Kentucky Academic Standards

Science

December 2022

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INTRODUCTION

Background on the Kentucky Academic Standards for Science

In a world that is becoming increasingly complex, it is important that students have the knowledge and understanding to engage in public discussions around issues infused in science. The *Framework for K-12 Science Education* outlines three dimensions that, when used together, support students' deep understanding of the sciences, how science knowledge is acquired and understood and how the sciences are all connected through concepts that have a common application across the disciplines.

Promoting scientific literacy in an equitable and quality manner for *all* students is an ideal worthy of focused attention and continued effort. Equitable access to high-quality educational standards provides common expectations for all students and equips students with the strong science-based skills, including critical thinking and inquiry-based problem-solving, to be scientifically literate and succeed in college, careers and citizenship.

Engineering is taking science and applying it to create solutions that benefit society and the environment. The *Kentucky Academic Standards for Science* represents a commitment to integrate engineering thinking through engineering design practices into the structure of science education from kindergarten through grade 12 by raising engineering design thinking to the same level as scientific inquiry when teaching science disciplines. Providing all students with a foundation in engineering design allows them to better engage in and aspire to solve major societal and environmental challenges they will face in the decades ahead and to engage in public discussions on science-related issues related to their everyday lives.

Kentucky's Vision for Students

Knowledge about science and the ability to be critically educated consumers of scientific information related to their everyday lives directly aligns with the vision of the Kentucky Board of Education (KBE). The board's vision is that each and every student is empowered and equipped to pursue a successful future. To equip and empower students, the following capacity and goal statements frame instructional programs in Kentucky schools. These statements were established by the Kentucky Education Reform Act (KERA) of 1990, as found in Kentucky Revised Statute (KRS) 158.645 and KRS 158.6451, stating that all students shall have the opportunity to acquire the following capacities and learning goals:

- Communication skills necessary to function in a complex and changing civilization;
- Knowledge to make economic, social and political choices;
- Core values and qualities of good character to make moral and ethical decisions throughout life;
- Understanding of governmental processes as they affect the community, the state and the nation;
- Sufficient self-knowledge and knowledge of their mental health and physical wellness;
- Sufficient grounding in the arts to enable each student to appreciate their cultural and historical heritage;
- Sufficient preparation to choose and pursue their life's work intelligently; and
- Skills to enable students to compete favorably with students in other states

Furthermore, schools shall:

- Expect a high level of achievement from all students.
- Develop their students' ability to:
    - Use basic communication and mathematics skills for purposes and situations they will encounter throughout their lives;
    - Apply core concepts and principles from mathematics, the sciences, the arts, the humanities, social studies and practical living studies to situations they will encounter throughout their lives;
    - Become self-sufficient individuals of good character exhibiting the qualities of altruism, citizenship, courtesy, hard work, honesty, human worth, justice, knowledge, patriotism, respect, responsibility and self-discipline;
    - Become responsible members of a family, work group or community, including demonstrating effectiveness in community service;
    - Think and solve problems in school situations and a variety of other situations they will encounter in life;
    - Connect and integrate experiences and new knowledge from all subject matter fields with what students have previously learned and build on past learning experiences to acquire new information through various media sources; and
    - Express their creative talents and interests in visual arts, music, dance and dramatic arts.
- Increase student attendance rates.
- Increase students' graduation rates and reduce dropout and retention rates.
- Reduce physical and mental health barriers to learning.
- Be measured on the proportion of students who make a successful transition to work, postsecondary education and the military.

To ensure legal requirements of science classes are met, the Kentucky Department of Education (KDE) encourages schools to use the *Model Curriculum Framework* to ensure curricular coherence in the development of curricula that meet the grade-level expectations set forth by standards. The Model Curriculum Framework describes curricular coherence as the "local alignment of the standards, curriculum, instructional resources, assessment and instructional practices within and across grade-levels in a school or district to help students meet grade-level expectations."

Legal Basis

The following KRS and Kentucky Administrative Regulations (KAR) provide a legal basis for this publication:

> **KRS 156.160 Promulgation of administrative regulations by the Kentucky Board of Education**
> With the advice of the Local Superintendents Advisory Council (LSAC), the KBE shall promulgate administrative regulations establishing standards that public school districts shall meet in student, program, service and operational performance. These regulations shall comply with the expected outcomes for students and schools set forth in KRS 158:6451.

KRS 158.6453 Review of academic standards and assessments
Beginning in fiscal year 2017-2018, and every six (6) years thereafter, the Kentucky Department of Education shall implement a process for reviewing Kentucky's academic standards and the alignment of corresponding assessments for possible revision or replacement to ensure alignment with post-secondary readiness standards necessary for global competitiveness and with state career and technical education standards. The revisions to the content standards shall:

1. Focus on critical knowledge, skills, and capacities needed for success in the global economy;
2. Result in fewer but more in-depth standards to facilitate mastery learning;
3. Communicate expectations more clearly and concisely to teachers, parents, students and citizens;
4. Be based on evidence-based research;
5. Consider international benchmarks; and
6. Ensure that the standards are aligned from elementary to high school to post-secondary education so that students can be successful at each education level.

704 KAR 3:305 Minimum high school graduation requirements
This administrative regulation establishes the minimum high school graduation requirements necessary for entitlement to a public high school diploma.

704 KAR 008:120 Kentucky Academic Standards for Science
This administrative regulation adopts into law the *Kentucky Academic Standards for Science*.

Standards Creation Process

Per KRS 158.6453, the *Kentucky Academic Standards for Science* were entirely conceived and written by teams of Kentucky educators. Kentucky teachers understand that elementary and secondary academic standards must align with postsecondary readiness standards and state career and technical education standards. This focus helps ensure that students are prepared for the jobs of the future and can compete with students from other states and nations.

The Science Advisory Panel (AP) was composed of 28 teachers, three public post-secondary professors from institutes of higher education and three community members. The function of the AP was to review public comments on the existing standards and make recommendations for changes to a Review Committee (RC). The Science RC was composed of six science teachers, two public post-secondary professors from institutes of higher education and three community members. The function of the Science RC was to review the work and findings from the AP and make recommendation to revise or replace existing standards.

The team was selected based on their expertise in the field of science and their role as practicing science teachers. When choosing writers, the selection committee considered state-wide representation for public elementary, middle and high school teachers as well as higher education instructors and community members.

Writers' Vision Statement

The writing team was guided by a vision for equitable science education in Kentucky that begins in kindergarten and progresses yearly through grade 12 to ensure that all students possess sufficient understanding of the science and engineering practices, crosscutting concepts and core ideas of science to engage in public discussions on science-related issues and are critically educated consumers of scientific information related to their everyday lives. To achieve this, *all* students at *all* grade levels must experience multiple sustained and authentic learning opportunities to investigate phenomena, engage in collaborative conversations and reflect the diversity encountered within the classroom in the local community and across the globe.

To meet this vision, the writers recognize that students need sustained opportunities to work with and develop the ideas that underly science and engineering practices and to appreciate how those ideas are interconnected over a period of years rather than weeks or months. Students should be provided multiple, ongoing opportunities to engage with the interconnectedness of the three dimensions of science as they work to make sense of the natural world. To assist teachers in this endeavor, the writers recommend that teachers at all grade levels have ongoing access to high-quality professional learning and resources about science.

The KDE provided the following foundational documents to inform the writing team's work:

- Bell, P. (2019). Infrastructuring Teacher Learning about Equitable Science Instruction. *Journal of Science Teacher Education*, *30*(7), 681–690. https://doi.org/10.1080/1046560X.2019.1668218
- Bell, P. & Bang, M. (2015). *STEM Teaching Tool #15 Overview: How can we promote equity in science education?* http://stemteachingtools.org/brief/15
- Michaels, S., Shouse, A., & Schweingruber, H. (2008). Ready, Set, SCIENCE!: Putting Research to Work in K-8 Science Classrooms. The National Academies Press. https://www.nap.edu/catalog/11882/ready-set-science-putting-research-to-work-in-k-8
- Morrison, D. & Bell, P. (2018). *STEM Teaching Tool #54 How to build an equitable learning community in your science classroom.* http://stemteachingtools.org/brief/54
- National Research Council. (2012). *A Framework for K-12 Science Education Practices, Crosscutting Concepts, and Core Ideas.* https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts
- NGSS Lead States. (2013). *The Next Generation Science Standards: For States, By States.* Appendix D: All Standards, All Students. https://www.nextgenscience.org/sites/default/files/Appendix%20D%20Diversity%20and%20Equity%206-14-13.pdf
- NGSS Lead States. (2013). *The Next Generation Science Standards: For States, By States.* Appendix E: DCI Progressions in the NGSS. https://www.nextgenscience.org/sites/default/files/resource/files/AppendixE-ProgressionswithinNGSS-061617.pdf
- NGSS Lead States. (2013). *The Next Generation Science Standards: For States, By States.* Appendix F: Science and Engineering Practices. https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

- NGSS Lead States. (2013). *The Next Generation Science Standards: For States, By States.* Appendix G: Crosscutting Concepts. https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf
- Review of state academic documents and frameworks (Alaska, Arizona, Massachusetts, New York, Oklahoma, South Dakota, Tennessee, Utah).
- Duncan, R., Krajcik, J., & Rivet, A. (Eds.). (2017). *Disciplinary Core Ideas Reshaping Teaching and Learning*. NSTA Press.
- Schwarz, C., Passmore, C., & Reiser, B. (Eds.). (2017). *Helping Students Make Sense of the World Using Next Generation Science and Engineering Practices.* NSTA Press.

Additionally, participants brought their own knowledge to the process. The writers also thoughtfully considered feedback from the public and science community.

Design Considerations

Design considerations were informed by research, public comment and review of science standards from other states. A recurring theme reported from the first round of public comment was the desire to have more clarity about what specific performance expectations required. Upon examination, it was determined that examples and further information were provided but that the information was not readily accessible. This resulted in a redesign of the layout to address this concern.

Three-Dimensional Science

Understanding science and how it works goes beyond knowing discrete pieces of information. To meet the vision of scientifically literate students, the integration of the three dimensions of science, as outlined in the *Framework for K-12 Science Education*, must be maintained. These dimensions are:

- Science and Engineering Practices – describe the methods and way that:
  - Scientists investigate and develop models about the natural world and
  - Engineers design and build systems;
- Crosscutting Concepts – intellectual tools that students can draw from as they begin to investigate the natural/designed world;
- Disciplinary Core Ideas – ideas that have broad importance across multiple sciences or a key principle in a discipline

For students to develop a deep understanding of the core ideas, they must engage in exploring the natural and designed world. This is accomplished through the use of the practices and the crosscutting concepts. While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery of a performance expectation at the end of instruction, students should still use all of the science and engineering practices and crosscutting concepts as they develop their understanding of each disciplinary core idea.

Engineering, Technology and Application of Science

The linkage between learning science and learning engineering is demonstrated within the *Kentucky Academic Standards for Science*.

> *Just as new science enables or sometimes demands new technologies, new technologies enable new scientific investigations, allowing scientists to probe realms and handle quantities of data previously inaccessible to them. It is impossible to do engineering today without applying science in the process, and, in many areas of science, designing and building new experiments requires scientists to engage in some engineering practices. This interplay of science and engineering makes it appropriate to [include] engineering and technology.* (National Research Council, 2012)

Engineering design in the earliest grades introduces students to "problems" as situations that people want to change. They can use tools and materials to solve simple problems, use different representations to convey solutions, and compare different solutions to a problem and determine which is best. Students in all grade levels are not expected to come up with original solutions, although original solutions are always welcome. Emphasis is on thinking through the needs or goals that need to be met, and which solutions best meet those needs and goals.

For those engineering design standards with no crosscutting concepts identified, the crosscutting concept will be identified by the nature of the problem chosen.

Clarification Statements and Assessment Boundaries

A recurring theme reported from the first round of public comment was the desire to have more clarity about what specific performance expectations required. Most of the performance expectations defined in the *Kentucky Academic Standards for Science* include clarification statements and assessment boundaries. Clarification statements are one or two sentences that provide examples or particular emphasis that can assist in further understanding of the intent and in developing instructional experiences. Assessment boundaries define the limits of large-scale assessment. This, however, does not limit assessment practices within the classroom.

Science for All

The vision set forth by the writers emphasizes that "*all* students will possess sufficient understanding … to engage in public discussion … and be critically educated consumers of scientific information." The *Kentucky Academic Standards for Science*, written as performance expectations, imply that students will be active participants in the scientific and engineering process. The inclusion of the science and engineering practices "offer rich opportunities and demands for language learning while they support science learning for all students" (Appendix D, p. 5).

The crosscutting concepts demonstrate the interrelatedness of scientific concepts, which is often seen as implied background knowledge – knowledge that derives from experiences that not all students have access to. As noted in Appendix D of the Next Generation Science Standards (NGSS), "Explicit teaching of the crosscutting concepts enables less privileged students … to make connections among big ideas that cut across science disciplines" (Appendix D, p. 6). As such, the multidimensionality demonstrated in the *Kentucky Academic Standards for Science* levels the playing field for all students to actively engage in scientific sensemaking and engineering design.

Standards Use and Development

The Kentucky Academic Standards Are Standards, Not Curriculum

The *Kentucky Academic Standards for Science* outlines the minimum standards Kentucky students should learn in each grade level kindergarten through eighth grade or high school grade-span. The standards address a foundational framework of what is to be learned, but do not address how learning experiences are to be designed or what resources should be used.
A standard represents a goal or outcome of an educational program; standards are vertically aligned expected outcomes for all students. The standards do not dictate the design of a lesson plan or how units should be organized. The standards establish a statewide baseline of what students should know and be able to do at the conclusion of a grade or grade-span. The instructional program should emphasize the development of students' abilities to acquire and apply the standards. The curriculum must ensure that appropriate accommodations are made for diverse populations of students found within Kentucky schools.

These standards are not a set of instructional or assessment tasks, but rather statements of what students should be able to master after instruction. Decisions on how best to help students meet these program goals are left to local school districts and teachers. Curriculum includes the vast array of instructional materials, readings, learning experiences and local mechanisms of assessment, including the full body of content knowledge to be covered, all of which are to be selected at the local level according to Kentucky law.

Translating the Standards into Curriculum

The Kentucky Department of Education does not require specific curricula or strategies to be used to engage students in the *Kentucky Academic Standards*. Local schools and districts choose to meet the minimum required standards using a locally adopted curriculum according to KRS 160.345, which outlines the method by which the curriculum is to be determined. As educators implement academic standards, they, along with community members, must guarantee postsecondary readiness that will ensure all learners are transition ready. To achieve this, Kentucky students need a curriculum designed and structured for a rigorous, relevant and personalized learning experience, including a wide variety of learning opportunities. The Kentucky *Model Curriculum Framework* is a resource to support districts and schools in the continuous process of designing and reviewing local curriculum.

Organization of the Standards

The *Kentucky Academic Standards for Science* are organized by grade level for kindergarten through grade 8, with high school standards being grade banded. Within each grade level/band, the performance expectations are organized around the disciplinary core ideas, resulting in a coherence of understanding as students move through their academic career. This, in turn, provides for greater flexibility for arranging the performance expectations in a grade level in a way that best represents the needs of schools and districts without sacrificing coherence.

The National Research Council, the functional staffing of the National Academies of Science, released the *Framework for K-12 Science Education* in 2011, which is the research base that was used in the development of the science standards. The framework provides that a quality science education for K-12 students integrates the three dimensions of science: science and engineering practices, disciplinary core ideas and the crosscutting concepts.

This results in the *Kentucky Academic Standards for Science* being written at the intersection of these three dimensions and being described as performance expectations students are required to demonstrate to show mastery. These dimensions describe the processes of doing science, the structure that helps organize and connect understanding and the deep knowledge that provides predictive power. Taken together, these represent how we use science to make sense of the natural/designed world and are most meaningful when learned in concert with one another.

Science and Engineering Practices: Practices refer to the way in which scientists and engineers engage in their work. They engage in wonder, design, modeling, argumentation, communication, and engineering thinking. While a specific practice may be identified in each performance expectation, students should engage in all practices because this helps them understand how scientific knowledge develops and the links between science and engineering.

Disciplinary Core Ideas: Core ideas found in the *Kentucky Academic Standards for Science* are foundational understandings so that students may later acquire additional information on their own. The core ideas are organized within physical, life and earth/space science, which are traditionally associated with science knowledge. Also found here are the ideas used in the engineering design process, identified as ETS (engineering, technology, and application of science).

Crosscutting Concepts: Crosscutting concepts are conceptual tools that are used as lenses for understanding the natural/designed world. They provide ways of thinking and reasoning about phenomena across disciplines, uniting core ideas throughout the fields of science and engineering. While specific crosscutting concepts may be identified in each performance expectation, explicit instruction and engagement in all of the crosscutting concepts is expected. This will help deepen students' sensemaking across a range of disciplinary contexts.

The table below provides a summary of each science dimension mentioned above.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking questions or defining problems: Students engage in asking testable questions and defining problems to pursue understanding of phenomena. **Developing and using models:** Students develop physical, conceptual and other models to represent relationships, explain mechanisms, communicate ideas and predict outcomes. **Planning and carrying out investigations:** Students plan and conduct scientific investigations to test, revise or develop explanations.	**Physical Sciences:** (PS1) Matter and Its Interactions (PS2) Motion and Stability: Forces and Interactions (PS3) Energy (PS4) Waves **Life Sciences:** (LS1) Molecules to Organisms (LS2) Ecosystems (LS3) Heredity (LS4) Biological Evolution	**Patterns:** Students observe patterns to organize and classify factors that influence relationships. **Cause and effect mechanisms and explanation**: Students investigate and explain causal relationships and their mechanisms to make tests and predictions. **Scale, proportion and quantity:** Students recognize the relevancy of and changes in scale, proportions and quantities of measurement within and between various systems.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and interpreting data: Students analyze various types of data to identify features or patterns for interpretation and further use. **Using mathematics and computational thinking:** Students use fundamental tools in science to compute relationships and interpret results. **Constructing explanations and designing solutions:** Students construct explanations about the world and design solutions to problems using observations that are consistent with current evidence and scientific principles. **Engaging in argument from evidence:** Students support their best conclusions and solutions with lines of reasoning using evidence to defend their claims. **Obtaining, evaluating and communicating information:** Students obtain, evaluate and derive meaning from scientific information or presented evidence using appropriate scientific language. They communicate their findings clearly and persuasively in a variety of ways including written text, graphs, diagrams, charts, tables or orally.	**Earth and Space Sciences:** (ESS1) Earth's Place in the Universe (ESS2) Earth's Systems (ESS3) Earth and Human Activity **Engineering Design:** (ETS1.A) Defining and Delimiting an Engineering Problem (ETS1.B) Developing Possible Solutions (ETS1.B) Optimizing the Design Solution	**Systems and system models:** Students use models to explain the boundaries and relationships that describe complex systems. **Energy and matter flows, cycles and conservation:** Students describe cycling of matter and flow of energy through systems, including transfer, transformation and conservation of energy and matter. **Structure and function:** Students relate the shape and structure of an object or living thing to its properties and functions. **Stability and change:** Students explain how and why a natural or built system can change or remain stable over time.

How to Read the Standards

Performance Expectation (PE): The performance students demonstrate to show mastery →

Foundation Boxes: Provides further information about each dimension that was combined to develop the PE. →

K-PS2-1. **Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.**		
Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, swings on a playground, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other. **Assessment Boundary:** Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations With guidance, plan and conduct an investigation in collaboration with peers.	**PS2.A: Forces and Motion** 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. **PS2.B: Types of Interactions** When objects touch or collide, they push on one another and can change motion. **PS3.C: Relationship Between Energy and Forces** A bigger push or pull makes things speed up or slow down more quickly.	**Cause and Effect** Simple tests can be designed to gather evidence to support or refute student ideas about causes.

← Clarification Statement: Provide examples or additional information

← Assessment Boundary: States the limit of assessment for large-scale assessment

Meaning of Each Component

Performance Expectation: The performance students demonstrate to show mastery. It states how a student will demonstrate their understanding of a core idea on a large-scale assessment. Some performance expectations include an asterisk, which signifies the inclusion of engineering design.

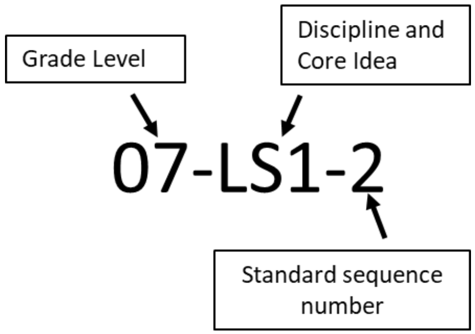
Clarification Statement: These provide examples or additional information about the performance expectation. Not all performance expectations include a clarification statement. In instances in which the committee felt clarification was not necessary, the notation "none provided" is present.

Assessment Boundary: This states the limit of assessment for a large-scale assessment. It does not, however, limit the assessment that could occur in the classroom. The notation "none provided" indicates that the committee did not believe a boundary needed to be identified.

Foundation Boxes: These boxes represent the foundational components of three dimensions that encompass the performance expectation, which are:

- Science and Engineering Practices: This box describes the element of the practice associated with the performance expectation.
- Disciplinary Core Idea: This box includes conceptual information related to the overall core idea of the performance expectation. The coding found in this box is consistent with the coding and component ideas described in the framework.
- Crosscutting Concepts: This box describes the element of the concept associated with the performance expectation.

How to Read the Coding



Discipline Codes	
PS	Physical Science
LS	Life Science
ESS	Earth and Space Science
ETS	Engineering, Technology and Applications of Science

Supplementary Materials to the Standards

Appendix A: Writing and Review Teams

This appendix includes information on the writing teams who developed the Kentucky Academic Standards for Science.

Kindergarten Overview

To meet the kindergarten performance expectations, students are expected to demonstrate grade-appropriate proficiency in asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; designing solutions; engaging in argument from evidence; and obtaining, evaluating and communicating information. Students are expected to use these practices to demonstrate their understanding of the core ideas. Kindergarten performance expectations include pushes and pulls, weather and animal habitats. Students are expected to develop understanding of patterns and variations in local weather and the purpose of weather forecasting to prepare for, and respond to, severe weather. Students can apply an understanding of the effects of different strengths or different directions of pushes and pulls on the motion of an object to analyze a design solution. Students also are expected to develop understanding of what plants and animals (including humans) need to survive and the relationship between their needs and where they live. The crosscutting concepts of patterns that include cause and effect, systems and system models are highlighted as organizing concepts for these disciplinary core ideas.

Note While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all of the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information.

K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, swings on a playground, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.

Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Planning and Carrying Out Investigations With guidance, plan and conduct an investigation in collaboration with peers.	**PS2.A: Forces and Motion** 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. **PS2.B: Types of Interactions** When objects touch or collide, they push on one another and can change motion. **PS3.C: Relationship Between Energy and Forces** A bigger push or pull makes things speed up or slow down more quickly.	**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 a pull. *

Clarification Statement: Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.

Assessment Boundary: Assessment does not include friction as a mechanism for change in speed.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Analyzing and Interpreting Data Analyze data from tests of an object or tool to determine if it works as intended.	**PS2.A: Forces and Motion** Pushes and pulls can have different strengths. Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. **ETS1.A: Defining Engineering Problems** 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.

K-PS3-1. Make observations to determine the effect of sunlight on Earth's surface.		
Clarification Statement: Examples of Earth's surface could include sand, soil, rocks, and water. **Assessment Boundary:** Assessment of temperature is limited to relative measures such as warmer/cooler.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Make observations (firsthand or from media) to collect data that can be used to make comparisons.	**PS3.B: Conservation of Energy and Energy Transfer** Sunlight warms 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 umbrellas, canopies, and tents that minimize the warming effect of the sun. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and 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.	**PS3.B: Conservation of Energy and Energy Transfer** Sunlight warms Earth's surface.	**Cause and Effect** Events have causes that generate observable patterns.

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

Clarification Statement: Examples of patterns could include that animals need to take in food but plants make their food, 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.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	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.	**LS1.C: Organization for Matter and Energy Flow in Organisms** All animals need food in order to live and grow. They 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.

K-ESS2-1. Use and share observations of local weather conditions to describe patterns over time.		
Clarification Statement: Examples of qualitative observations could include descriptions of the weather (such as sunny, cloudy, rainy, and warm); examples of quantitative observations could include numbers of sunny, windy, and rainy days in a month. Examples of patterns could include that it is usually cooler in the morning than in the afternoon and the number of sunny days versus cloudy days in different months. **Assessment Boundary:** Assessment of quantitative observations limited to whole numbers and relative measures such as warmer/cooler.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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.	**ESS2.D: Weather and Climate** 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.	**Cause and Effect** Patterns in the natural world can be observed, used to describe phenomena, and used as evidence.

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: Examples of plants and animals changing their environment could include that a squirrel digs in the ground to hide its food, and tree roots can break concrete. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Engaging in Argument from Evidence Construct an argument with evidence to support a claim.	**ESS2.E: Biogeology** Plants and animals can change their environment. **ESS3.C: Human Impacts on Earth Systems** 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.	**Systems and System Models** Systems in the natural and designed world have parts that work together.

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: Examples of relationships could include that deer eat buds and leaves; therefore, they usually live in forested areas; and, grasses need sunlight, so they often grow in meadows. Plants, animals, and their surroundings make up a system.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Use a model to represent relationships in the natural world.	**ESS3.A: Natural Resources** 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.

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

Clarification Statement: Emphasis is on local forms of severe weather.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Asking Questions and Defining Problems Ask questions based on observations to find more information about the designed world. **Obtaining, Evaluating and Communicating Information** Read grade-appropriate texts and/or use media to obtain scientific information to describe patterns in the natural world.	**ESS3.B: Natural Hazards** 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. **ETS1.A: Defining and Delimiting an Engineering Problem** Asking questions, making observations, and gathering information are helpful in thinking about problems.	**Cause and Effect** Events have causes that generate observable patterns.

K-ESS3-3.	Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.*	
Clarification Statement: Examples of human impact on the land could include cutting down trees to produce paper and using resources to produce bottles. Examples of solutions could include reusing paper and recycling cans and bottles. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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.	**ESS3.C: Human Impacts on Earth Systems** 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. **ETS1.B: Developing Possible Solutions** 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.

First Grade Overview

To meet the first-grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in planning and carrying out investigations; analyzing and interpreting data; constructing explanations and designing solutions; and obtaining, evaluating and communicating information. Students are expected to use these practices to demonstrate their understanding of the core ideas. First grade performance expectations include sound and light, object movement, and plant and animal survival. Students can observe, describe and predict some patterns of the movement of objects in the sky. Students are expected to develop understanding of the relationship between sound and vibrating materials as well as between the availability of light and ability to see objects. The idea that light travels from place to place can be understood by students at this level through determining the effect of placing objects made with different materials in the path of a beam of light. Students also are expected to develop understanding of how plants and animals use their external parts to help them survive, grow and meet their needs as well as how behaviors of parents and offspring help the offspring survive. The understanding is developed that young plants and animals are like, but not exactly the same as, their parents. The crosscutting concepts of patterns that include cause and effect, structure and function are highlighted as organizing concepts for these disciplinary core ideas.

****Note**** While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all of the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information.

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 and plucking a stretched string. Examples of how sound can make matter vibrate could include holding a piece of paper near a speaker making sound and holding an object near a vibrating tuning fork.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Planning and Carrying Out Investigations Plan and conduct investigations collaboratively in order to produce data to serve as the basis for evidence to answer a question.	**PS4.A: Wave Properties** Sound can make matter vibrate, and vibrating matter can make sound. **PS4.C: Information Technologies and Instrumentation** People also use a variety of devices to communicate (send and receive information) over long distances.	**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, a pinhole box, and a video of a cave explorer with a flashlight. Illumination could be from an external light source or by an object giving off its own light. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena.	**PS4.B: Electromagnetic Radiation** 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.

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.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Planning and Carrying Out Investigations Plan and conduct investigations collaboratively in order to produce data to serve as the basis for evidence to answer a question.	**PS4.B: Electromagnetic Radiation** 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 Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Use tools and materials provided to design a device that solves a specific problem.	**PS4.C: Information Technologies and Instrumentation** People also use a variety of devices to communicate (send and receive information) over long distances.	**Cause and Effect** Simple tests can be designed to gather evidence to support or refute student ideas about causes.

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: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Use materials to design a device that solves a specific problem or a solution to a specific problem.	**LS1.A: Structure and Function** 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. **LS1.D: Information Processing** Animals have body parts that capture and convey different kinds of information needed for growth and survival. Animals respond to these inputs with behaviors that help them survive. Plants also respond to some external inputs.	**Structure and Function** The shape and stability of structures of natural and designed objects are related to their function(s).

1-LS1-2. Read texts and use media to determine patterns in the behavior of parents and offspring that help offspring survive.		
Clarification Statement: Examples of patterns of behavior 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). **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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.	**LS1.B: Growth and Development of Organisms** 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.

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 that plants or animals share. Examples of observations could include leaves from the same kind of plant that are the same shape but can differ in size, and a particular breed of dog that 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 Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena.	**LS3.A: Inheritance of Traits** Young animals are very much but not exactly like their parents. Plants also are very much but not exactly like their parents. **LS3.B: Variation of Traits** 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.

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 Idea**	**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.	**ESS1.A: The Universe and Its Stars** 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 to the time of year.		
Clarification Statement: Emphasis is on relative comparisons of the amount of daylight in the winter to the amount in the spring or fall. **Assessment Boundary:** Assessment is limited to relative amounts of daylight, not quantifying the hours or time of daylight.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Make observations (firsthand or from media) to collect data that can be used to make comparisons.	**ESS1.B: Earth and the Solar System** 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.

Second Grade Overview

To meet second-grade performance expectations, students are expected to demonstrate grade appropriate proficiency in developing and using models; planning and carrying out investigations; analyzing and interpreting data; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating and communicating information. Students are expected to use these practices to demonstrate their understanding of the core ideas. Second grade performance expectations include plant growth, diversity of life, classification of different materials, and how water affects the land. Students can apply their understanding of the idea that wind and water can change the shape of the land to compare design solutions to slow or prevent such change. Students can use information and models to identify and represent the shapes and kinds of land and bodies of water in an area and where water is found on Earth. Students are expected to develop an understanding of what plants need to grow and how plants depend on animals for seed dispersal and pollination. Students also are expected to compare the diversity of life in different habitats. An understanding of observable properties of materials is developed by students at this level through their analysis and classification of different materials. The crosscutting concepts of patterns that include cause and effect, energy and matter, structure and function, and stability and change are highlighted as organizing concepts for these disciplinary core ideas.

Note While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all of the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information

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. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Plan and conduct an investigation collaboratively in order to produce data to serve as the basis for evidence to answer a question.	**PS1.A: Structure and Properties of Matter** 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.	**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 an intended purpose. *		
Clarification Statement: Examples of properties could include strength, flexibility, hardness, texture, and absorbency. **Assessment Boundary:** Assessment of quantitative measurements is limited to length.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Analyze data from tests of an object or tool to determine if it works as intended.	**PS1.A: Structure and Properties of Matter** Different properties are suited to different purposes.	**Cause and Effect** Simple tests can be designed to gather evidence to support or refute student ideas about causes.

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 blocks, building bricks, or other assorted small objects. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena.	**PS1.A: Structure and Properties of Matter** Different properties are suited to different purposes. A great variety of objects can be built up from a small set of pieces.	**Energy and Matter** Objects may break into smaller pieces and be put together into larger pieces, or they may change shape.

2-PS1-4. Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.		
Clarification Statement: Examples of reversible changes could include materials such as water and butter at different temperatures. Examples of irreversible changes could include cooking an egg, freezing a plant leaf, and heating paper. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Engaging in Argument from Evidence Construct an argument with evidence to support a claim.	**PS1.B: Chemical Reactions** 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.

2-LS2-1. Plan and conduct an investigation to determine if plants need sunlight and water to grow.		
Clarification Statement: None provided. **Assessment Boundary:** Assessment is limited to testing one variable at a time.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Plan and conduct an investigation collaboratively in order to produce data to serve as the basis for evidence to answer a question.	**LS2.A: Interdependent Relationships in Ecosystems** 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: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a simple model based on evidence to represent a proposed object or tool.	**LS2.A: Interdependent Relationships in Ecosystems** Plants depend on animals for pollination or to move their seeds around. **ETS1.B: Developing Possible Solutions** 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).

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. **Assessment Boundary:** Assessment does not include specific animal and plant names in specific habitats.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Make observations (firsthand or from media) to collect data that can be used to make comparisons.	**LS4.D: Biodiversity and Humans** There are many different kinds of living things in any area, and they exist in different places on land and in water.	**Patterns** Patterns in the natural world can be observed.

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 rock, which occurs slowly. **Assessment Boundary:** Assessment does not include quantitative measurements of timescales.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Make observations from several sources to construct an evidence-based account for natural phenomena.	**ESS1.C: The History of Planet Earth** 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.

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. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Compare multiple solutions to a problem.	**ESS2.A: Earth Materials and Systems** Wind and water can change the shape of the land. **ETS1.C: Optimizing the Design Solution** Because there is always more than one possible solution to a problem, it is useful to compare and test designs.	**Stability and Change** Things may change slowly or rapidly.

2-ESS2-2. Develop a model to represent the shapes and kinds of land and bodies of water in an area.		
Clarification Statement: None provided. **Assessment Boundary:** Assessment does not include quantitative scaling in models.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model to represent patterns in the natural world.	**ESS2.B: Plate Tectonics and Large-Scale System Interactions** 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: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information Obtain information using various texts, text features (e.g., headings, tables of contents, glossaries, electronic menus, icons), and other media that will be useful in answering a scientific question.	**ESS2.C: The Roles of Water in Earth's Surface Processes** Water is found in oceans, rivers, lakes, and ponds. Water exists as solid ice and in liquid form.	**Patterns** Patterns in the natural world can be observed.

K-2 Engineering Design Overview

Engineering design in the earliest grades introduces students to "problems" as situations that people want to change. Students can use tools and materials to solve simple problems, use different representations to convey solutions, and compare different solutions to a problem and determine which is best. Students in all grade levels are not expected to produce original solutions, although original solutions are always welcome. Emphasis is on thinking through the needs or goals that need to be met, and which solutions best meet those needs and goals.

K-2-ETS1-1. Ask questions, make observations, and gather information about a situation that people want to change to define a simple problem that can be solved through the development of a new or improved object or tool. *

Clarification Statement: None provided.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Asking Questions and Defining Problems Ask questions based on observations to find more information about the natural and/or designed world(s). Define a simple problem that can be solved through the development of a new or improved object or tool.	**ETS1.A: Defining and Delimiting Engineering Problems** A situation that people want to change or create can be approached as a problem to be solved through engineering. Asking questions, making observations, and gathering information are helpful in thinking about problems. Before beginning to design a solution, it is important to clearly understand the problem.	

K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem. *		
Clarification Statement: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a simple model based on evidence to represent a proposed object or tool.	**ETS1.B: Developing Possible Solutions** 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).

K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs. *

Clarification Statement: None provided.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Analyzing and Interpreting Data Analyze data from tests of an object or tool to determine if it works as intended.	**ETS1.C: Optimizing the Design Solution** Because there is always more than one possible solution to a problem, it is useful to compare and test designs.	

Third Grade Overview

To meet the third-grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in asking questions and defining problems; developing and using models; planning and conducting investigations; analyzing and interpreting data; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating and communicating information. Students are expected to use these practices to demonstrate their understanding of the core ideas. Third-grade performance expectations include weather conditions and hazards, life cycles, traits, the environment, balanced and unbalanced forces, and magnetic interactions. Students can organize and use data to describe typical weather conditions expected during a particular season. By applying their understanding of weather-related hazards, students can make a claim about the merit of a design solution that reduces the impacts of such hazards. Third graders are expected to develop an understanding of the idea that when the environment changes some organisms survive and reproduce, some move to new locations, some move into the transformed environment, and some die. Students can determine the effects of balanced and unbalanced forces on the motion of an object and the cause-and-effect relationships of electric or magnetic interactions between two objects not in contact with each other. They are then able to apply their understanding of magnetic interactions to define a simple design problem that can be solved with magnets. The crosscutting concepts of patterns that include cause and effect; scale, proportion and quantity; and systems and system models are highlighted as organizing concepts for these disciplinary core ideas.

Note While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all of the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information.

3-PS2-1.	**Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.**	
Clarification Statement: Examples could include that an unbalanced force on one side of a ball can make it start moving, and balanced forces pushing on a box from both sides will not produce any motion at all. **Assessment Boundary:** Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Plan and conduct an investigation collaboratively in order to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials is considered.	**PS2.A: Forces and Motion** Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add up to zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual but not quantitative addition of forces are used at this level.) **PS2.B: Types of Interactions** Objects in contact exert forces on each other.	**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, 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 Idea**	**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 or to test a design solution.	**PS2.A: Forces and Motion** 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.

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 the 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 Idea	Crosscutting Concepts
Asking Questions and Defining Problems Ask questions that can be investigated based on patterns, such as cause-and-effect relationships.	**PS2.B: Types of Interactions** 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 constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Asking Questions and Defining Problems Define a simple problem that can be solved through the development of a new or improved object or tool.	**PS2.B: Types of Interactions** 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** Identify and test causal relationships and use these relationships to explain change.

3-LS1-1.	**Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death.**

Clarification Statement: Changes organisms go through during their life form a pattern.

Assessment Boundary: Assessment of plant life cycles is limited to those of flowering plants. Assessment does not include details of human reproduction.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop models to describe phenomena.	**LS1.B: Growth and Development of Organisms** 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.

3-LS2-1. Construct an argument that some animals form groups that help members survive.		
Clarification Statement: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Engaging in Argument from Evidence Construct an argument with evidence, data, and/or a model.	**LS2.D: Social Interactions and Group Behavior** 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 identified and used to explain change.

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 Idea	Crosscutting Concepts
Analyzing and Interpreting Data Analyze and interpret data to make sense of phenomena using logical reasoning.	**LS3.A: Inheritance of Traits** Many characteristics of organisms are inherited from their parents. **LS3.B: Variation of Traits** 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 phenomena.

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, and a pet dog that is given too much food and little exercise may become overweight. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Use evidence (e.g., observations, patterns) to support an explanation.	**LS3.A: Inheritance of Traits** Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. **LS3.B: Variation of Traits** The environment also affects the traits that an organism develops.	**Cause and Effect** Cause-and-effect relationships are routinely identified and used to explain change.

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, finding mates, and reproducing.**

Clarification Statement: Examples of cause-and-effect relationships could be that 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: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Use evidence (e.g., observations, patterns) to construct an explanation.	**LS4.B: Natural Selection** 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 and used to explain change.

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. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Engaging in Argument from Evidence Construct an argument with evidence.	**LS4.C: Adaptation** For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.	**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 Idea**	**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.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** When the environment changes in ways that affect a place's physical characteristics, temperature, or the availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. **LS4.D: Biodiversity and Humans** Populations live in a variety of habitats, and changes in those habitats affect the organisms living there.	**Systems and System Models** A system can be described in terms of its components and their interactions.

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 could include average temperature, precipitation, and wind direction. **Assessment Boundary:** Assessment of graphical displays is limited to pictographs and bar graphs. Assessment does not include climate change.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships.	**ESS2.D: Weather and Climate** Scientists record patterns of 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.

3-ESS2-2. Obtain and combine information to describe climates in different regions of the world.		
Clarification Statement: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information Obtain and combine information from books and other reliable media to explain phenomena.	**ESS2.D: Weather and Climate** Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years.	**Patterns** Patterns of change can be used to make predictions.

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-resistant roofs, and lightning rods. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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.	**ESS3.B: Natural Hazards** A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts.	**Cause and Effect** Cause-and-effect relationships are routinely identified, tested, and used to explain change.

Fourth Grade Overview

To meet the fourth-grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating and communicating information. Students are expected to use these practices to demonstrate their understanding of the core ideas. Fourth-grade performance expectations include waves, weathering, impacts of Earth processes, Earth features, map analysis, animal and plant anatomy, speed, energy transfer and encoding with patterns. Students can use evidence to construct an explanation of the relationship between the speed of an object and the energy of that object. Students will be able to model patterns that can encode, send, receive, and decode information. Students are expected to develop an understanding that energy can be transferred from place to place by sound, light, heat, and electric currents or from object to object through collisions. They apply their understanding of energy to design, test and refine a device that converts energy from one form to another. The crosscutting concepts of patterns that include cause and effect, energy and matter, and systems and system models are highlighted as organizing concepts for these disciplinary core ideas.

Note While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all of the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.		
Clarification Statement: None provided. **Assessment Boundary:** Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Use evidence (e.g., measurements, observations, patterns) to construct an explanation.	**PS3.A: Definitions of Energy** The faster a given object is moving, the more energy it possesses.	**Energy and Matter** Energy can be transferred in various ways and between objects.

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: None provided.

Assessment Boundary: Assessment does not include quantitative measurements of energy.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Planning and Carrying Out Investigations Make observations in order to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.	**PS3.A: Definitions of Energy** Energy can be moved from place to place by moving objects or through sound, light, or electric currents. **PS3.B: Conservation of Energy and Energy Transfer** 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. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.	**Energy and Matter** Energy can be transferred in various ways and between objects.

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.		
Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact. **Assessment Boundary:** Assessment does not include quantitative measurements of energy.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Asking Questions and Defining Problems Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause-and-effect relationships.	**PS3.A: Definitions of Energy** Energy can be moved from place to place by moving objects or through sound, light, or electric currents. **PS3.B: Conservation of Energy and Energy Transfer** 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. **PS3.C: Relationship Between Energy and Forces** When objects collide, the contact forces transfer energy so as to change the objects' motions.	**Energy and Matter** Energy can be transferred in various ways and between objects.

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 electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; 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: Devices should be limited to those that convert motion energy to electrical energy or use stored energy to cause motion or produce light or sound.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Apply scientific ideas to solve design problems.	**PS3.B: Conservation of Energy and Energy Transfer** 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. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. **PS3.D: Energy in Chemical Processes and Everyday Life** The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. **ETS1.A: Defining Engineering Problems** Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). 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.	**Energy and Matter** Energy can be transferred in various ways and between objects.

4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.		
Clarification Statement: Examples of models could include diagrams, analogies, and physical models to illustrate wavelength and amplitude of waves. **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 Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model using an analogy, example, or abstract representation to describe a scientific principle.	**PS4.A: Wave Properties** 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 natural phenomena.

4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.		
Clarification Statement: Examples of models could include diagrams, analogies, and physical models that illustrate light reflecting from objects and entering the eye. **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 Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model to describe phenomena.	**PS4.B: Electromagnetic Radiation** An object can be seen when light reflected from its surface enters the eyes.	**Cause and Effect** Cause and effect relationships are routinely identified.

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, and using Morse code to send text. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.	**PS4.C: Information Technologies and Instrumentation** Patterns can encode, send, receive, and decode information. **ETS1.C: Optimizing the Design Solution** 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.

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 Idea	Crosscutting Concepts
Engaging in Argument from Evidence Construct an argument with evidence, data, and/or a model.	**LS1.A: Structure and Function** Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.	**System and System Models** A system can be described in terms of its components and their interactions.

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.

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 Idea	Crosscutting Concepts
Developing and Using Models Use a model to test interactions concerning the functioning of a natural system.	**LS1.D: Information Processing** Different sense receptors are specialized for particular kinds of information, which may then be 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.

4-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 distributions 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 Idea	Crosscutting Concepts
Analyzing and Interpreting Data Analyze and interpret data to make sense of phenomena using logical reasoning.	**LS4.A: Evidence of Common Ancestry and Diversity** 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.

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 of the mechanism of rock formation or memorization of specific rock formations and layers. Assessment is limited to relative time.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Identify the evidence that supports particular points in an explanation.	**ESS1.C: The History of Planet Earth** 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.

4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.		
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 Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Make observations and/or measurements in order to produce data to serve as the basis for evidence for an explanation of a phenomenon.	**ESS2.A: Earth Materials and Systems** 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. **ESS2.E: Biogeology** Living things affect the physical characteristics of their regions.	**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: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Analyzing and Interpreting Data Analyze and interpret data to make sense of phenomena using logical reasoning.	**ESS2.B: Plate Tectonics and Large-Scale System Interactions** 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 of Earth.	**Patterns** Patterns can be used as evidence to support an explanation.

4-ESS3-1.	**Obtain and combine information to describe that energy and fuels are derived from natural resources and that their uses affect the environment.**	
Clarification Statement: Natural resources are derived from both renewable energy (e.g., wind, water, biomass) and non-renewable energy (e.g., fossil fuels and fissile materials). Examples of environmental effects could include loss of habitat, soil erosion, or air pollution. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information Obtain and combine information from books and other reliable media to explain phenomena or solutions to a design problem.	**ESS3.A: Natural Resources** 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 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 and improving the monitoring of volcanic activity. **Assessment Boundary:** Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.	**ESS3.B: Natural Hazards** 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. **ETS1.B: Designing Solutions to Engineering Problems** Testing a solution involves investigating how well it performs under a range of likely conditions.	**Cause and Effect** Cause-and-effect relationships are routinely identified, tested, and used to explain change.

Fifth Grade Overview

To meet the fifth-grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; engaging in argument from evidence; and obtaining, evaluating and communicating information. Students are expected to use these practices to demonstrate their understanding of the core ideas. Fifth-grade performance expectations include matter and substances, interactions of Earth systems, water distribution, plant development, movement of matter and energy and Earth's rotation. Students can describe that matter is made of particles too small to be seen through the development of a model. Students understand that matter undergoes changes, but the weight is conserved. Students develop an understanding of the idea that regardless of the type of change that matter undergoes, the total weight of matter is conserved. Students determine whether the mixing of two or more substances results in new substances. Through the development of a model using an example, students can describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. They describe and graph data to provide evidence about the distribution of water on Earth. Students develop an understanding of the idea that plants get the materials they need for growth chiefly from air and water. Using models, students can describe the movement of matter among plants, animals, decomposers, and the environment and that energy in animals' food was once energy from the sun. Students are expected to develop an understanding that Earth's rotation causes shadows, day and night and affects seasonal changes of patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky. The crosscutting concepts of patterns that include cause and effect; scale, proportion and quantity; energy and matter; and systems and systems models are highlighted as organizing concepts for these disciplinary core ideas.

Note While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information

5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.		
Clarification Statement: Examples of evidence could 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 the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model to describe phenomena.	**PS1.A: Structure and Properties of Matter** 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 and 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 form new substances. **Assessment Boundary:** Assessment does not include distinguishing mass and weight.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Measure and graph quantities such as weight to address scientific and engineering questions and problems.	**PS1.A: Structure and Properties of Matter** The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. **PS1.B: Chemical Reactions** 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.

5-PS1-3. Make observations and measurements to identify materials based on their properties.		
Clarification Statement: Examples of materials to be identified could include baking soda and other powders, 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.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Make observations and measurements in order to produce data to serve as the basis for evidence for an explanation of a phenomenon.	**PS1.A: Structure and Properties of Matter** 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: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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 is considered.	**PS1.B: Chemical Reactions** 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.

5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.		
Clarification Statement: "Down" is a local description of the direction that points toward the center of the spherical Earth. **Assessment Boundary:** Assessment does not include mathematical representation of gravitational force.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Engaging in Argument from Evidence Support an argument with evidence, data, or a model.	**PS2.B: Types of Interactions** 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 and used to explain change.

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:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Use models to describe phenomena.	**PS3.D: Energy in Chemical Processes and Everyday Life** 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). **LS1.C: Organization for Matter and Energy Flow in Organisms** Food provides animals with the materials they need for body repair and growth and the energy they need to maintain body warmth and for motion.	**Energy and Matter** Energy can be transferred in various ways and between objects.

5-LS1-1. Support an argument that plants get the materials they need for growth chiefly from air and water.		
Clarification Statement: Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Engaging in Argument from Evidence Support an argument with evidence, data, or a model.	**LS1.C: Organization for Matter and Energy Flow in Organisms** Plants acquire their material for growth chiefly from air and water.	**Energy and Matter** Matter is transported into, out of, and within systems.

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 that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth. **Assessment Boundary:** Assessment does not include molecular explanations.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model to describe phenomena.	**LS2.A: Interdependent Relationships in Ecosystems** 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 plant parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials 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. **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** 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 then 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.

5-ESS1-1.	**Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.**

Clarification Statement: None provided.

Assessment Boundary: Assessment is limited to the relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar mass, age, stage).

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Engaging in Argument from Evidence Support an argument with evidence, data, or a model.	**ESS1.A: The Universe and Its Stars** The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.	**Scale, Proportion, and Quantity** Natural objects exist from the very small to the immensely large.

5-ESS1-2. Represent data in graphical displays to reveal patterns of daily changes in the length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.		
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. **Assessment Boundary:** Assessment does not include the causes of seasons.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Represent data in graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.	**ESS1.B: Earth and the Solar System** 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.

5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

Clarification Statement: Examples 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. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.

Assessment Boundary: Assessment is limited to the interactions of two systems at a time.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop a model using an example to describe a scientific principle.	**ESS2.A: Earth Materials and Systems** Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). 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 the landforms to determine patterns of weather.	**Systems and System Models** A system can be described in terms of its components and their interactions.

5-ESS2-2. Describe and graph the amounts and percentages of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.

Clarification Statement: None provided.

Assessment Boundary: Assessment is limited to oceans, lakes, rivers, glaciers, ground water, and polar ice caps; it does not include the atmosphere.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Using Mathematics and Computational Thinking Describe and graph quantities such as area and volume to address scientific questions.	**ESS2.C: The Roles of Water in Earth’s Surface Processes** Nearly all of Earth’s available water is in the ocean. Most fresh water 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.

5-ESS3-1. Obtain and combine information about solutions individual communities use to protect the Earth’s resources and environment.*

Clarification Statement: Examples could include agricultural solutions to prevent fertilizer runoff or using goats to control invasive plant species.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	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.	**ESS3.C: Human Impacts on Earth Systems** Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, oceans, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments. **ETS1.A: Defining and Delimiting Engineering Problems** Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). 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.	**Systems and System Models** A system can be described in terms of its components and their interactions.

3-5 Engineering Design Overview

At the upper elementary grades, engineering design engages students in more formalized problem solving. Students define a problem using criteria for success and constraints or limits of possible solutions. Students research and consider multiple possible solutions to a given problem. Generating and testing solutions also becomes more rigorous as the students learn to optimize solutions by revising them several times to obtain the best possible design.

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. *

Clarification Statement: None provided.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Asking Questions and Defining Problems Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.	**ETS1.A: Defining and Delimiting Engineering Problems** Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). 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.	

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. *		
Clarification Statement: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem.	**ETS1.B: Developing Possible Solutions** Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.	

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. *

Clarification Statement: None provided.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Planning and Carrying Out Investigations Plan and conduct an investigation collaboratively in order to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials is considered.	**ETS1.B: Developing Possible Solutions** Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. **ETS1.C: Optimizing the Design Solution** Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	

Sixth Grade Overview

To meet the sixth-grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in developing and using models, analyzing and interpreting data, constructing explanations and engaging in arguments from evidence. Students are expected to use these practices to demonstrate their understanding of the core ideas. Sixth grade performance expectations include gravitational interactions, Earth-Sun-Moon system, scale and properties of the solar system, scales of geoscience processes, evidence of plate tectonics, cycling of Earth's materials, cycling of water, motions and interactions of air masses, Earth's circulation patterns, resource availability on organisms, cycling of matter within ecosystems, patterns of interactions among organisms, atomic composition, and changes in particle motion with thermal energy. Students are expected to develop an understanding of the role of gravity in astronomy. Students will develop an understanding of the role of photosynthesis in the cycling of matter and energy. Students will also develop understanding that resource availability and energy flow influence patterns of organism interactions. Students will apply their understanding of changes in Earth's materials including plate movement, water and air. Students will model the cyclical patterns of lunar phases and eclipses are a result of the Earth-Sun-Moon system. Through the development and use of a model, students will describe the role of gravity in the motions of the solar system and galaxies, building towards creating arguments that gravitational interactions depend on the masses of interacting objects. Students will construct an explanation of how geoscience processes occur at varying time and spatial scales. Students will use models to describe atomic composition and changes in particle motion and state based on energy changes. The crosscutting concepts of patterns that include scale, proportion and quantity; systems and system models; energy and matter; and cause and effect are highlighted as organizing concepts for these disciplinary core ideas.

Note While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all of the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information.

6-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.		
Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball-and-stick structures, or computer representations showing different molecules with different types of atoms. **Assessment Boundary:** Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model to predict and/or describe phenomena.	**PS1.A: Structure and Properties of Matter** 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.

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 the 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: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop a model to predict and/or describe phenomena.	**PS1.A: Structure and Properties of Matter** Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. **PS3.A: Definitions of Energy** 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 may be used to predict phenomena in natural or designed systems.

6-PS2-1. Apply Newton's third law to design a solution to a problem involving the motion of two colliding objects. *

Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.

Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Apply scientific ideas or principles to design an object, tool, process, or system.	**PS2.A: Forces and Motion** 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).	**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.

6-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 also 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.

Science and Engineering Practice	Disciplinary Core Idea	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.	**PS2.B: Types of Interactions** 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 a 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.

6-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 Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS1.C: Organization for Matter and Energy Flow in Organisms** Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide in 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.	**Energy and Matter** Within a natural system, the transfer of energy drives the motion and/or cycling of matter.

6-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, the growth of individual organisms, and the numbers of organisms in ecosystems during periods of abundant and scarce resources.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Analyzing and Interpreting Data Analyze and interpret data to provide evidence for phenomena.	**LS2.A: Interdependent Relationships in Ecosystems** Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with non-living 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. The 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.

6-LS2-2. Construct an explanation that predicts patterns of interaction among organisms across multiple ecosystems.		
Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interaction could include competitive, predatory, and mutually beneficial. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.	**LS2.A: Interdependent Relationships in Ecosystems** 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 non-living, are shared.	**Patterns** Patterns can be used to identify cause-and-effect relationships.

6-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and non-living 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 Idea	Crosscutting Concepts
Developing and Using Models Develop a model to describe phenomena.	**LS2.B: Cycle of Matter and Energy Transfer in Ecosystems** Food webs are models that demonstrate how matter and energy are 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 non-living parts of the ecosystem.	**Energy and Matter** The transfer of energy can be tracked as energy flows through a natural system.

6-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.		
Clarification Statement: Examples of models can be physical, graphical, or conceptual. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop and use a model to describe phenomena.	**ESS1.A: The Universe and Its Stars** Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. **ESS1.B: Earth and the Solar System** This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.	**Patterns** Patterns can be used to identify cause-and-effect relationships.

6-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).

Assessment Boundary: Assessment does not include Kepler's laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop and use a model to describe phenomena.	**ESS1.A: The Universe and Its Stars** Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. **ESS1.B: Earth and the Solar System** 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.

6-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 size of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models. **Assessment Boundary:** Assessment does not include recalling facts about properties of the planets and other solar system bodies.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Analyze and interpret data to determine similarities and differences in findings.	**ESS1.B: Earth and the Solar System** 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.	**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.

6-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.

Assessment Boundary: Assessment does not include the identification and naming of minerals.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop and use a model to describe phenomena.	**ESS2.A: Earth's Materials and Systems** All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.	**Stability and Change** Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.

6-ESS2-2. Construct an explanation based on evidence for how biological and 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, biological or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition caused by the movements of water, ice, and wind. Examples of biological processes could include the decomposition of living organisms resulting in soil formation, the effect of vegetation on erosion, and the impact of beaver dams on the natural flow of waterways. Emphasis is on biological processes and geoscience processes that shape local geographic features, where appropriate. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.	**ESS2.A: Earth's Materials and Systems** The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. **ESS2.C: The Roles of Water in Earth's Surface Processes** Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. **ESS2.E: Biogeology** The evolution and proliferation of living things over geological time have in turn changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere.	**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.

6-ESS2-3. **Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of past plate motions.**		
Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches). **Assessment Boundary:** Paleomagnetic anomalies in oceanic and continental crust are not assessed.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Analyze and interpret data to provide evidence for phenomena.	**ESS1.C: The History of Planet Earth** Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** 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 rates of change and other numerical relationships can provide information about natural systems.

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 Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model to describe unobservable mechanisms.	**ESS2.C: The Roles of Water in Earth's Surface Processes** 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 collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation). **Assessment Boundary:** Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Planning and Carrying Out Investigations Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.	**ESS2.C: The Roles of Water in Earth's Surface Processes** The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. **ESS2.D: Weather and Climate** Because these patterns are so complex, weather can only be predicted probabilistically.	**Cause and Effect** Cause-and-effect relationships may be used to predict phenomena in natural or designed systems.

6-ESS2-6. **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.**		
Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations. **Assessment Boundary:** Assessment does not include the dynamics of the Coriolis effect.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop and use a model to describe phenomena.	**ESS2.C: The Roles of Water in Earth's Surface Processes** Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. **ESS2.D: Weather and Climate** Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.	**Systems and System Models** Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Seventh Grade Overview

To meet the seventh-grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in developing and using models, asking questions and defining problems, analyzing and interpreting data, constructing explanations and designing solutions, planning and carrying out investigations, using mathematics and computational thinking, and engaging in arguments from evidence. Students are expected to use these practices to demonstrate their understanding of the core ideas. Seventh-grade performance expectations include forces and motion, kinetic energy, cellular organization and function, matter and energy flow in organisms, stimuli response, chemical reactions, conservation of mass, thermal energy, electromagnetic forces and fields, gravitational interactions and potential energy, transfer of energy, energy and movement of waves, and transmission of information.

Students will be able to apply Newton's third law of motion to relate forces to explain the motion of objects. Students also apply ideas about gravitational, electrical and magnetic forces to explain a variety of phenomena including beginning ideas about why some materials attract each other while others repel. Students can describe, predict, and model characteristic properties and behaviors of waves when the waves interact with matter. Students can apply an understanding of waves as a means to send digital information. Students also can apply an understanding of design to the process of energy transfer. Students can gather information and use this information to support explanations of the structural and functional relationship of cells. Students will synthesize information relating sensory receptors and processing of stimuli by the brain.

By the end of the seventh grade, students will be able to provide molecular-level accounts to explain that chemical reactions involve regrouping of atoms to form new substances, and that atoms rearrange during chemical reactions. Students will develop an understanding that gravitational interactions are always attractive but that electrical and magnetic forces can be both attractive and negative. Students also develop ideas that objects can exert forces on each other even though the objects are not in contact, through fields. Students develop their understanding of important qualitative ideas about energy including that the interactions of objects can be explained and predicted using the concept of transfer of energy from one object or system of objects to another, and the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students understand that objects that are moving have kinetic energy and that objects also may contain stored (potential) energy, depending on their relative positions. Students also will come to know the difference between energy and temperature and begin to develop an understanding of the relationship between force and energy. Students develop the understanding that cells, the basic unit of life, carry out life's functions of growth, development and reproduction (cell theory).

The crosscutting concepts of patterns that include structure and function; energy and matter; scale, proportion and quantity; systems and system models; cause and effect; and stability and change are highlighted as organizing concepts for these disciplinary core ideas.

Note While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all of the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information.

7-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.		
Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrochloric acid. **Assessment Boundary:** Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Analyze and interpret data to determine similarities and differences in findings.	**PS1.A: Structure and Properties of Matter** Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **PS1.B: Chemical Reactions** 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.

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, balancing symbolic equations, or intermolecular forces.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model to describe unobservable mechanisms.	**PS1.B: Chemical Reactions** 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.	**Energy and Matter** Matter is conserved because atoms are conserved in physical and chemical processes.

7-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy.*		
Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride. **Assessment Boundary:** Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.	**PS1.B: Chemical Reactions** Some chemical reactions release energy, others store energy. **ETS1.B: Developing Possible Solutions** A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. **ETS1.C: Optimizing the Design Solution** 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.

7-PS2-2.	Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.	
Clarification Statement: Emphasis is on balanced (Newton's first law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's second law), frame of reference, and specification of units. **Assessment Boundary:** Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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.	**PS2.A: Forces and Motion** The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.	**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.

7-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.		
Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor. **Assessment Boundary:** Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Asking Questions and Defining Problems Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	**PS2.B: Types of Interactions** 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.

7-PS2-5.	**Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.**	
Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations. **Assessment Boundary:** Assessment is limited to electric and magnetic fields and limited to qualitative evidence for the existence of fields.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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.	**PS2.B: Types of Interactions** 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.

7-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.		
Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a whiffle ball versus a tennis ball. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Construct and interpret graphical displays of data to identify linear and nonlinear relationships.	**PS3.A: Definitions of Energy** 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 the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

7-PS3-2.	Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.

Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop a model to describe unobservable mechanisms.	**PS3.A: Definitions of Energy** A system of objects may also contain stored (potential) energy, depending on their relative positions. **PS3.C: Relationship Between Energy and Forces** 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-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*		
Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup. **Assessment Boundary:** Assessment does not include calculating the total amount of thermal energy transferred.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.	**PS3.A: Definitions of Energy** Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **PS3.B: Conservation of Energy and Energy Transfer** Energy is spontaneously transferred out of hotter regions or objects and into colder ones. **ETS1.A: Defining and Delimiting an Engineering Problem** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. **ETS1.B: Developing 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.

7-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 Idea	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.	**PS3.A: Definitions of Energy** Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **PS3.B: Conservation of Energy and Energy Transfer** 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.

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 Idea**	**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.	**PS3.B: Conservation of Energy and Energy Transfer** When the motion energy of an object changes, there is inevitably some other change in energy at the same time.	**Energy and Matter** Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).

7-PS4-1.	**Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.**	
Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking. **Assessment Boundary:** Assessment does not include electromagnetic waves and is limited to standard repeating waves.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Use mathematical representations to describe and/or support scientific conclusions and design solutions.	**PS4.A: Wave Properties** 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.

7-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.		
Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions. **Assessment Boundary:** Assessment is limited to qualitative applications pertaining to light and mechanical waves.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop and use a model to describe phenomena.	**PS4.A: Wave Properties** A sound wave needs a medium through which it is transmitted. **PS4.B: Electromagnetic Radiation** When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. However, because light can travel through space, it cannot be a matter wave, like sound or water waves.	**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.

7-PS4-3.	Integrate qualitative scientific and technical information to support the claim that designed technologies can transmit digital information as wave pulses.	
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 Wi-Fi devices, and conversion of stored binary patterns to make sound or text on a computer screen. **Assessment Boundary:** Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.	**PS4.C: Information Technologies and Instrumentation** Technologies allow us to detect and interpret waves and signals in waves that cannot be detected directly.	**Structure and Function** Structures can be designed to serve particular functions.

7-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: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Planning and Carrying Out Investigations Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation.	**LS1.A: Structure and Function** 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.

7-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.

Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.

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

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop and use a model to describe phenomena.	**LS1.A: Structure and Function** 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, therefore complex natural and designed structures/systems can be analyzed to determine how they function.

7-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.

Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.

Science and Engineering Practice	Disciplinary Core Idea	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.	**LS1.A: Structure and Function** 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.

7-LS1-7.	**Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.**

Clarification Statement: Emphasis is on describing that molecules are broken apart, rearranged and put back together and that in this process, energy is released.

Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop a model to describe unobservable mechanisms.	**LS1.C: Organization for Matter and Energy Flow in Organisms** Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. **PS3.D: Energy in Chemical Processes and Everyday Life** Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.	**Energy and Matter** Matter is conserved because atoms are conserved in physical and chemical processes.

7-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: None provided. **Assessment Boundary:** Assessment does not include mechanisms for the transmission of this information.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information Gather, read, and 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.	**LS1.D: Information Processing** 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.

Eighth Grade Overview

To meet the eighth-grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in obtaining, evaluating and communicating information; constructing explanations and designing solutions; developing and using models; analyzing and interpreting data; planning and carrying out investigations; engaging in arguments from evidence; and using mathematics and computational thinking. Students are expected to use these practices to demonstrate their understanding of the core ideas. Eighth-grade performance expectations include sources and impacts of synthetic materials, organism growth factors, information transmission, geological time scale, geoscience processes and resource distribution, global temperature rise, natural disaster forecasting and mitigation, human impact monitoring, natural resource consumption, stimuli response, ecosystem and population interactions, maintaining biodiversity, change of life forms throughout Earth's history, impact of mutations on structure and function of organisms, asexual and sexual reproduction, human influence on desired traits, evolutionary relationships based on anatomical and embryological similarities, genetic influence on survival and reproduction, and natural selection and trait selection.

Students will support the claim that technologies allow us to detect and interpret waves and signals in waves that cannot be detected directly. Students can construct an explanation for how environmental and genetic factors affect growth of organisms. Students will synthesize information relating sensory receptors and processing of stimuli by the brain. They also can study patterns of the interactions among organisms within an ecosystem. They evaluate competing design solutions for maintaining biodiversity and ecosystem services. Students can construct explanations based on evidence to support fundamental understandings of natural selection and evolution. They can use ideas of genetic variation in a population to make sense of organisms surviving and reproducing, hence passing on the traits of the species. They can use fossil records and anatomical similarities of the relationships among organisms and species to support their understanding. Students can use models to describe ways gene mutations and sexual reproduction contribute to genetic variation. Students examine geoscience data in order to understand the processes and events in Earth's history.

Students understand the ways that human activities and natural disasters impact Earth's systems and natural resources. They develop an understanding of the significant and complex issues surrounding human uses of land, energy, mineral, and water resources and the resulting impacts of their development. Mapping natural hazards helps humans forecast future events. Students build on their understanding of how environmental and genetic factors affect growth of organisms by connecting this to the role of animal behaviors in reproduction of animals as well as the dependence of some plants on animal behaviors for their reproduction. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. They evaluate competing design solutions for maintaining biodiversity and healthy ecosystems. Students describe ways gene mutations and sexual reproduction contribute to genetic variation. They can use ideas of genetic variation in a population to make sense of organisms surviving and reproducing, hence passing on the traits of the species. They can use fossil records and anatomical similarities of the relationships among organisms and species to support their understanding.

The crosscutting concepts of cause and effect, stability and change, patterns, and structure and function contribute to provide deeper understanding of the core ideas.

Note While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all of the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information.

8-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.

Assessment Boundary: Assessment is limited to qualitative information.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Gather, read, and 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.	**PS1.A: Structure and Properties of Matter** Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **PS1.B: Chemical Reactions** 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. **ESS3.A: Natural Resources** 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 geological processes (link to ESS2.B). Renewable energy resources, and the technologies to exploit them, are being rapidly developed.	**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.

8-LS1-4.	Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	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 a phenomenon or a solution to a problem.	**LS1.B: Growth and Development of Organisms** 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 Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS1.B: Growth and Development of Organisms** 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.

8-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:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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 a model for a phenomenon or a solution to a problem.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations **LS2.D: Social Interactions and Group Behavior** Groups often dissolve if they no longer function to meet individuals' needs, if dominant members lose their place, or if other key members are removed from the group through death, predation, or exclusion by other members.	**Stability and Change** Small changes in one part of a system might cause large changes in another part.

8-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:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Engaging in Argument from Evidence Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. **LS4.D: Biodiversity and Humans** 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. **ETS1.B: Developing Possible Solutions** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	**Stability and Change** Small changes in one part of a system might cause large changes in another part.

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. **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 Idea**	**Crosscutting Concepts**
Developing and Using Models Develop and use a model to describe phenomena.	**LS3.A: Inheritance of Traits** Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. **LS3.B: Variation of 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.

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:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop and use a model to describe phenomena.	**LS1.B: Growth and Development of Organisms** Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. **LS3.A: Inheritance of Traits** Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. **LS3.B: Variation of Traits** 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.

8-LS4-1. **Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.**		
Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers. **Assessment Boundary:** Assessment does not include the names of individual species or geological eras in the fossil record.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Analyze and interpret data to determine similarities and differences in findings.	**LS4.A: Evidence of Common Ancestry and Diversity** The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.	**Patterns** Graphs, charts, and images can be used to identify patterns in data.

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

Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events.	**LS4.A: Evidence of Common Ancestry and Diversity** Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.	**Patterns** Patterns can be used to identify cause-and-effect relationships.

8-LS4-3. Analyze data to compare patterns in the embryological development across multiple species to identify relationships not evident in the fully formed adult anatomy.

Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.

Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Analyzing and Interpreting Data Analyze displays of data to identify linear and nonlinear relationships.	**LS4.A: Evidence of Common Ancestry and Diversity** Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.	**Patterns** Graphs, charts, and images 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. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena.	**LS4.B: Natural Selection** 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.

8-LS4-5. Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms.		
Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information Gather, read, and 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.	**LS4.B: Natural Selection** In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.	**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:** Assessment does not include Hardy Weinberg calculations.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Use mathematical representations to support scientific conclusions and design solutions.	**LS4.C: Adaptation** Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.	**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-ESS1-4. Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.		
Clarification Statement: Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of Earth's major events could range from being very recent (such as the last Ice Age or the earliest fossils of *Homo sapiens*) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant volcanic eruptions. **Assessment Boundary:** Assessment does not include recalling the names of specific periods or epochs and events within them.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**ESS1.C: The History of Planet Earth** 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.	**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.

8-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth’s mineral, energy, and groundwater resources are the result of past and current geoscience processes.

Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**ESS3.A: Natural Resources** 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.

8-ESS3-2. **Analyze and interpret data to forecast future catastrophic events to inform the development of technologies to mitigate the effects of natural hazards.**		
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:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Analyze and interpret data to determine similarities and differences in findings.	**ESS3.B: Natural Hazards** 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.

8-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.*

Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Apply scientific principles to design an object, tool, process or system.	**ESS3.C: Human Impacts on Earth Systems** 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.	**Cause and Effect** Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.

8-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: None provided.

Science and Engineering Practice	Disciplinary Core Idea	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 a model for a phenomenon or a solution to a problem.	**ESS3.C: Human Impacts on Earth Systems** 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.

8-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.		
Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Asking Questions and Defining Problems Ask questions to identify and clarify evidence of an argument.	**ESS3.D: Global Climate Change** Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.	**Stability and Change** Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

6-8 Engineering Design Overview

At the middle school level, students learn to sharpen the focus of problems by precisely specifying criteria and constraints of successful solutions, considering not only what needs the problem is intended to meet, but also the larger context within which the problem is defined, including limits to possible solutions. Students can identify elements of different solutions and combine them to create new solutions. Students at this level are expected to use systematic methods to compare different solutions to see which best meet criteria and constraints, and to test and revise solutions several times in order to arrive at an optimal design.

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. *

Clarification Statement: None provided.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Asking Questions and Defining Problems Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	**ETS1.A: Defining and Delimiting Engineering Problems** The more precisely a design task’s criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.	

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. *		
Clarification Statement: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Engaging in Argument from Evidence Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	**ETS1.B: Developing Possible Solutions** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. *		
Clarification Statement: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Analyzing and Interpreting Data Analyze and interpret data to determine similarities and differences in findings.	**ETS1.B: Developing Possible Solutions** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. **ETS1.C: Optimizing the Design Solution** Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.	

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. *

Clarification Statement: None provided.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	**ETS1.B: Developing Possible Solutions** A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. Models of all kinds are important for testing solutions. **ETS1.C: Optimizing the Design Solution** The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	

High School Overview

High School Physical Sciences

There are four HS Physical Science core ideas: Matter and its Interactions (PS1); Motion and Stability: Forces and Interactions (PS2); Energy (PS3); Waves and Their Applications in Technologies for Information Transfer (PS4). These four core ideas are divided into 12 topics: Structure and Properties of Matter, Chemical Reactions, Nuclear Processes, Forces and Motion and Types of Interactions, Definitions of Energy, Conservation of Energy and Energy Transfer, the Relationship between Energy and Forces, Energy in Chemical Processes and Everyday Life, Wave Properties, Electromagnetic Radiation, and Information Technologies and Instrumentation. To meet the Physical Science performance expectations, students are expected to demonstrate proficiency in asking questions, developing and using models, analyzing data and using math to support claims, planning and carrying out investigations, using mathematical thinking, and constructing explanations and designing solutions, communicating scientific and technical information, engaging in argument from evidence and obtaining, evaluating and communicating information; and to use these practices to demonstrate their understanding of the core ideas. Performance expectations for PS1 include substructure of atoms, chemical reactions, energy changes, periodic properties, and radioactivity. Performance expectations for PS2 include forces and interactions, momentum, gravitational and electrostatic forces. Performance expectations for PS3 include system energy, energy flow, energy transfer, energy fields, and energy conversions. Performance expectations for PS4 include wave properties, wave interactions, electromagnetic radiation, and encoding and transmitting information. The crosscutting concepts of patterns that include energy and matter; stability and change; cause and effect; systems and system models; structure and function; and the influence of science, engineering and technology on society and the natural world are highlighted as organizing concepts for these disciplinary core ideas.

High School Life Sciences

There are four HS Life Sciences core ideas: From Molecules to Organisms: Structures and Processes (LS1); Ecosystems: Interactions, Energy, and Dynamics (LS2); Heredity: Inheritance and Variation of Traits (LS3); and Biological Evolution: Unity and Diversity (LS4). These four core ideas are divided into eight topics: Structure and Function, Matter and Energy, Inheritance and Variation of Traits, Matter and Energy in Organisms, Matter and Energy in Ecosystems, Interdependent Relationships in Ecosystems, Inheritance of and Variation of Traits, and Natural Selection and Evolution. To meet these performance expectations, students are expected to demonstrate proficiency in analyzing and interpreting data, constructing explanations and designing solutions, developing and using models, planning and carrying out investigations, using mathematical and computational thinking, engaging in argument, and obtaining, evaluating and communicating information; and to use these practices to demonstrate their understanding of the core ideas. Performance expectations for LS1 include the role of DNA in the essential functions of life through specialized cells; organization and function of interacting systems; role of feedback mechanisms in homeostasis, photosynthesis, carbon-based molecules, cellular respiration, and mitosis. Performance expectations for LS2 include carrying capacity, biodiversity and populations, cycling of matter and energy flow, roles of photosynthesis and cellular respiration, ecosystem stability, impacts of human activities on environment, and group behavior. The LS3 performance expectations include DNA/chromosomes, inheritable genetic variations and variation and distribution of expressed traits. The LS4 performance expectations include evidence of common ancestry, factors of evolution, heredity of advantageous traits, effect of environmental conditions on species and mitigate impacts of human activity on biodiversity. The crosscutting concepts of matter and energy, structure and function, and systems and system models, cause and effect, scale, proportion and quantity, and stability and change play an important role in students' understanding and are highlighted as organizing concepts for these core ideas.

High School Earth and Space Sciences

There are three HS Earth and Space Sciences core ideas: Earth's Place in the Universe (ESS1), Earth's Systems (ESS2), and Earth and Human Activity (ESS3). These three core ideas are divided into five topics: Space Systems, History of Earth, Earth's Systems, Weather and Climate, and Human Impacts. To meet these performance expectations, students are expected to demonstrate grade-appropriate proficiency in developing and using models; using mathematical and computational thinking; constructing explanations and designing solutions; and obtaining, evaluating, and communicating information. Performance expectations for ESS1 include life span of the sun, Big Bang theory, element production by stars, motion of orbiting objects, plate tectonics, and Earth's formation and early history. Performance expectations for ESS2 include Earth's internal and surface processes, Earth systems, thermal convection within the Earth, properties of water and its effects on Earth's materials, carbon cycling, coevolution of life and Earth's systems, energy flow, and climate. Performance expectations for ESS3 include future impacts of global climate change, impact of natural resources/hazards on human activities, evaluating competing designs for management of mineral and energy resources, natural resource management and sustainability, reducing human impact on natural systems, and how human activity modifies relationships among Earth systems. The crosscutting concepts of cause and effect; systems and system models; patterns; scale, proportion and quantity; structure and function; energy and matter; and stability and change are highlighted as organizing concepts for these disciplinary core ideas.

High School Engineering Design

There is one HS Engineering Design core idea: Engineering Design (ETS1). This core idea is divided into three topics: defining and delimiting engineering problems, developing solutions and optimizing design solutions. To meet these performance expectations, students are expected to demonstrate grade-appropriate proficiency in asking questions and defining problems, using mathematical and computational thinking, and constructing explanations and designing solutions. Performance expectations for ETS 1 include analyzing global challenges, designing solutions to real-world problems, evaluating solutions, and modeling the impacts of proposed solutions. The crosscutting concept of systems and system models is used as an organizing concept for these disciplinary core ideas.

Note While only a subset of science and engineering practices and crosscutting concepts are explicitly identified as the mechanism for how students demonstrate mastery at the end of instruction, students should still utilize all of the science and engineering practices and crosscutting concepts as they develop their understanding. See front matter for more information.

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.		
Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen. **Assessment Boundary:** Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Use a model to predict the relationships between systems or between components of a system.	**PS1.A: Structure and Properties of Matter** 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. **PS2.B: Types of Interactions** 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.	**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.

HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.

Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**PS1.A: Structure and Properties of Matter** The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **PS1.B: Chemical Reactions** 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.

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the macro and micro scale to infer the strength of electrical forces between particles.

Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.

Assessment Boundary: Assessment does not include Raoult’s law calculations of vapor pressure.

Science and Engineering Practice	Disciplinary Core Idea	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 and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time) and refine the design accordingly.	**PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **PS2.B: Types of Interactions** 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.	**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.

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.

Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS1.A: Structure and Properties of Matter** A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	**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.

HS-PS1-5. **Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.**		
Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules. **Assessment Boundary:** Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	**PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	**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.

HS-PS1-6.	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*	
Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products. **Assessment Boundary:** Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**PS1.B: Chemical Reactions** 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. **ETS1.C: Optimizing the Design Solution** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.

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

Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.

Assessment Boundary: Assessment does not include complex chemical reactions.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Using Mathematics and Computational Thinking Use mathematical representations of phenomena to support claims.	**PS1.B: Chemical Reactions** 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.

HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.		
Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations. **Assessment Boundary:** Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS1.C: Nuclear Processes** Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.	**Energy and Matter** In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

HS-PS2-1.	**Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.**	
Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force. **Assessment Boundary:** Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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 or determine an optimal design solution.	**PS2.A: Forces and Motion** 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.

HS-PS2-2. **Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.**		
Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle. **Assessment Boundary:** Assessment is limited to systems of two macroscopic bodies moving in one dimension.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Use mathematical representations of phenomena to describe explanations.	**PS2.A: Forces and Motion** 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 changes 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.

HS-PS2-3.	**Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.***	
Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute. **Assessment Boundary:** Assessment is limited to qualitative evaluations and/or algebraic manipulations.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.	**PS2.A: Forces and Motion** If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. **ETS1.A: Defining and Delimiting Engineering Problems** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. **ETS1.C: Optimizing the Design Solution** 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.	**Cause and Effect** Systems can be designed to cause a desired effect.

HS-PS2-4. **Use mathematical representations of Newton's law of gravitation and Coulomb's law to describe and predict the gravitational and electrostatic forces between objects.**		
Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields. **Assessment Boundary:** Assessment is limited to systems with two objects.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Use mathematical representations of phenomena to describe explanations.	**PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.	**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.

HS-PS2-5.	**Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.**	
Clarification Statement: None provided. **Assessment Boundary:** Assessment is limited to designing and conducting investigations with provided materials and tools.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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 and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**PS2.B: Types of Interactions** Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. **PS3.A: Definitions of Energy** "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.

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*

Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.

Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.

Science and Engineering Practice	Disciplinary Core Idea	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 orally, graphically, textually, and mathematically).	**PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **PS2.B: Types of Interactions** 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 new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions modeled in common phenomena.

Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Using Mathematics and Computational Thinking Create a computational model or simulation of a phenomenon, designed device, process, or system.	**PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. **PS3.B: Conservation of Energy and Energy Transfer** 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.	**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.

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects).		
Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS3.A: Definitions of Energy** 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 systems.

HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*		
Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency. **Assessment Boundary:** Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**PS3.A: Definitions of Energy** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. **PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. **ETS1.A: Defining and Delimiting Engineering Problems** 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.	**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.

HS-PS3-4.	**Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).**

Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.

Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.

Science and Engineering Practice	Disciplinary Core Idea	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 and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms— for example, to thermal energy in the surrounding environment.	**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.

HS-PS3-5. **Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.**		
Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other. **Assessment Boundary:** Assessment is limited to systems containing two objects.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed.	**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.

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the earth.

Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Using Mathematics and Computational Thinking Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.	**PS4.A: Wave Properties** 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.

HS-PS4-2. **Evaluate questions about the advantages 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:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Asking Questions and Defining Problems Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.	**PS4.A: Wave Properties** 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.	**Stability and Change** Systems can be designed for greater or lesser stability.

HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.

Assessment Boundary: Assessment does not include using quantum theory.

Science and Engineering Practice	Disciplinary Core Idea	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.	**PS4.A: Wave Properties** Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) **PS4.B: Electromagnetic Radiation** 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 models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

HS-PS4-4.	**Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.**	
Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias. **Assessment Boundary:** Assessment is limited to qualitative descriptions.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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.	**PS4.B: Electromagnetic Radiation** 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.	**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.

HS-PS4-5. **Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.***		
Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology. **Assessment Boundary:** Assessments are limited to qualitative information. Assessments do not include band theory.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information Communicate technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	**PS3.D: Energy in Chemical Processes** Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. **PS4.A: Wave Properties** Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. **PS4.B: Electromagnetic Radiation** Photoelectric materials emit electrons when they absorb light of a high-enough frequency. **PS4.C: Information Technologies and Instrumentation** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.	**Cause and Effect** Systems can be designed to cause a desired effect.

HS-LS1-1. **Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.**		
Clarification Statement: None provided. **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 Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions 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.	**LS1.A: Structure and Function** 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 cells.	**Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

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

Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, organism movement and behavioral response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.

Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.A: Structure and Function** Multicellular organisms have a hierarchical structural organization in which any one system is made up of numerous parts and is itself a component of the next level. **LS1.D: Information Processing** In a more complex organism, the systems become more complex to provide more input to allow for decision making regarding events around the organism. The organism begins to develop memories that motivate it to seek rewards and avoid punishments. The integration of the systems is important for the successful interpretation of inputs and generation of behaviors in response to them.	**Systems and System Models** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions— including energy, matter, and information flows—within and between systems at different scales.

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

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

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

Science and Engineering Practice	Disciplinary Core Idea	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 and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**LS1.A: Structure and Function** Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. **LS1.D: Information Processing** Some circuits give rise to emotions and memories that motivate organisms to seek rewards, avoid punishments, develop fears, or form attachments to members of their own species and, in some cases, to individuals of other species (e.g., mixed herds of mammals, mixed flocks of birds). The integrated functioning of all parts of the brain is important for successful interpretation of inputs and generation of behaviors in response to them.	**Stability and Change** Feedback (negative or positive) can stabilize or destabilize a system.

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

Clarification Statement: None provided.

Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.B: Growth and Development of Organisms** 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 models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales.

HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.		
Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models. **Assessment Boundary:** Assessment does not include specific biochemical steps.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.C: Organization for Matter and Energy Flow in Organisms** 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.

HS-LS1-6. **Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.**		
Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations. **Assessment Boundary:** Assessment does not include the details of the specific chemical reactions or identification of macromolecules.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS1.C: Organization for Matter and Energy Flow in Organisms** The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational 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.

HS-LS1-7.		**Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.**
Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration. **Assessment Boundary:** Assessment should not include identification of the steps or specific processes involved in cellular respiration.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.C: Organization for Matter and Energy Flow in Organisms** As matter and energy flow through different organizational 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 and another place, between objects and/or fields, or between systems.

HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.

Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Using Mathematics and Computational Thinking Use mathematical and/or computational representations of phenomena or design solutions to support explanations.	**LS2.A: Interdependent Relationships in Ecosystems** 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.	**Scale, Proportion, and Quantity** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

HS-LS2-2.	**Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.**	
Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data. **Assessment Boundary:** Assessment is limited to provided data.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Use mathematical representations of phenomena or design solutions to support and revise explanations.	**LS2.A: Interdependent Relationships in Ecosystems** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	**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.

HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.		
Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments. **Assessment Boundary:** Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** 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.

HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.		
Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem. **Assessment Boundary:** Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Use mathematical representations of phenomena or design solutions to support claims.	**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.	**Energy and Matter** Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.

HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.		
Clarification Statement: Examples of models could include simulations and mathematical models. **Assessment Boundary:** Assessment does not include the specific chemical steps of photosynthesis and respiration.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or components of a system.	**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** 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. **PS3.D: Energy in Chemical 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 models) can be used to simulate systems and interactions— including energy, matter, and information flows—within and between systems at different scales.

HS-LS2-6. Evaluate 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: None provided.

Science and Engineering Practice	Disciplinary Core Idea	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.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*		
Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and 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.	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. **LS4.D: Biodiversity and Humans** 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 through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. **ETS1.B: Developing Possible Solutions** 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.

HS-LS2-8. Evaluate evidence for the role of group behavior on individual and species' chances to survive and reproduce.		
Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Engaging in Argument from Evidence Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**LS2.D: Social Interactions and Group Behavior** 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.

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Clarification Statement: None provided.

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 Idea	Crosscutting Concepts
Asking Questions and Defining Problems Ask questions that arise from examining models or a theory to clarify relationships.	**LS1.A: Structure and Function** 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. **LS3.A: Inheritance of Traits** Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.

Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Engaging in Argument from Evidence Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.	**LS3.B: Variation of Traits** In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.		
Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits. **Assessment Boundary:** Assessment does not include Hardy-Weinberg calculations.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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.	**LS3.B: Variation of Traits** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**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).

HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Communicate scientific 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).	**LS4.A: Evidence of Common Ancestry and Diversity** Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.	**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.

HS-LS4-2.	**Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.**

Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.

Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions 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.	**LS4.B: Natural Selection** Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. **LS4.C: Adaptation** 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.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

HS-LS4-3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.

Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.

Science and Engineering Practice	Disciplinary Core Idea	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.	**LS4.B: Natural Selection** 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. **LS4.C: Adaptation** 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 of phenomena.

HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions 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.	**LS4.C: Adaptation** 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.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Clarification Statement: Emphasis is on determining cause-and-effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Engaging in Argument from Evidence Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**LS4.C: Adaptation** Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*		
Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Create or revise a simulation of a phenomenon, designed device, process, or system.	**LS4.C: Adaptation** Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. **LS4.D: Biodiversity and Humans** Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. **ETS1.B: Developing Possible Solutions** 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. Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

HS-ESS1-1. Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.		
Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11- year sunspot cycle, and non-cyclic variations over centuries. **Assessment Boundary:** Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**ESS1.A: The Universe and Its Stars** The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. **PS3.D: Energy in Chemical Processes and Everyday Life** Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.	**Scale, Proportion, and Quantity** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

HS-ESS1-2. Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.		
Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium). **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions 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.	**ESS1.A: The Universe and Its Stars** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. **PS4.B Electromagnetic Radiation** 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 - only moved between one place and another place, between objects and/or fields, or between systems.

HS-ESS1-3. Communicate scientific ideas about the way stars, over their life cycle, produce elements.		
Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime. **Assessment Boundary:** Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Obtaining, Evaluating, and Communicating Information Communicate scientific ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	**ESS1.A: The Universe and Its Stars** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.	**Energy and Matter** In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.		
Clarification Statement: Emphasis is on Newtonian gravitational laws and Kepler's Laws governing orbital motions, which apply to human-made satellites as well as planets and moons. **Assessment Boundary:** Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematical and Computational Thinking Use mathematical or computational representations of phenomena to describe explanations.	**ESS1.B: Earth and the Solar System** 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.	**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).

HS-ESS1-5. Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.

Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages of oceanic crust increasing 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 of the continental plate (a result of past plate interactions).

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Engaging in Argument from Evidence Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**ESS1.C: The History of Planet Earth** Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** 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. **PS1.C: Nuclear Processes** 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.	**Patterns** Empirical evidence is needed to identify patterns.

HS-ESS1-6. Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.		
Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.	**ESS1.C: The History of Planet Earth** 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. **PS1.C: Nuclear Processes** 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.

HS-ESS2-1. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).

Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**ESS2.A: Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.	**Stability and Change** Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.		
Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**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 or determine an optimal design solution.	**ESS2.A: Earth Materials and Systems** Earth's systems, being dynamic and interacting , cause feedback effects that can increase or decrease the original changes **ESS2.D: Weather and Climate** The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space.	**Stability and Change** Feedback (negative or positive) can stabilize or destabilize a system.

HS-ESS2-3. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.

Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**ESS2.A: Earth Materials and Systems** Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** 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. **PS4.A: Wave Properties** 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.

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.		
Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition. **Assessment Boundary:** Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Use a model to provide mechanistic accounts of phenomena.	**ESS1.B: Earth and the Solar System** Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. **ESS2.A: Earth Materials and Systems** The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. **ESS2.D: Weather and Climate** The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption,	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

	storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	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 and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**ESS2.C: The Roles of Water in Earth's Surface Processes** 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.

HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.		
Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Developing and Using Models Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**ESS2.D: Weather and Climate** 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** The total amount of energy and matter in closed systems is conserved.

HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth’s systems and life on Earth.

Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth’s other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth’s surface. Examples include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.

Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth’s other systems.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Engaging in Argument from Evidence Construct an oral and written argument or counterarguments based on data and evidence.	**ESS2.D: Weather and Climate** Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. **ESS2.E: Biogeology** The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth’s surface and the life that exists on it.	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions 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.	**ESS3.A: Natural Resources** Resource availability has guided the development of human society. **ESS3.B: Natural Hazards** 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.

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

Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	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).	**ESS3.A: Natural Resources** All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. **ETS1.B. Developing Possible Solutions** 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.	

HS-ESS3-3. Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.		
Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning. **Assessment Boundary:** Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Using Mathematics and Computational Thinking Create a computational model or simulation of a phenomenon, designed device, process, or system.	**ESS3.C: Human Impacts on Earth Systems** The sustainability of human societies and the 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 system changes are irreversible.

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*

Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ESS3.C: Human Impacts on Earth Systems** Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. **ETS1.B. Developing Possible Solutions** 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** Feedback (negative or positive) can stabilize or destabilize a system.

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).

Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Analyzing and Interpreting Data Analyze data using computational models in order to make valid and reliable scientific claims.	**ESS3.D: Global Climate Change** Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.	**Stability and Change** Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.

Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Using Mathematics and Computational Thinking Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.	**ESS2.D: Weather and Climate** Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. **ESS3.D: Global Climate Change** Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.	**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.

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. *

Clarification Statement: None provided.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Asking Questions and Defining Problems Analyze complex real-world problems by specifying criteria and constraints for successful solutions.	**ETS1.A: Defining and Delimiting Engineering Problems** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.	

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. *

Clarification Statement: None provided.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Constructing Explanations and Designing Solutions Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.C: Optimizing the Design Solution** 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.	

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. *		
Clarification Statement: None provided. **Assessment Boundary:** None provided.		
Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concepts**
Constructing Explanations and Designing Solutions Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.B: Developing Possible Solutions** 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.	

HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. *

Clarification Statement: None provided.

Assessment Boundary: None provided.

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concepts
Using Mathematics and Computational Thinking Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.	**ETS1.B: Developing Possible Solutions** Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.	**Systems and System Models** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions— including energy, matter, and information flows— within and between systems at different scales.

Appendix A: Writing and Review Teams

The writing team, composed of current science teachers, included representation from all regions of the state and represented both urban and rural areas. While these teachers taught a variety of courses and grade levels throughout their careers, the selected committee members were currently teaching courses related to the standards development process: physical science, life science, and earth and space science. Additionally, the selected writers served in many roles in their schools, science community and a wide variety of professional organizations. To ensure fidelity to the standards, the writing committee provided feedback at all stages of the development process. The writing and review committee members listed below represented Kentucky's best as evidenced by their countless qualifications.

Science Advisory Panel (AP) members

Freda Rigsby, Allen County
Andy Sherlock, Boone County
Stephanie Parrot, Madison County
Shannon Wells, Pulaski County
Gerald Brashear, Perry County
Gina Crider, Calloway County
Sarah Barker, Montgomery County
Mindy Crider, Christian County
Jillian Booth, Fort Thomas Independent
Denise Donahue, Murray State University
Jeanine Huss, Western Kentucky University
Carey Ruff, Kentucky State Parks
Robbie Sergent, Clark County
Kathleen Taft, Webster County
Claire Johnson, Fayette County
Asheley Hoskins, Perry County
Hallie Booth, Boone County
Brittany Rutledge, Jefferson County
Amanda Staggs, Bowling Green Independent
Amanda Ballman, Bath County
Robert Boram, Morehead State University
Brittany Wray, Kentucky Association of Environmental Education
Derek Stice, Edmonson County
Steven Martell, Henry County
Samantha Norris, Kenton County
Stephanie Harmon, Rockcastle County
Brandon Sumner, Knott County

Emaleigh Osborn, Marin County
Nancy Broyles, Paducah Independent
Cathy Sammons, Fayette County
Matthew Hayes, Grayson County
Justin McFadden, University of Louisville
Geoffrey Gearner, Morehead State University
Dan Pascucci, Bernheim Arboretum and Research Forest

Science Review Committee (RC) Members

Samuel Northern, Simpson County
Emily Barber, Bath County
Christina Morris, Christian County
Tanya Begley, Owsley County
Brian Womack, Warren County
Jamaal Stiles, Washington County
Devin Cherry, Owen County
Diane Gilb, Boone County
Diane Johnson, Morehead State University
Kim Yates, Northern Kentucky University
Denny Potter, Makers Mark Whiskey
Megan Schargorodski, Kentucky Mesonet
Lester Pesterfield, Kentucky Academy of Sciences