and interpret patterns of data related to the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Clarification Statement: Analyze characteristic chemical and physical properties of pure substances. Examples of chemical reactions could include burning sugar or steel wool, baking a cake, milk curdling, or metal rusting. **Assessment Boundary:** Assessment is limited to analysis of the following properties: color change, formation of a gas, temperature change, density, melting point, boiling point, solubility, flammability, and odor.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data: • Analyze and interpret data to determine similarities and differences in findings.	• Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. • 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.	**Patterns:** • Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Matter and Its Interactions (PS1)		
7.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:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• Each pure substance has characteristics, physical and chemical properties (for any bulk quantity under given conditions), that can be used to identify it. • Substances react chemically in characteristic ways. • In a chemical process, the atoms that make up the original substances regroup into different molecules, and these new substances have different properties from those of the reactants. • Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.	**Structure and Function:** • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Matter and Its Interactions (PS1)		
7.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 or intermolecular forces.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model to describe unobservable mechanics.	• 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. • The total number of each type of atom is conserved and thus, the mass does not change. Laws are regularities or mathematical descriptions of natural phenomena.	**Energy and Matter:** • Matter is conserved because atoms are conserved in physical and chemical processes.

Matter and Its Interactions (PS1)		
7.PS1.6 Construct, test, and modify a device that releases or absorbs thermal energy by chemical processes to solve a problem.*		
Clarification Statement: Examples of device modification could include changing factors such as type and concentration of a substance. Examples of problems could be keeping a chemical ice pack cold longer or chemical heat pack warm longer. 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 substances in testing the device.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• Some chemical reactions release energy, others store energy. • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. • 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. • 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.	**Energy and Matter:** • The transfer of energy can be tracked as energy flows through a designed or natural system.

Energy (PS3)		
7.PS3.1 Construct and interpret graphical displays of data to describe the proportional 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. **Assessment Boundary:** Does not include mathematical calculations of kinetic energy.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyze and Interpret Data: • Construct and interpret graphical displays of data to identify linear and nonlinear relationships.	• 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.	**Scale, Proportion and Quantity:** • Proportional relationships (e.g., speed as a ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and process.

Energy (PS3)

7.PS3.2 Develop a model to describe that when objects interacting at a distance change their arrangement, 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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop a model to predict and/or describe phenomena.	• A system of objects may also contain stored (potential) energy, depending on their relative positions. • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	**Systems and System Models:** • Models can be used to represent systems and their interactions (such as inputs, processes, and outputs) and energy and matter flows within systems.

7.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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.	• When the motion energy of an object changes, there is inevitably some other change in energy at the same time.	**Energy and Matter:** • The transfer of energy can be tracked as energy flows through a designed or natural system.

From Molecules to Organisms: Structure and Function (LS1)		
7.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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • 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.	• 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. • 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.	**Energy and Matter:** • Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
7.LS1.7 Develop a model to describe how food molecules in plants and animals are broken down and rearranged through chemical reactions to form new molecules that support growth and/or release energy as matter moves through an organism.		
Clarification Statement: Emphasis is on describing how energy stored within food molecules is released as they are broken apart and rearranged into new molecules. **Assessment Boundary:** Assessment does not include details of the chemical reactions for photosynthesis or respiration.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model to predict and/or describe phenomena.	• Within an individual organism, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or release energy. • Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.	**Energy and Matter:** • Matter is conserved because atoms are conserved in physical and chemical processes.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
7.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. **Assessment Boundary:** Determining the carrying capacity of ecosystems is beyond the intent.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyzing and Interpreting Data: • Analyze and interpret data to provide evidence for phenomena.	• 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.	**Cause and Effect:** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.
7.LS2.2 Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.		
Clarification Statement: Emphasis is on constructing explanations that predict consistent patterns of interactions in different ecosystems in terms of the relationships among and between living organisms and nonliving components of ecosystems. Examples of types of interactions could include competition, predation, parasitism, commensalism, mutualism. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Construct an explanation that includes qualitative or quantitative relationships between variables that predict and/or describe phenomena.	• 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.	**Patterns:** • Patterns can be used to identify cause and effect relationships.

Ecosystems: Interactions, Energy, and Dynamics (LS2)

7.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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop a model to describe phenomena.	• 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.	**Energy and Matter:** • The transfer of energy can be tracked as energy flows through a natural system.

7.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. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or model for a phenomenon.	• 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.	**Stability and Change:** • Small changes in one part of a system might cause large changes in another part.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
7.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. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	• 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. • 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. • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. • The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies form region to region and over time.	**Stability and Change:** • Small changes in one part of a system might cause large changes in another part.

Earth and Human Activity (ESS3)		
7.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 geological 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). **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Apply scientific ideas, principles, and evidence (including students' own investigations, models, theories, simulations, peer review) to provide an explanation of phenomena.	• 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.	**Cause and Effect:** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Earth and Human Activity (ESS3)

7.ESS3.3 Apply scientific principles to design a method for monitoring and minimizing 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). **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Apply scientific principles to design an object, tool, process, or system.	• 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. • The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region, and over time.	**Cause and Effect:** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Earth and Human Activity (ESS3)		
7.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. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or model for a phenomenon.	• 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.	**Cause and Effect:** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Earth and Human Activity (ESS3)		
7.ESS3.5 Obtain, evaluate, and communicate evidence of the factors that have caused changes in global temperatures over the past century.		
Clarification Statement: 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 impact humans have on the environment. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Obtaining, Evaluating and Communicating Evidence: • 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.	• Understanding atmospheric changes 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.	**Stability and Change:** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

8TH GRADE (8)		
Motion and Stability: Forces and Interactions (PS2)		
8.PS2.1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects in a system.*		
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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Designing Solutions • Apply scientific principles to design an object, tool, process, or system.	• 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). • The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.	**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 the systems.

Motion and Stability: Forces and Interactions (PS2)		
8.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. An increase in force can be caused by increasing the mass, the acceleration, or both the mass and acceleration of an object. An example of evidence could include reasoning from mathematical expressions (F=ma). **Assessment Boundary:** Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and a change in one variable at a time. Assessment does not include the use of trigonometry.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Planning and Carrying Out Investigations: • Plan an investigation individually and collaboratively; 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.	• 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.	**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.

Motion and Stability: Forces and Interactions (PS2)		
8.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. Assessment of Coulomb's Law is not intended.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Asking Questions: • 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.	• 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.	**Cause and Effect:** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

8.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. Assessment should be focused on qualitative observations and data, or other quantitative data that does not require mathematical computations beyond basic central tendencies.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence • Construct and present oral and written arguments 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.	• 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).	**Systems and System Models:** • Models can be used to represent systems and their interactions (such as inputs, processes and outputs) and energy and matter flows within systems.

Motion and Stability: Forces and Interactions (PS2)

8.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 balloons. 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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations: • Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.	• 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).	**Cause and Effect:** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Waves and Their Applications in Technologies for Information Transfer (PS4)

8.PS4.1 Use mathematical representations to describe patterns in 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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematical and Computational Thinking: • Use mathematical representation to describe and/or support scientific conclusions and design solutions.	• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.	**Patterns:** • Graphs and charts can be used to identify patterns in data.

Waves and Their Applications in Technologies for Information Transfer (PS4)

8.PS4.3 Integrate qualitative scientific and technical information to support the claim that digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.*

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. Examples of reliability in encoding could include transmitting digital information at a higher quality than analog signals (digital vs. analog photographs or videos, or digital vs. analog thermometer). Examples of reliability in transmission could include the degradation of an analog signal compared to a digital signal.
Assessment Boundary: Assessment does not include binary counting or the specific mechanism of any given device.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Evidence: • Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.	• Many modern communications devices use digitized signals (sent as wave pulses) as they are a more reliable way to encode and transmit information.	**Structure and Function:** • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

From Molecules to Organisms: Structure and Processes (LS1)

8.LS1.4 Use arguments 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. **Assessment Boundary:** Assessment should not focus on the identification of the reproductive plant structures.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for phenomena.	• 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.	**Cause and Effect:** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

8.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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • 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.	• Genetic factors, as well as local conditions, affect the growth of the adult plant.	**Cause and Effect:** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Heredity: Inheritance and Variation of Traits (LS3)

8.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. Examples: Radiation treated plants, genetically modified organisms (e.g. roundup resistant crops, bioluminescence), mutations both harmful and beneficial. **Assessment Boundary:** Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop and use a model to describe phenomena.	• 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. • 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.	**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 structures/systems can be analyzed to determine how they function.

Heredity: Inheritance and Variation of Traits (LS3)

8.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. **Assessment Boundary:** The assessment should measure the students' abilities to explain the general outcomes of sexual versus asexual reproduction in terms of variation seen in the offspring.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop and use a model to describe phenomena.	• Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. • 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.	**Cause and Effect:** • Cause and effect relationships may be used to predict phenomena in natural systems.

Biological Unity and Diversity (LS4)

8.LS4.1 Analyze and interpret data to identify patterns within the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth.

Clarification Statement: Emphasis is on finding patterns of change in the complexity of anatomical structures in organisms and the chronological order of fossils' appearance in the rock layers. The natural laws that operate today are assumed to operate as they have in the past. **Assessment Boundary:** Assessment does not include the names of individual species or geological time scales in the fossil record.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyze and Interpret Data: • Analyze and interpret data to determine similarities and differences in findings.	• The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found) 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.	**Patterns:** • Graphs and charts can be used to identify patterns in data.

8.LS4.2 Apply scientific ideas to construct an explanation for the patterns of anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer ancestral relationships.

Clarification Statement: Emphasis is on explanations of the ancestral relationships among organisms in terms of similarities or differences of anatomical features or structures. Examples could include how structural similarities/differences could determine relationships between two modern organisms (e.g., wings of birds vs. bats vs. insects) or modern and fossil organisms (e.g., fossilized horses compared to modern horses, trilobites compared to horseshoe crabs). **Assessment Boundary:** Assessment does not include the names of individual species or geological eras in the fossil record.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Construct a scientific explanation based on valid and reliable evidence.	• The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found) 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. • Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record serve as evidence of ancestral relationships among organisms and changes in populations over time.	**Patterns:** • Graphs and charts can be used to identify patterns in data.

Biological Unity and Diversity (LS4)

8.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 in diagrams or pictures. **Assessment Boundary:** Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyze and Interpret Data: • Analyze and interpret data to determine similarities and differences in findings.	• Comparison of embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.	**Patterns:** • Graphs and charts can be used to identify patterns in data.

8.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 for why in a specific environment impacted by different factors (e.g., limited food availability, predators, nesting site availability, light availability), some traits confer advantages that make it more probable that an organism will be able to survive and reproduce there. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Construct an explanation that includes qualitative or quantitative relationships between variables that predict and/or describe phenomena.	• Natural selection leads to the predominance of certain traits in a population, and the suppression of others.	**Cause and Effect:** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Biological Unity and Diversity (LS4)

8.LS4.5 Gather and synthesize information about the practices 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 practices have on society, as well as the technologies leading to these scientific discoveries. **Assessment Boundary:** The assessment should provide evidence of students' abilities to understand and communicate how technology affects both individuals and society.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information: • Gather, read, synthesize information from multiple appropriate sources; assess the credibility, accuracy, and possible bias of each publication and methods used; and describe how they are supported or not supported by evidence.	• In artificial selections, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits by genes, which are then passed on to offspring. • Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.	**Cause and Effect:** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

8.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:** The assessment should provide evidence of students' abilities to explain trends in data for the number of individuals with specific traits changing over time. Assessment does not include Hardy Weinberg calculations.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking: • Use mathematical representation to describe and/or support scientific conclusions and design solutions.	• 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 change.	**Cause and Effect:** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Earth's Place in the Universe (ESS1)

8.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: Earth's rotation relative to the positions of the Moon and Sun describes the occurrence of tides; the revolution of Earth around the Sun explains the annual cycle of the apparent movement of the constellations in the night sky; the Moon's revolution around Earth explains the cycle of spring/neap tides and the occurrence of eclipses; and the Moon's elliptical orbit mostly explains the occurrence of total and annular eclipses. The position and tilt of Earth, as it revolves around the Sun, explain why seasons occur. Examples of models can be physical, graphical, or conceptual. **Assessment Boundary:** Definitions of spring or neap tides should not be included.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop and use a model to describe a phenomenon.	• Patterns of the apparent motion of the Sun, Moon, and stars in the sky can be observed, described, predicted, and explained with models. • The model of the solar system can explain eclipses of the Sun and 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 its tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.	**Patterns:** • Patterns can be used to identify cause-and- effect relationships.

Earth's Place in the Universe (ESS1)

8.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 effects of gravity and inertia as the forces that hold 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 a 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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop and use a model to describe a phenomenon.	• Earth and its solar system are part of the Milky Way Galaxy, which is one of the many galaxies in the universe. • 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.	**Systems and System Models:** • Models can be used to represent systems and their interactions.

8.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 emphasis is on data analysis of properties of the planets and should not include recalling facts about the planets and other solar system bodies.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data: • Analyze and interpret data to determine similarities and differences in findings.	• 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. • Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.	**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.

PHYSICAL SCIENCE (PS)		
Matter and Its Interactions (PS1)		
PS.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 trends and 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 understanding of ionization energy and electronegativity.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Use a model to predict the relationships between systems or between components of a system.	• 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.	**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.

Matter and Its Interactions (PS1)		
PS.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, knowledge of the patterns of chemical properties, and formation of compounds.		
Clarification Statement: Identifying patterns in reactions allows the emphasis to be on student explanation of observed reaction outcomes. Reactions that students could be exposed to are synthesis (limited to elements forming a compound), decomposition (limited to a compound producing two or more elements), combustion, single displacement, or double displacement. **Assessment Boundary:** Assessment is limited to chemical reactions involving main group elements.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of 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.	• 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. • 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.	**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.

Matter and Its Interactions (PS1)

PS.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 qualitative evidence for number and energy of collisions (Collison Theory) and relationships between rate and temperature. **Assessment Boundary:** Assessment is limited to explaining the result of changing one condition at a time in a simple reaction in which there are only two reactants.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • 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.	• 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 rearrangement 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.	**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.

PS.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. Mathematical representation can include balancing chemical equations to represent the laws of conservation of mass, constant composition (definite proportions) and understanding the ratio of the coefficients between reactants and products. **Assessment Boundary:** Assessment does not include complex chemical reactions or stoichiometry. Emphasis is on assessing students' use of mathematical reasoning and not on memorization and rote application of problem-solving techniques.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking: • Use mathematical representations of phenomena to support claims.	• 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.	**Energy and Matter:** • The total amount of energy and matter in closed systems is conserved.

Motion and Stability: Forces and Interactions (PS2)

PS.PS2.1 Analyze and interpret data to support the claim of a causal relationship between the net force on an object and its change in motion, as described in Newton's second law of motion.

Clarification Statement: Examples of data could include tables or graphs of position or velocity of an object as a function of time. Examples of objects subjected to a net force can include objects in free-fall, objects sliding down a ramp, or moving objects pulled by a constant force.

Assessment Boundary: Assessment is limited to macroscopic objects moving in one-dimensional motion, at non-relativistic speeds. Air-resistance is ignored.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• Newton's second law accurately predicts changes in the motion of macroscopic objects.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

PS.PS2.2 Use mathematical representations to support the explanation 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 and does not include naming the types of collisions. Assessment should provide evidence of students' abilities to explain the mathematical relationships between momentum, mass, and velocity.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by change in the momentum of objects outside the system.	**Systems and System Models:** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Motion and Stability: Forces and Interactions (PS2)		
PS.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: An example of evaluation could include determining the success of the device at protecting an object from damage. Examples of devices could include football helmets, parachutes, and car restraint systems, such as seatbelts and airbags. Refinement of the device may include modifying one or more parts or all of the device to improve performance of the device. **Assessment Boundary:** Assessment is limited to qualitative evaluations and/or algebraic manipulations.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Designing Solutions: • Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.	• If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by change in the momentum of objects outside the system. • 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.	**Cause and Effect:** • Systems can be designed to cause a desired effect.

Motion and Stability: Forces and Interactions (PS2)		
PS.PS2.5 Plan and conduct an investigation to provide evidence that an electric current can cause a magnetic field and that a changing magnetic field can cause an electric current.		
Clarification Statement: Students' investigations should describe the data that will be collected and the evidence to be derived from that data. Examples could include electromagnets/solenoids, motors, current carrying wires, and compasses. **Assessment Boundary:** Assessment is limited to planning and conducting investigations with provided materials and tools.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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; consider limitations on the precision of the data (e.g., number of trials, cost, risk, time); and refine the design accordingly.	• 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. • "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Energy (PS3)

PS.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 utilizing calculations to understand that energy is transferred in and out of systems and conserved, as well as explaining the meaning of mathematical expressions used in the model. **Assessment Boundary:** Assessment is limited to two or three components and the transfer of thermal energy, kinetic energy, potential energy, and/or the energies in gravitational, magnetic, or electric fields.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking: • Create a computational model of a phenomenon, process, or system based on basic assumptions.	• 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. • 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.	**System 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.

Energy (PS3)

PS.PS3.2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.

Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to the position of an object above the earth (considered as stored in fields), and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations. **Assessment Boundary:** Assessment does not include quantitative calculations, chemical energy, or effects of air resistance/friction.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• 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 com- bination 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.	**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.

Energy (PS3)		
PS.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 placed on a device could include the cost of materials, types of materials available, having to use renewable energy, an efficiency threshold, and time to build and/or operate the device. **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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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 trade-off considerations.	• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • 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. • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.	**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.

Energy (PS3)

PS.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 thermal 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 devices constructed with materials provided to students. Assessment includes both quantitative and conceptual descriptions of energy change.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• 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 surrounding environments cool down).	**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.

Waves and Their Applications in Technologies for Information Transfer (PS4)

PS.PS4.1 Use mathematical representations to explain both qualitative and quantitative relationships among frequency, wavelength, and speed of waves traveling in various media.

Clarification Statement: Emphasis is on using mathematical representations to understand how various media change the speed of waves. Examples of waves moving through various media could include electromagnetic radiation traveling in a vacuum or glass, sound waves traveling through air or water, or seismic waves traveling through Earth. **Assessment Boundary:** Assessment is limited to algebraic relationships and describing those relationships qualitatively.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Mathematical and Computational Thinking: • Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.	• 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.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

PS.PS4.2 Evaluate questions about the advantages and disadvantages 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.
Assessment Boundary: N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions: • Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.	• 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. • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.	**Stability and Change:** • Systems can be designed for greater or lesser stability.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
PS.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 different frequencies of electromagnetic radiation have different energies, and the damage to living tissue depends on the energy of the radiation. Examples of published materials could include peer-reviewed scientific articles, or trade books, magazines, web resources, videos, and other passages that may reflect bias. **Assessment Boundary:** Assessment is limited to qualitative descriptions.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• 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. • Photoelectric materials emit electrons when they absorb light of high enough frequency.	**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.

CHEMISTRY (CH)		
Matter and Its Interactions (PS1)		
CH.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 could include trends in ionization energy, atomic radius, or electronegativity. Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and ion formation. **Assessment Boundary:** Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends or exception explanations (e.g. Be to B or N to O).		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Use a model to predict the relationships between systems or between components of a system.	• 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.	**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.

Matter and Its Interactions (PS1)		
CH.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, knowledge of the patterns of chemical properties, and formation of compounds.		
Clarification Statement: Periodic trends (ionization energy, electronegativity, reactivity), patterns of valence electrons, and classifying reaction types should be utilized when constructing and revising explanations for the prediction of products (e.g. synthesis/combination, decomposition, combustion, single displacement, double displacement, oxidation/reduction, and/or acid/base). **Assessment Boundary:** Assessment is limited to chemical reactions involving main group elements and polyatomic ions (e.g. Nitrate, Nitrite, Sulfate, Hydroxide, Carbonate, and Phosphate).		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and 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.	• 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. • 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.	**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.

Matter and Its Interactions (PS1)		
CH.PS1.3 Plan and conduct an investigation to compare the structure of substances at the bulk scale level to infer the strength of electrical forces between particles.		
Clarification Statement: Emphasis is on understanding the relative 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. The intent of the performance expectation is limited to evaluation of bulk-scale properties and not microscale properties. **Assessment Boundary:** Assessment does not include calculations related to any bulk-scale property.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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; consider limitations on the precision of the data (e.g., number of trials, cost, risk, time); and refine the design accordingly.	• The structure and interactions of matter at the bulk-scale are determined by electrical forces within and between atoms.	**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.

Matter and Its Interactions (PS1)		
CH.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 involves an overall change in energy that is due to the absorption of energy when bonds are broken and the release of energy when new bonds are formed. 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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	• 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. • Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and 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.	**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.

Matter and Its Interactions (PS1)		
CH.PS1.5 Apply scientific principles and evidence to provide an explanation about the effects of changing the conditions 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 (Collision Theory). Examples of reaction conditions that affect rate could include temperature, concentration, surface area/particle size, pressure, or the addition of a catalyst. **Assessment Boundary:** Assessment is limited to explaining the result of changing one condition at a time in a simple reaction in which there are only two reactants.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • 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.	• 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 rearrangement 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.	**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.

Matter and Its Interactions (PS1)		
CH.PS1.6 Refine the design of a chemical system by specifying a change in conditions that would produce a change in the amounts of products at equilibrium.*		
Clarification Statement: Emphasis is on the qualitative application of Le Châtelier'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. Designs may include ways to achieve the desired effect on a system at equilibrium by changing temperature, pressure, and/or adding or removing reactants or 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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Designing Solutions: • Refine a solution to a complex real- world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations.	• 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. • 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.	**Stability and Change:** • Much of science deals with constructing explanations of how things change and how they remain stable.

Matter and Its Interactions (PS1)

CH.PS1.7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Clarification Statement: Mathematical representations could include balanced chemical equations that represent the laws of conservation of mass and constant composition (definite proportions) and mass-to-mass stoichiometry. The mole concept and stoichiometry are used to show proportional relationships between masses of reactants and products. **Assessment Boundary:** Assessment does not include complex chemical reactions. Emphasis is on assessing students' use of mathematical reasoning and does not include recall of mathematical equations and rote application of problem-solving techniques.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking: • Use mathematical representations of phenomena to support claims.	• 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.	**Energy and Matter:** • The total amount of energy and matter in closed systems is conserved.

CH.PS1.8 Develop models to illustrate the changes in 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 qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations. Examples of nuclear processes could include the formation of elements through fusion in stars, generation of electricity in a nuclear power plant, or the use of radioisotopes in nuclear medicine. **Assessment Boundary:** Assessment does not include quantitative calculation of energy released (i.e., binding energy). Assessment is limited to alpha, beta, and gamma radioactive decay.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• Nuclear processes, including fusion, fission, and radioactive decay of unstable nuclei, involve release or absorption of energy. • The total number of neutrons plus protons does not change in any nuclear process.	**Energy and Matter:** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons are conserved.

Motion Stability: Forces and Interactions (PS2)		
CH.PS2.6 Communicate scientific and technical information about why the molecular level structure of designed materials determines how the material functions.*		
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. Scientific and technical information should include molecular structures of specific designed materials and limit comparison to two substances of the same type. **Assessment Boundary:** Assessment is limited to provided molecular structures or specific designed materials.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information: • Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including oral, graphical, textual, and mathematical).	• 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.	**Structure and Function:** • Investigating or designing net systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and the connections of components to reveal its function and/or solve a problem.

Energy (PS3)		
CH.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. Sources of energy could include those from chemical or nuclear reactions. Examples of devices could include lemon or potato clock, a voltaic cell (batteries), hand warmers, solar panels/solar ovens, and nuclear power generation through simulations. Examples of constraints placed on a device could include the cost of materials, types of materials available, having to use renewable energy, an efficiency threshold, and time to build and/or operate the device. **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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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 trade-off considerations.	• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • 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. • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.	**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.

Energy (PS3)		
CH.PS3.4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy between components in a closed system involves changes in energy dispersal and heat content and 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 thermal energy changes both quantitatively and conceptually. Examples of investigations could include calorimetry (i.e., dissolving a substance in water, mixing two solutions, and combining two components) where students measure temperatures and calculate heat. **Assessment Boundary:** Assessment is limited to conceptual understanding of energy and investigations based on materials and tools provided to students. Assessment includes both quantitative and conceptual descriptions of energy change.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Planning and Carrying Out Investigations: • Plan and conduct investigations 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; consider limitations on the precision of the data (e.g., number of trials, cost, risk, time); and refine the design accordingly.	• 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 surrounding environments cool down).	**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.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
CH.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: Emphasis is on using mathematical relationships to understand how various media change the speed of waves. Examples of different media that could be explored include electromagnetic radiation traveling in a vacuum or glass, sound waves traveling through air or water, or seismic waves traveling through Earth. **Assessment Boundary:** Assessment is limited to algebraic relationships and describing those relationships qualitatively.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• 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.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
CH.PS4.3 Develop an argument for how scientific evidence supports the explanation that electromagnetic radiation can be described either by the wave model or the particle model, and in 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 the photoelectric effect. **Assessment Boundary:** Assessment does not include using quantum theory.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.	• 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 sounds can pass a location in different directions without getting mixed up. • 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.	**Systems and System Models:** • Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions, including energy, matter, and information flow within and between systems at different scales.

PHYSICS (PH)

Matter and Its Interactions (PS1)

PH.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 qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations. Examples of nuclear processes could include, the formation of elements through fusion in stars, generation of electricity in a nuclear power plant, or the use of radioisotopes in nuclear medicine. **Assessment Boundary:** Assessment does not include quantitative calculation of energy released (i.e., binding energy). Assessment is limited to alpha, beta, and gamma radioactive decay.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• Nuclear processes, including fusion, fission, and radioactive decay of unstable nuclei, involve release or absorption of energy. • The total number of neutrons plus protons does not change in any nuclear process.	**Energy and Matter:** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons are conserved.

Motion and Stability: Forces and Interactions (PS2)

PH.PS2.1 Analyze and interpret 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 of an object as a function of time. Examples of objects subjected to a net force can include objects in free-fall, objects sliding down a ramp, or moving objects pulled by a constant force. The relationship $F_{net} = ma$ should be explored qualitatively and quantitatively. **Assessment Boundary:** Assessment is limited to macroscopic objects moving in one-dimensional motion, at non-relativistic speeds.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data: • Analyze data using tools, technologies, and/or models (e.g., computations, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.	• Newton's Second Law accurately predicts changes in the motion of macroscopic objects.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Motion and Stability: Forces and Interactions (PS2)

PH.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. Examples could include one-dimensional elastic or inelastic collisions between objects within the system. **Assessment Boundary:** Assessment is limited to systems of two macroscopic bodies moving in one dimension and does not include naming the types of collisions.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by change in the momentum of objects outside the system.	**Systems and System Models:** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

PH.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: An example of evaluation could include determining the success of the device at protecting an object from damage. Examples of devices could include football helmets, parachutes, and car restraint systems, such as seatbelts and airbags. Refinement of the device may include modifying one or more parts or all of the device to improve performance of the device. **Assessment Boundary:** Assessment is limited to qualitative evaluations and/or algebraic manipulations.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by change in the momentum of objects outside the system. • 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.	**Cause and Effect:** • Systems can be designed to cause a desired effect.

Motion and Stability: Forces and Interactions (PS2)		
PH.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 object.		
Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of interactions between masses in gravitational fields and electrical charges in electric fields. **Assessment Boundary:** Assessment is limited to systems with two objects.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• 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 fields cause magnetic fields; electric charges or changing magnetic fields causes electric fields.	**Patterns:** • Different patterns may be observed at each of the scales at which a system is studied and can provide for causality in explanations of phenomena.

Motion and Stability: Forces and Interactions (PS2)		
PH.PS2.5 Plan and conduct an investigation to provide evidence that an electric current can cause a magnetic field and that a changing magnetic field can cause an electric current.		
Clarification Statement: Students' investigations should describe the data that will be collected and the evidence to be derived from that data. Examples could include electromagnets/solenoids, motors, current carrying wires, and compasses. **Assessment Boundary:** Assessment is limited to planning and conducting investigations with provided materials and tools.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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; consider limitations on the precision of the data (e.g., number of trials, cost, risk, time); and refine the design accordingly.	• 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. • "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Energy (PS3)

PH.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 utilizing calculations to understand that energy is transferred in and out of systems and conserved, as well as 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, potential energy, and/or the energies in gravitational, magnetic, or electric fields.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking: • Create a computational model of a phenomenon, process, or system based on basic assumptions.	• 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. • Conservation of energy means energy cannot be created or destroyed and the total change of energy in a system is always equal to the 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.	**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.

Energy (PS3)		
PH.PS3.2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.		
Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to the position of an object above the earth (considered as stored in fields), and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations. **Assessment Boundary:** Assessment does not include quantitative calculations.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• 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.	**Energy and Matter:** • Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between system.

Energy (PS3)		
PH.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 placed on a device could include the cost of materials, types of materials available, having to use renewable energy, an efficiency threshold, and time to build and/or operate the device. **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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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 trade-off considerations.	• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. • 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. • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.	**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.

Energy (PS3)		
PH.PS3.4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy between components in 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 thermal 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. Assessment includes both quantitative and conceptual descriptions of energy change.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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; consider limitations on the precision of the data (e.g., number of trials, cost, risk, time) and refine the design accordingly.	• 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).	**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.

Energy (PS3)		
PH.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, including an explanation of how the change in energy of the objects is related to the change in energy of the field. Examples of electric field phenomena may include volcanic lightning or laser printing and examples of magnetic field phenomena may include a mag-lev or magnetic braking. **Assessment Boundary:** Assessment is limited to systems containing two objects.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• When two objects interact, each one exerts a force on the other. These forces can transfer energy between the objects. Forces between two objects at a distance are explained by force fields (gravitational, electric, or magnetic) between them.	**Energy and Matter:** • Energy cannot be created or destroyed. It only moves between one place to another, between objects and/or fields, or between systems.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
PH.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: Emphasis is on using mathematical relationships to understand how various media change the speed of waves. Examples of different media that could be explored include electromagnetic radiation traveling in a vacuum or glass, sound waves traveling through air or water, or seismic waves traveling through Earth. **Assessment Boundary:** Assessment is limited to algebraic relationships and describing those relationships qualitatively.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• 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.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
PH.PS4.2 Evaluate questions about the advantages and disadvantages of using 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. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Asking Questions: • Evaluate questions that challenge the premises(s) of an argument, the interpretation of a data set, or the suitability of a design.	• Information can be digitized (e.g., 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. • Modern civilization depends on major technological systems. • Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.	**Stability and Change:** • Systems can be designed for greater or lesser stability.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
PH.PS4.3 Develop an argument for how scientific evidence supports the explanation that electromagnetic radiation can be described either by the wave model or the particle model, and in 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 the photoelectric effect. **Assessment Boundary:** Assessment does not include using quantum theory.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.	• 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 sounds can pass a location in different directions without getting mixed up. • 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.	**Systems and System Models:** • Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions (including energy, matter and information flows) within and between systems at different scales.

Waves and Their Applications in Technologies for Information Transfer (PS4)		
PH.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 different frequencies of electromagnetic radiation have different energies, and the damage to living tissue depends on the energy of the radiation. Examples of published materials could include peer-reviewed scientific articles, or trade books, magazines, web resources, videos, and other passages that may reflect bias. **Assessment Boundary:** Assessment is limited to qualitative descriptions.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• 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. • Photoelectric materials emit electrons when they absorb light of high enough frequency.	**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.

Waves and Their Applications in Technologies for Information Transfer (PS4)

PH.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 and transmitting an audio file through a modulated laser signal. Other examples can be found in medical imaging and communication technology. **Assessment Boundary:** Assessments are limited to qualitative information. Assessments do not include band theory.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information: • Communicate scientific and/or technical information (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).	• Solar cells are human-made devices that capture the Sun's energy and produce electrical energy. • 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. • Photoelectric materials emit electrons when they absorb light of a high enough frequency. • Multiple technologies based on the understanding of waves and their interactions with matter are part of every day 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. • Modern civilization depends on major technological systems.	**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.

BIOLOGY (B)		
From Molecules to Organisms: Structures and Processes (LS1)		
B.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.		
Clarification Statement: Emphasis is on the conceptual understanding that the sequence of nucleotides in DNA determines the amino acid sequence of proteins through the processes of transcription and translation. **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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • 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.	• Systems of specialized cells within organisms help them perform the essential functions of life. • 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 the cells.	**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 their various materials.

From Molecules to Organisms: Structures and Processes (LS1)		
B.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 developing a model in which relevant parts (e.g., an organ system, organs, and their component tissues) and processes (e.g., transport of fluids, motion) of body systems in multicellular organisms are identified and described. Models should then be used to illustrate how relevant parts within a system interact and how systems interact with one another to provide specific functions in multicellular organisms. **Assessment Boundary:** Assessment does not include interactions and functions at the molecular or chemical reaction level and is limited to two systems interacting at a time.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• 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.	**Systems and System Models:** • Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions, including energy, matter, and information flow within and between systems at different scales.

From Molecules to Organisms: Structures and Processes (LS1)

B.LS1.3 Plan and conduct an investigation to provide evidence of the importance of maintaining homeostasis in living organisms.

Clarification Statement: A state of homeostasis (stability) must be maintained for organisms to remain alive and functional even as external conditions change within some range. Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, root development in response to water levels, and cell response to hypertonic and hypotonic environments. **Assessment Boundary:** Assessment does not include the cellular processes involved in the feedback mechanism.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Conducting Investigations: • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence.	• 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. Outside that range (e.g., at too high or low external temperature, with too little food or water available) the organism cannot survive.	**Stability and Change:** • Feedback (negative or positive) can stabilize or destabilize a system.

B.LS1.4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Clarification Statement: Emphasis is not on the details of each phase of mitosis but on the conceptual understanding that mitosis produces genetically identical cells via DNA replication and cell division and that immature cells may become specialized through differentiation.
Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• 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.	**Systems and System Models:** • Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions, including energy, matter, and information flow within and between systems at different scales.

From Molecules to Organisms: Structures and Processes (LS1)

B.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, or conceptual models developed from investigations.
Assessment Boundary: The assessment should provide evidence of students' abilities to describe the inputs and outputs of photosynthesis, not the specific biochemical steps (e.g., photosystems, electron transport, and Calvin Cycle).

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.	**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.

B.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/or simulations to support explanations for how organisms take in matter and rearrange the atoms in chemical reactions to form amino acids and/or other large carbon-based molecules.
Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation.	• 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 large molecules (such as proteins or DNA), used, for example, to form new cells. • As matter and energy flow through different organization levels of living systems, chemical elements are recombined in different ways to form different products.	**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.

From Molecules to Organisms: Structures and Processes (LS1)		
B.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. Examples of models could include diagrams, chemical equations, or conceptual models developed from investigations. **Assessment Boundary:** Assessment should not include identification of the steps or specific processes involved in cellular respiration (e.g. glycolysis, Kreb's Cycle, and electron transport).		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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.	• As matter and energy flow through different organization levels of living systems, chemical elements are recombined in different ways to form different products. • 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.	**Energy and Matter:** • Energy cannot be created or destroyed. It only moves between one place to another, between objects and/or fields, or between systems.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
B.LS2.1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacities 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, or population changes gathered from simulations or historical data sets. **Assessment Boundary:** Assessment does not include deriving mathematical equations to make comparisons.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking: • Use mathematical, computational, and/or algorithmic representations of phenomena to describe and/or support claims and/or explanations.	• Ecosystems have carrying capacities, which are limits to the number 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 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.	**Scale, Proportion, and Quantity:** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
B.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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking: • Use mathematical representation to describe and/or support scientific conclusions.	• 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. • A complex set of interactions within an ecosystem can keep its number 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 populations, however, can challenge the functions of ecosystems in terms of resources and habitat availability.	**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).

Ecosystems: Interactions, Energy, and Dynamics (LS2)

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

Clarification Statement: Emphasis is on describing the role of aerobic and anaerobic respiration in the conservation of matter and flow of energy into, out of, and within various ecosystems (e.g., chemosynthetic bacteria near deep ocean vents, yeast in various environments, muscle cells during exertion, water-logged plants). **Assessment Boundary:** Assessment focuses on the conceptual understanding and does not include the specific chemical processes of either aerobic or anaerobic respiration.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • 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.	• Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.	**Energy and Matter:** • Energy drives the cycling of matter within and between systems.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
B.LS2.4 Use a mathematical representation to support claims for the cycling of matter and the 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:** The assessment should provide evidence of students' abilities to develop and use energy pyramids, food chains, food webs, and other models from data sets.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking: • Use mathematical representation to describe and/or support scientific conclusions.	• Plants or algae form the lowest level of the food chain. • 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.	**Energy and Matter:** • Energy cannot be created or destroyed. It only moves between one place to another, between objects and/or fields, or between systems.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
B.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. The emphasis is on the movement of carbon. **Assessment Boundary:** Assessment does not include the specific chemical steps of photosynthesis and respiration.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model based on evidence to illustrate the relationships between systems or components of a system.	• 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. • The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.	**Systems and System Models:** • Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions; including energy, matter, and information flow within and between systems at different scales.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
B.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. **Assessment Boundary:** The assessment should provide evidence of students' abilities to derive trends from graphical representations of population trends. Assessments should focus on describing drivers of ecosystem stability and change, not on the organismal mechanisms of responses and interactions.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merit of arguments.	• A complex set of interactions within an ecosystem can keep its number 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 populations, however, can challenge the functions of ecosystems in terms of resources and habitat availability.	**Stability and Change:** • Much of science deals with constructing explanations of how things change and how they remain stable.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
B.LS2.8 Evaluate evidence for the role of group behavior on individual and species' chances to survive and reproduce.		
Clarification Statement: Emphasis is on advantages of grouping behaviors (e.g., flocking, schooling, herding) and cooperative behaviors (e.g., hunting, migrating, swarming) on survival and reproduction. **Assessment Boundary:** The assessment should provide evidence of students' abilities to: (1) distinguish between group versus individual behavior, (2) identify evidence supporting the outcomes of group behavior, and (3) develop logical and reasonable arguments based on evidence.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merit of arguments.	• Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Heredity: Inheritance and Variation of Traits (LS3)

B.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.

Clarification Statement: Emphasis is on the use of models of DNA to formulate questions, the answers to which would clarify the cause and effect relationships (including distinguishing between causal and correlational relationships) between DNA, the proteins it codes for, and the resulting traits observed in an organism. **Assessment Boundary:** Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions: • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.	• 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 the cells. • 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 protein; some segments of DNA are involved in regulatory or structural functions, and some have no, as of yet, known functions.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Heredity: Inheritance and Variation of Traits (LS3)

B.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 mechanisms of specific steps in the process.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• 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 also cause mutations in genes, and variables in mutations are also inherited. • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in the population; thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Heredity: Inheritance and Variation of Traits (LS3)		
B.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 distribution and variation of traits in a population and the use of mathematics (e.g., calculations of frequencies based on data from Punnett squares, graphical representations) to describe the distribution of traits in a population, not individuals. **Assessment Boundary:** Emphasis is on students' use of genetic models to explain the variation and patterns observed in a population as a combination of genetic and environmental factors. Assessment does not include Hardy-Weinberg calculations.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
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 questions and problems, using digital tools when feasible.	• Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in the population; thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**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).

Biological Unity and Diversity (LS4)

B.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 should include similarities in DNA and amino acid sequences, but could also include fossil record, anatomical structures, and the order of appearance of structures in embryological development. **Assessment Boundary:** Emphasis is on students' abilities to use evidence such as DNA and amino acid sequences, cladograms, analogous/homologous structures, and fossil records to communicate their understanding of common ancestry and biological evolution.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information: • Communicate scientific information (e.g., about phenomena) in multiple formats (including orally, graphically, textually, and mathematically).	• Genetic information provides evidence of common ancestry and diversity. 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. • 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.	**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.

Biological Unity and Diversity (LS4)		
B.LS4.2 Construct an explanation based on evidence that biological diversity is influenced by (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 survive and reproduce. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning. **Assessment Boundary:** Assessment does not include genetic drift, gene flow through migration, and co-evolution.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Construct 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.	• 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.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Biological Unity and Diversity (LS4)

B.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 for adaptations. **Assessment Boundary:** Emphasis is on students' abilities to analyze shifts in numerical distribution of traits as evidence to support explanations. Analysis is limited to basic statistical and graphical analysis, not allele or gene frequency calculations.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
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.	• 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. • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. • 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. • Adaptation also means that the distribution of traits in a population can change when conditions change.	**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 and phenomena.

Biological Unity and Diversity (LS4)		
B.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 adaptation of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Construct 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.	• 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. • 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.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Biological Unity and Diversity (LS4)		
B.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. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.	• 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' adaptation over time is lost.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

EARTH AND SPACE SCIENCE (ES)		
Earth's Place in the Universe (ESS1)		
ES.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 convert matter to 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.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Develop and Use 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.	• The star called the Sun is changing and will burn out over a lifespan of approximately 10 billion years. • Nuclear Fusion processes in the center of the Sun release the energy that ultimately reaches Earth as radiation.	**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.

Earth's Place in the Universe (ESS1)

ES.ESS1.2 Construct an explanation of how the universe formed as a single point and continues to expand based on astronomical evidence of light spectra, motion of distant galaxies, and the 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 remnant cosmic microwave background radiation, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases. **Assessment Boundary:** Details about the mapped distribution of galaxies and clusters are not assessed.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.	• The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. • Observations of distant galaxies receding from our own, the measured composition of stars and non-stellar gases, and maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe are used as evidence to support the explanation of formation. • Other than the hydrogen and helium formed at the time of formation, 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. • 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.	**Energy and Matter:** • Energy cannot be created or destroyed. It only moves between one place to another, between objects and/or fields, or between systems.

Earth's Place in the Universe (ESS1)

ES.ESS1.3 Construct an explanation about the process that causes stars to produce elements throughout their life cycle.

Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, depend on the mass of a star and the stage of its lifetime. **Assessment Boundary:** Details of the many different nucleosynthesis pathways for stars of different masses are not assessed.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation.	• 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 formation, 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.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

ES.ESS1.4 Use mathematical or computational representations to determine patterns that can be used 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 (e.g. graphical representations of orbits). **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.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use mathematical representations of phenomena or design solutions to support and revise explanations.	• The solar system consists of the Sun and a collection of objects of varying sizes and conditions-including planets and their moons-that are held in orbit around the Sun by its gravitational pull on them. • 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.	**Patterns:** • Mathematical representations are needed to identify some patterns.

Earth's Place in the Universe (ESS1)

ES.ESS1.5 Evaluate evidence in the patterns 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 of oceanic crust increases with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core (a result of past plate interactions). **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merit of arguments.	• 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.	**Stability and Change:** • Much of science deals with constructing explanations of how things change and how they remain stable.

ES.ESS1.6 Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of changes in 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. 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. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • 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.	• 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. • 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.	**Stability and Change:** • Much of science deals with constructing explanations of how things change and how they remain stable.

Earth Systems (ESS2)		
ES.ESS2.1 Develop a model to illustrate how Earth's internal and surface processes operate at different scales of space and time 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 mountain building) and destructive mechanisms (such as weathering, erosion, and landslides or mudslides). **Assessment Boundary:** Assessment does not include memorization of formation details of specific geographic features of Earth's surface.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model based on evidence to illustrate the relationships between systems or components of a system.	• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. • Plate tectonics is the unifying theory that explains the past and current movements of 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 the Earth's crust.	**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.

Earth Systems (ESS2)		
ES.ESS2.2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks and interactions that cause changes to other Earth's systems.		
Clarification Statement: Examples could be taken from system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion, which limits additional vegetation patterns; how dammed rivers increase groundwater recharge, decrease sediment transport, and increased coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent. Examples could also include climate feedbacks that increase surface temperatures through geologic time. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyzing and Interpreting Data: • Analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims.	• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. • The foundation for Earth's global climate system 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.	**Stability and Change:** • Feedback (negative or positive) can stabilize or destabilize a system.

Earth Systems (ESS2)

ES.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 the Earth's surface features as well as three-dimensional structure in the subsurface, obtained from seismic waves; records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core); and prediction of the composition of Earth's layers from high pressure laboratory experiments. **Assessment Boundary:** Emphasis is on the processes occurring in the layers of the Earth.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop a model based on evidence to illustrate the relationships between systems or components of a system.	• Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface features, 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. • 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. • Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.	**Energy and Matter:** • Energy drives the cycling of matter within and between systems.

Earth Systems (ESS2)		
ES.ESS2.4 Analyze and interpret data to explore how variations in the flow of energy into and out of Earth's systems causes changes to the atmosphere and climate.		
Clarification Statement: Changes differ by timescale, from sudden (large volcanic eruption, ocean circulation), to intermediate (ocean circulation, solar output, human activity), and long-term (Earth's orbit and the orientation of its axis and changes in atmospheric composition). Examples of human activities could include fossil fuel combustion, cement production, or agricultural activity and natural processes such as changes in incoming solar radiation or volcanic activity. Examples of data can include tables, graphs, maps of global and regional temperatures, and atmospheric levels of gases. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyzing and Interpreting Data: • Analyze data using computational models in order to make valid and reliable scientific claims.	• 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). • The foundation for Earth's global climate system 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. • 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 changes in climate.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Earth Systems (ESS2)		
ES.ESS2.5 Plan and conduct investigations of how the structure and resulting properties of water interact with the Earth's materials and surface processes.		
Clarification Statement: Emphasis is on how the structure of water affects its physical and chemical properties. These properties can lead to 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). **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Planning and Carrying Out Investigations: • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence.	• 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.	**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 their various materials.

Earth Systems (ESS2)		
ES.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. Examples could include more carbon absorbed in the oceans leading to ocean acidification or more carbon present in the atmosphere. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model based on evidence to illustrate the relationships between systems or components of a system.	• 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.	**Energy and Matter:** • Energy drives the cycling of matter within and between systems.
ES.ESS2.7 Engage in argument from evidence for how the simultaneous co-evolution of Earth's systems and life on Earth led to periods of stability and change over geologic time.		
Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors influence conditions for life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and affected animal life; how microbial life on land increased the formation of soil, which in turn allowed for the development of land plant species; or how the changes in coral species created reefs that altered patterns of erosion and deposition along coastlines and provided habitats to support biodiversity. Geologic timescale should be considered with the emphasis above. **Assessment Boundary:** Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Construct an oral and written argument or counter- argument based on data and evidence.	• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. • The many dynamic and delicate feedback mechanisms between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	**Stability and Change:** • Much of science deals with constructing explanations of how things change and how they remain stable.

Earth and Human Activities (ESS3)		
ES.ESS3.1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate affect 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, landslides, mudslides, and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Natural hazards and other geologic events exhibit some non-random patterns of occurrence. 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. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Construct 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.	• Resource availability has guided the development of human society. • 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.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Earth and Human Activities (ESS3)

ES.ESS3.2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios on large and small scales.*

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 of large-scale solutions include developing best practices for agriculture; soil use; forestry; mining; and production of conventional, unconventional, or renewable energy resources. Examples of small-scale solutions could include mulching lawn clippings or adding biomass to gardens. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).	• 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. • 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.	**Scale, Proportion, and Quantity:** • Using concepts of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

ES.ESS3.5 Construct a scientific explanation from evidence for how geological processes cause uneven distribution of natural resources.

Clarification Statement: Emphasis is on how geological processes have led to geological sedimentary basins that provide significant accumulations of crude oil and natural gas in some areas and not others, how geological processes lead to diverse soil profiles that support a diversity and range of agricultural crops, and how plate tectonics lead to concentrations of mineral deposits. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations: • Construct 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.	• Most elements exist in Earth's crust at concentrations too low to be extracted, but in some locations-where geological processes have concentrated them-extraction is economically viable.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

ENVIRONMENTAL SCIENCE (EN)		
Ecosystems: Interactions, Energy, and Dynamics (LS2)		
EN.LS2.1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacities 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, or population changes gathered from simulations or historical data sets. **Assessment Boundary:** Assessment does not include deriving mathematical equations to make comparisons.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking: • Use mathematical, computational, and/or algorithmic representations of phenomena to describe and/or support claims and/or explanations.	• Ecosystems have carrying capacities, which are limits to the number 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 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.	**Scale, Proportion, and Quantity:** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
EN.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:** The assessments should provide evidence of students' abilities to analyze and interpret the effect new information has on explanations (e.g., DDT effects on raptor populations, effects of water temperature below reservoirs on fish spawning, invasive species effects when spread to larger scale).		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking: • Use mathematical representation to describe and/or support scientific conclusions.	• 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. • A complex set of interactions within an ecosystem can keep its number 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 populations, however, can challenge the functions of ecosystems in terms of resources and habitat availability.	**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.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
EN.LS2.4 Use a mathematical representation to support claims for the cycling of matter and the 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:** The assessment should provide evidence of students' abilities to develop and use energy pyramids, food chains, food webs, and other models from data sets.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking: • Use mathematical representation to describe and/or support scientific conclusions.	• Plants or algae form the lowest level of the food chain. • 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.	**Energy and Matter:** • Energy cannot be created or destroyed. It only moves between one place to another, between objects and/or fields, or between systems.

Ecosystems: Interactions, Energy, and Dynamics (LS2)		
EN.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. **Assessment Boundary:** The assessment should provide evidence of students' abilities to derive trends from graphical representations of population trends. Assessments should focus on describing drivers of ecosystem stability and change, not on the organismal mechanisms of responses and interactions.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merit of arguments.	• A complex set of interactions within an ecosystem can keep its number 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 populations, however, can challenge the functions of ecosystems in terms of resources and habitat availability.	**Stability and Change:** • Much of science deals with constructing explanations of how things change and how they remain stable.

Ecosystems: Interactions, Energy, and Dynamics (LS2)

EN.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 habitat destruction, pollution, introduction of invasive species, overexploitation, climate change, overpopulation, urbanization, and building dams. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Designing Solutions: • Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	• Anthropogenic changes (induced by human activity) in the environment can disrupt an ecosystem and threaten the survival of some species. • Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). • 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. 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. • 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.	**Stability and Change:** • Much of science deals with constructing explanations of how things change and how they remain stable.

Earth Systems (ESS2)		
EN.ESS2.1 Develop a model to illustrate how Earth's internal and surface processes operate at different scales of space and time 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 mountain building) and destructive mechanisms (such as weathering, erosion, and landslides or mudslides). **Assessment Boundary:** Assessment does not include memorization of formation details of specific geographic features of Earth's surface.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model based on evidence to illustrate the relationships between systems or components of a system.	• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. • Plate tectonics is the unifying theory that explains the past and current movements of 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 the Earth's crust.	**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.

Earth Systems (ESS2)		
EN.ESS2.2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks and interactions that cause changes to other Earth systems.		
Clarification Statement: Examples could be taken from system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion, which limits additional vegetation patterns; 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. Examples could also include climate feedbacks that increase surface temperatures through geologic time. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Analyzing and Interpreting Data: • Analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims.	• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. • The foundation for Earth's global climate system 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.	**Stability and Change:** • Feedback (negative or positive) can stabilize or destabilize a system.

Earth Systems (ESS2)		
EN.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 the Earth's surface features as well as three-dimensional structure in the subsurface, obtained from seismic waves; records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core); and prediction of the composition of Earth's layers from high pressure laboratory experiments. **Assessment Boundary:** Emphasis is on the processes occurring in the layers of the Earth.		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models: • Develop a model based on evidence to illustrate the relationships between systems or components of a system.	• Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface features, 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, and 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. • 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. • Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.	**Energy and Matter:** • Energy drives the cycling of matter within and between systems.

<table>
<tr><th colspan="3">Earth Systems (ESS2)</th></tr>
<tr><td colspan="3">EN.ESS2.4 Analyze and interpret data to explore how variations in the flow of energy into and out of Earth's systems causes changes to the atmosphere and climate.</td></tr>
<tr><td colspan="3">Clarification Statement: Changes differ by timescale, from sudden (large volcanic eruption, ocean circulation), to intermediate (ocean circulation, solar output, human activity), and long-term (Earth's orbit and the orientation of its axis and changes in atmospheric composition). Examples of human activities could include fossil fuel combustion, cement production, or agricultural activity and natural processes such as changes in incoming solar radiation or volcanic activity. Examples of data can include tables, graphs, maps of global and regional temperatures,
and atmospheric levels of gases. Assessment Boundary: N/A</td></tr>
<tr><th>Science and Engineering Practice</th><th>Disciplinary Core Ideas</th><th>Crosscutting Concepts</th></tr>
<tr><td>Analyzing and Interpreting Data:
• Analyze data using computational models in order to make valid and reliable scientific claims.</td><td>• 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).
• The foundation for Earth's global climate system 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.
• 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 changes in climate.</td><td>Cause and Effect:
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
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Earth Systems (ESS2)		
EN.ESS2.5 Plan and conduct investigations of how the structure and resulting properties of water interact with the Earth's materials and surface processes.		
Clarification Statement: Emphasis is on how the structure of water affects its physical and chemical properties. These properties can lead to 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). **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Planning and Conducting Investigations: • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence.	• 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.	**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.

Earth Systems (ESS2)

EN.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. Examples could include more carbon absorbed in the oceans leading to ocean acidification or more carbon present in the atmosphere. **Assessment Boundary:** N/A

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models: • Develop a model based on evidence to illustrate the relationships between systems or components of a system.	• 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.	**Energy and Matter:** • Energy drives the cycling of matter within and between systems.

EN.ESS2.7 Engage in argument from evidence for how the simultaneous co-evolution of Earth's systems and life on Earth led to periods of stability and change over geologic time.

Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors influence conditions for life, which in turn continuously alters Earth's surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and affected animal life; how microbial life on land increased the formation of soil, which in turn allowed for the development of land plant species; or how the changes in coral species created reefs that altered patterns of erosion and deposition along coastlines and provided habitats to support biodiversity. Geologic timescale should be considered with the emphasis above. **Assessment Boundary:** Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.

Science and Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence: • Construct an oral and written argument or counter-argument based on data and evidence.	• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. • The many dynamic and delicate feedback mechanisms between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	**Stability and Change:** • Much of science deals with constructing explanations of how things change and how they remain stable.

Earth and Human Activities (ESS3)		
EN.ESS3.1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate affect 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, landslides, mudslides, and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Natural hazards and other geologic events exhibit some non-random patterns of occurrence. 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. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Construct 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.	• Resource availability has guided the development of human society. • 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.	**Cause and Effect:** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Earth Human Activities (ESS3)		
EN.ESS3.2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios on large and small scales.*		
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 of large-scale solutions include developing best practices for agriculture, soil use, forestry, mining, and production of conventional, unconventional, or renewable energy resources. Examples of small-scale solutions could include mulching lawn clippings or adding biomass to gardens. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Engaging in Argument from Evidence: • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).	• 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. • 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.	**Scale, Proportion, and Quantity:** • Using concepts of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
EN.ESS3.3 Use computational simulations to illustrate changes between the relationships of natural resources, human populations, and biodiversity and their sustainability within Earth systems.		
Clarification Statement: Emphasis is on the importance of responsible stewardship of Earth's resources. 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 consumption, and urban planning. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Using Mathematical and Computational Thinking: • Create a computational model or simulation of a phenomenon, design device, process, or system.	• The sustainability of human societies and biodiversity that supports them requires responsible management of natural resources.	**Stability and Change:** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some systems' changes are irreversible.

Earth and Human Activities (ESS3)		
EN.ESS3.4 Evaluate design solutions for a major global or local environmental problem that reduces or stabilizes the impacts of human activities on natural systems.*		
Clarification Statement: Examples of major global or local problems could include water pollution or availability, air pollution, deforestation, or energy production. 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. Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions. **Assessment Boundary:** N/A		
Science and Engineering Practice	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Constructing Explanations: • Design or refine a solution to a complex problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoff considerations.	• Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. • 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. • Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.	**Stability and Change:** • Feedback (negative or positive) can stabilize or destabilize a system.