# Science Standards for Alaska

Proposed Draft Standards

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# Science Standards for Alaska

Proposed November 2, 2018

## Introduction

Science and technology have been essential to the people for Alaska in its past, its present, and will be increasingly important in the future. Providing a firm foundation in science education for all students in Alaska is a bright opportunity and essential challenge. The State's science content standards provide the foundation for defining what students should know and be able to do in terms of scientific knowledge and skills.

## Development Process

In October of 2017, the Alaska Department of Education and Early Development (DEED) began a statewide application process to identify teachers, principals, curriculum directors, science specialists, and other qualified individuals to serve as writers and reviewers and aid in the creation of new science content standards for the State of Alaska.

Out of the pool of applicants, 15 diverse professionals were selected based upon merit, to serve on the science content standards Writing Committee. An additional 15 individuals were chosen to review the writing committee's recommendations.

The Writing Committee was provided with the following charge:

- The Writing Committee will identify and review influential sets of science content standards (e.g., *Next Generation Science Standards*; standards for the NAEP, PISA, and TIMSS assessments; science standards from College Board and ACT; standards from other leading states; science standards from leading textbook publishers; and past science standards such as AAAS' *Project 2061*).
- The Writing Committee will identify, modify, write, and compile a recommended set of science content standards drawing on its members' expertise and review of relevant materials. Ideally, the Writing Committee will produce a set of content standards to guide curriculum and instruction in the state. In addition, the Writing Committee will provide recommendations regarding the state summative assessment in science.
- The Writing Committee will receive feedback from the Review Committee. Following review, the Writing Committee will make appropriate changes. The Writing Committee will send its recommended set of science content standards to the Alaska Department of Education and Early Development, which will review and send to the State Board.

In April of 2018, the first meeting of the Writing Committee was held in Anchorage. From this review, the team decided to use the *Next Generation Science Standards* (NGSS) as a basis for Alaska Science Standards due to its three-dimensional design, and focus on science for all students. The three-dimensional design provides students with a context for the content of science, how science knowledge is acquired and understood, and how the individual sciences are connected through concepts that have universal meaning across disciplines.

It was the committee's decision to shape the Alaska Science Standards around the NGSS, with a strong focus on relevance to Alaskan students and allow educators the flexibility to determine the best way to help students meet the standards, based on local needs.

Following the first meeting, Writing Committee suggestions were sent to Reviewers for questions and comments. The Writing Committee met again in June of 2018 to discuss reviewers' input and revise the standards based on the feedback received.

Subsequently the Writing Committee's revisions went back to the Review Committee for a second round of review. The Reviewers' comments were again presented to the Writing Committee in October of 2018.

In October of 2018, the Writing Committee met again, reviewed comments of the Review Team, and finalized recommendations regarding the Alaska Science Standards, to be submitted to the Alaska Board of Education for review and adoption.

## Relation of the Science Content Standards for Alaska and the NGSS

The Science Content Standards for Alaska are largely the same as the NGSS. The Writing Committee strongly supported the general architecture and approach of the NGSS, and made no changes to the scientific content. The revisions made by the Writing Committee included:

- Adding many examples of how the standards could be made more relevant for students in Alaska by showing applications of scientific principles and skills in an Alaskan context
- Rephrasing several content standards statements to make them clearer and/or more age-appropriate
- Fewer than a handful of NGSS content standards were combined, moved to a different grade, or deleted.

The Science Content Standards for Alaska contain two main parts: Performance Expectations and Foundational Statements. These are also found in the NGSS. In addition, the NGSS content standards have a third part, called "Connections" that provide information for how the science content standards are related to each other and to other widely-used content standards in reading, writing, and mathematics. The Writing Committee recommended not incorporating the Connections information as a part of the state-adopted science content standards because such connections are likely to change more rapidly than the science content standards. The Writing Committee endorsed DEED providing such information, along with other support materials as supplemental to the actual state science content standards.

# How to Read the Science Content Standards for Alaska[1]

The Science Content Standards for Alaska are distinct from prior science standards in three essential ways.

1) Performance. Prior standards documents listed what students should “know” or “understand.” These ideas needed to be translated into performances that could be assessed to determine whether or not students met the standard. Different interpretations sometimes resulted in assessments that were not aligned with curriculum and instruction. The Science Content Standards for Alaska has avoided this difficulty by developing performance expectations that state what students should be able to do in order to demonstrate that they have met the standard, thus providing the same clear and specific targets for curriculum, instruction, and assessment.
2) Foundations. Each performance expectation incorporates all three dimensions from the Framework— a science or engineering practice, a core disciplinary idea, and a crosscutting concept.
3) Coherence. Each set of performance expectations lists connections to other ideas within the disciplines of science and engineering, and with Common Core State Standards in Mathematics and English Language Arts.

This chapter describes how these three unique characteristics are embodied in the format of the standards, beginning with the “system architecture.”

[1] This section paraphrases and quotes extensively from NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press.

## System Architecture


As shown in the illustration at right, each set of performance expectations has a title. Below the title is a box containing the performance expectations. Below that are three foundation boxes, which list (from left to right) the specific science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) that were combined to produce the performance expectations (PEs) above. These sections are described in further detail below.

## Performance Expectations

Performance expectations are the assessable statements of what students should know and be able to do. All students should be held accountable for demonstrating their achievement of all PEs, which are written to allow for multiple means of assessment.

The NGSS writers initially attempted to include all of the disciplinary core ideas (DCIs) verbatim from the Framework in the performance expectations, but found that the resulting statements were bulky and reduced readers’ comprehension of the standards. Instead, the performance expectations were written to communicate a “big idea” that combined content from the three foundation boxes. In the final phase of development NGSS writers further limited the number of performance expectations with input from the NGSS state teams, to ensure that this set of PEs is achievable at some reasonable level of proficiency by the vast majority of students.

The Science Content Standards for Alaska are for all students, and all students are expected to achieve proficiency with respect to all of the performance expectations in the Alaska standards.

A second essential point is that the Science Content Standards for Alaska should not limit the curriculum. Students interested in pursuing science further (through Advanced Placement or other advanced courses) should have the opportunity to do so. The Science Content Standards for Alaska provide a foundation for rigorous advanced courses in science or engineering that some students may choose to take.

A third point is that the Science Content Standards for Alaska are not a set of instructional or assessment tasks. They are statements of what students should be able to do after instruction. Decisions on how best to help students meet these PEs are left to states, districts, and teachers.

In the example below, notice how the performance expectation combines the skills and ideas that students need to learn, while it suggests ways of assessing whether or not third graders have the capabilities and understandings specified in the three foundation boxes.

**3-PS2-1**

**Students who demonstrate understanding can:**
Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

**Clarification Statement:** Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.

**Assessment Boundary:** Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. | **PS2.A: Forces and Motion**<br>• Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. | **Cause and Effect**<br>• Cause and effect relationships are routinely identified. |

As in this example, statements where the performance expectation is followed by an asterisk * indicate content standards especially appropriate to make connections with engineering and technology.

As shown in the example, most of the performance expectations are followed by one or two additional statements in smaller type. These include clarification statements, which supply examples or additional clarification to the performance expectations; and assessment boundary statements, which specify the limits to large scale assessment.

The codes for the performance expectations were derived from the Framework. As with the titles, the first digit indicates a grade K-5, or specifies MS (middle school) or HS (high school). The next alpha-numeric code specifies the discipline, core idea and sub-idea. All of these codes are shown in the table below, derived from the Framework. Finally, the number at the end of each code indicates the order in which that statement appeared as a DCI in the Framework.

| Physical Science | Life Science | Earth and Space Science |
|---|---|---|
| PS1 Matter and Its Interactions | LS1 From Molecules to Organisms: Structures and Processes | ESS1 Earth's Place in the Universe |
| PS1A Structure and Properties of matter | LS1A Structure and Function | ESS1A The Universe and Its Stars |
| PS1B Chemical Reactions | LS1B Growth and Development of Organisms | ESS1B Earth and the Solar System |
| PS1C Nuclear Processes | LS1C Organization for Matter and Energy Flow in Organisms | ESS1C The History of Planet Earth |
| PS2 Motion and Stability: Forces and Interactions | LS1D Information Processing | ESS2 Earth's Systems |
| | | ESS2A Earth Materials and Systems |

| Physical Science | Life Science | Earth and Space Science |
| --- | --- | --- |
| PS2A Forces and Motion PS2B Types of Interactions<br><br>PS2C Stability and Instability in Physical Systems<br><br>PS3 Energy<br><br>PS3A Definitions of Energy<br><br>PS3B Conservation of Energy and Energy Transfer<br><br>PS3C Relationship Between Energy and Forces<br><br>PS3D Energy and Chemical Processes in Everyday Life<br><br>PS4 Waves and Their Applications in Technologies for Information Transfer<br><br>PS4 Waves and Their Applications in Technologies for Information Transfer<br><br>PS4A Wave Properties<br>PS4B Electromagnetic Radiation<br><br>PS4C Information Technologies and Instrumentation | LS2 Ecosystems: Interactions, Energy, and Dynamics<br><br>LS2A Interdependent Relationships in Ecosystems<br><br>LS2B Cycles of Matter and Energy Transfer in Ecosystems<br><br>LS2C Ecosystem Dynamics, Functioning, and Resilience<br><br>LS2D Social Interactions and Group Behavior<br><br>LS3 Heredity: Inheritance and Variation of Traits<br><br>LS3A Inheritance of Traits<br><br>LS3B Variation of Traits<br><br>LS4 Biological Evolution: Unity and Diversity<br><br>LS4A Evidence of Common Ancestry<br><br>LS4B Natural Selection<br><br>LS4C Adaptation<br><br>LS4D Biodiversity and Humans | ESS2B Plate Tectonics and Large-Scale System Interactions<br><br>ESS2C The Roles of Water in Earth's Surface Processes<br><br>ESS2D Weather and Climate<br><br>ESS2E Biogeology<br><br>ESS3 Earth and Human Activity<br><br>ESS3A Natural Resources ESS3B Natural Hazards<br><br>ESS3C Human Impacts on Earth Systems<br><br>ESS3D Global Climate Change |

## Foundation Boxes

While the performance expectations can stand alone, a more coherent and complete view of what students should be able to do comes when the performance expectations are viewed in tandem with the contents of the foundation boxes that lie just below the performance expectations. These three boxes include the practices, core disciplinary ideas, and crosscutting concepts, derived from the Framework, that were used to construct this set of performance expectations.

**Disciplinary Core Ideas (DCIs).** The orange box in the middle includes statements that are taken from the Framework about the most essential ideas in the major science disciplines that all students should understand during 13 years of school. Including these detailed statements was very helpful to the NGSS writing team as they analyzed and “unpacked” the disciplinary core ideas and sub-ideas to reach a level that is helpful in describing what each student should understand about each sub-idea at the end of grades 2, 5, 8, and 12. Although they appear in paragraph form in the Framework, here they are bulleted to be certain that each statement is distinct.

**Science and Engineering Practices (SEPs).** The blue box on the left includes just the science and engineering practices used to construct the performance expectations in the box above. These statements are derived from and grouped by the eight categories detailed in the Framework to further explain the science and engineering practices important to emphasize in each grade band. Most sets of performance expectations emphasize only a few of the practice categories; however, all practices are emphasized within a grade band. Teachers should be encouraged to utilize several practices in any instruction, and need not be limited by the performance expectation, which is only intended to guide assessment. The SEPs are discussed more in Appendix A.

**Crosscutting Concepts (CCCs).** The green box on the right includes statements derived from the Framework’s list of crosscutting concepts, which apply to one or more of the performance expectations in the box above. Most sets of PEs limit the number of crosscutting concepts so as focus on those that are readily apparent when considering the DCIs. However, all are emphasized within a grade band. Again, the list is not exhaustive nor is it intended to limit instruction. The CCCs are discussed more in Appendix B.

**Title.** The organization of the Science Content Standards for Alaska is based on the core ideas in the major fields of natural science from A Framework for K-12 Science Education (NRC 2012), plus one set of PEs for engineering. For the elementary level, from Kindergarten to grade five, sets of performance expectations are assigned to specific grades. A numeral at the start of a title indicates the grade level; so the title in the example above identifies a content standard for grade 3. Titles for middle school (grades 6-8) standards begin with “MS” and those for high school standards (grades 9-12) begin with “HS.”

The titles also reveal the organization of the standards, which is based on the core ideas in the disciplines from the Framework. The Framework lists 11 core ideas, four in life science, four in physical science, and three in Earth and Space Science. The core ideas are divided into a total of 39 sub-ideas, and each sub-idea is elaborated in a list of what students should understand about that sub-idea at the end of grades 2, 5, 8, and 12. We have called these grade-specific statements Disciplinary Core Ideas (DCIs).

At the beginning of the process, the NGSS writers examined all of the DCIs in the Framework to eliminate redundant statements, find natural connections among DCIs, and develop PEs that were appropriate for the different grade levels. The result was a topical clustering of DCIs that usually, but did not always correspond to the core ideas identified in the Framework. This structure provided the original basis of the standards and has continued through the process. The Science Content Standards for Alaska have been presented in this topic organization.

# KINDERGARTEN

The performance expectations in kindergarten help students formulate answers to questions such as: “What happens if you push or pull an object harder? Where do animals live and why do they live there? What is the weather like today and how is it different from yesterday?” Kindergarten performance expectations include PS2, PS3, LS1, ESS2, ESS3, and ETS1

Disciplinary Core Ideas from the NRC Framework. 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 are able to 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 are also 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; cause and effect; systems and system models; interdependence of science, engineering, and technology; and influence of engineering, technology, and science on society and the natural world are called out as organizing concepts for these disciplinary core ideas. In 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 understanding of the core ideas.

## K. Forces and Interactions: Pushes and Pulls

**Students who demonstrate understanding can:**

**K-PS2-1** **Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.** [Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.] [*Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.*]

**K-PS2-2** **Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.*.** [Clarification Statement: Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.] [*Assessment Boundary: Assessment does not include friction as a mechanism for change in speed.*]

## K-PS2-1

**Students who demonstrate mastery can:**
Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

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

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Planning and Carrying Out Investigations<br>With guidance, plan and conduct an investigation in collaboration with peers. | **PS2.A: Forces and Motion**<br>• Pushes and pulls can have different strengths and directions.<br>• Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.<br>**PS2.B: Types of Interactions**<br>• When objects touch or collide, they push on one another and can change motion.<br>**PS3.C: Relationship Between Energy and Forces**<br>• A bigger push or pull makes things speed up or slow down more quickly. *(secondary)* | **Cause and Effect**<br>• Simple tests can be designed to gather evidence to support or refute student ideas about causes. |

## K-PS2-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Analyzing and Interpreting Data<br>• Analyze data from tests of an object or tool to determine if it works as intended. | **PS2.A: Forces and Motion**<br>• Pushes and pulls can have different strengths and directions.<br>• Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.<br>**ETS1.A: Defining Engineering Problems**<br>• 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. *(secondary)* | **Cause and Effect**<br>• Simple tests can be designed to gather evidence to support or refute student ideas about causes. |

## K. Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment

**Students who demonstrate understanding can:**

**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 do not; the different kinds of food needed by different types of animals; the requirement of plants to have light; and, that all living things need water.]

**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 a squirrel digs in the ground to hide its food and tree roots can break concrete, or local plant and animal observations.]

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

**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 trees to produce paper and using resources to produce bottles. Examples of solutions could include reusing paper and recycling cans and bottles.]

# K-LS1-1

**Students who demonstrate mastery can:**
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 do not; the different kinds of food needed by different types of animals; the requirement of plants to have light; and, that all living things need water.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Analyzing and Interpreting Data<br>• Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions.<br><br>Connections to Nature of Science<br><br>Scientific Knowledge is Based on Empirical Evidence<br>• Scientists look for patterns and order when making observations about the world | **LS1.C: Organization for Matter and Energy Flow in Organisms**<br>• 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**<br>• Patterns in the natural and human designed world can be observed and used as evidence. |

# K-ESS2-2

**Students who demonstrate understanding can:**
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 a squirrel digs in the ground to hide its food and tree roots can break concrete, or local plant and animal observations.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Engaging in Argument from Evidence**<br>• Construct an argument with evidence to support a claim. | **ESS2.E: Biogeology**<br>• Plants and animals can change their environment.<br>**ESS3.C: Human Impacts on Earth Systems**<br>• 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. *(secondary)* | **Systems and System Models**<br>• Systems in the natural and designed world have parts that work together. |

## K-ESS3-1

**Students who demonstrate understanding can:**
Use a model to represent the relationship between the needs of different plants and 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. Explain the characteristics of the model and the relationships.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Developing and Using Models<br>• Use a model to represent relationships in the natural world. | **ESS3.A: Natural Resources**<br>• 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**<br>• Systems in the natural and designed world have parts that work together. |

# K-ESS3-3

**Students who demonstrate understanding can:**
Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.*

**Clarification Statement**: Examples of human impact on the land could include cutting trees to produce paper and using resources to produce bottles. Examples of solutions could include reusing paper and recycling cans and bottles.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Obtaining, Evaluating, and Communicating Information<br>• 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**<br>• 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.<br>**ETS1.B: Developing Possible Solutions**<br>• 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. *(secondary)* | **Cause and Effect**<br>• Events have causes that generate observable patterns. |

## K. Weather and Climate

**Students who demonstrate understanding can:**

**K-PS3-1** **Make observations to determine the effect of sunlight on Earth's surface.** [Clarification Statement: Local observation of duration of sunlight. 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.*]

**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. Explain the characteristics of the structure and their effect on the temperature.]

**K-ESS2-1** **Use and share observations of local weather conditions to describe patterns over time.** [Clarification Statement: Examples of qualitative observations could include descriptions of the weather (such as sunny, cloudy, rainy, and warm); examples of quantitative observations could include numbers of sunny, windy, and rainy days in a month. Examples of patterns could include that it is usually cooler in the morning than in the afternoon and the number of sunny days versus cloudy days in different months.] [*Assessment Boundary: Assessment of quantitative observations limited to whole numbers and relative measures such as warmer/cooler.*]

**K-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.]

# K-PS3-1

**Students who demonstrate understanding can:**
Make observations to determine the effect of sunlight on Earth's surface.

**Clarification Statement:** Local observation of duration of sunlight. 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Planning and Carrying Out Investigations<br>• Make observations (firsthand or from media) to collect data that can be used to make comparisons.<br><br>**Connections to Nature of Science**<br><br>**Scientific Investigations Use a Variety of Methods**<br>• Scientists use different ways to study the world. | **PS3.B: Conservation of Energy and Energy Transfer**<br>• Sunlight warms Earth's surface. | **Cause and Effect**<br>• Events have causes that generate observable patterns. |

## K-PS3-2

**Students who demonstrates understanding can:**
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. Explain the characteristics of the structure and their effect on the temperature.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Constructing Explanations and Designing Solutions<br>• 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**<br>• Sunlight warms Earth's surface. | **Cause and Effect**<br>• Events have causes that generate observable patterns. |

## K-ESS2-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Analyzing and Interpreting Data<br>• Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions.<br><br>Connections to Nature of Science<br><br>Science Knowledge is Based on Empirical Evidence<br>• Scientists look for patterns and order when making observations about the world. | **ESS2.D: Weather and Climate**<br>• Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. | **Patterns**<br>• Patterns in the natural world can be observed, used to describe phenomena, and used as evidence. |

# K-ESS3-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Asking Questions and Defining Problems<br>• Ask questions based on observations to find more information about the designed world.<br>Obtaining, Evaluating, and Communicating Information<br>• Read grade-appropriate texts and/or use media to obtain scientific information to describe patterns in the natural world. | **ESS3.B: Natural Hazards**<br>• 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.<br>**ETS1.A: Defining and Delimiting an Engineering Problem**<br>• Asking questions, making observations, and gathering information are helpful in thinking about problems. *(secondary)* | **Cause and Effect**<br>• Events have causes that generate observable patterns.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Interdependence of Science, Engineering, and Technology**<br>• People encounter questions about the natural world every day.<br>**Influence of Engineering, Technology, and Science on Society and the Natural World**<br>• People depend on various technologies in their lives; human life would be very different without technology. |

# K-2.Engineering Design

**Students who demonstrate understanding can:**

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

**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.** [Clarifying Statement: Explain how the model functions to solve the problem.]

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

## K-2-ETS1-1

**Students who demonstrate understanding can:**

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Asking Questions and Defining Problems<br>• Ask questions based on observations to find more information about the natural and/or designed world(s).<br>• 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**<br>• A situation that people want to change or create can be approached as a problem to be solved through engineering.<br>• Asking questions, making observations, and gathering information are helpful in thinking about problems.<br>• Before beginning to design a solution, it is important to clearly understand the problem. | |

# K-2-ETS1-2

**Students who demonstrate understanding can:**
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.

**Clarifying Statement:** Explain how the model functions to solve the problem.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Developing and Using Models<br>• Develop a simple model based on evidence to represent a proposed object or tool. | **ETS1.B: Developing Possible Solutions**<br>• 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**<br>• The shape and stability of structures of natural and designed objects are related to their function(s). |

# K-2-ETS1-3

**Students who demonstrate understanding can:**
Analyze and discuss data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

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

# FIRST GRADE

The performance expectations in first grade help students formulate answers to questions such as: "What happens when materials vibrate? What happens when there is no light? What are some ways plants and animals meet their needs so that they can survive and grow? How are parents and their children similar and different? What objects are in the sky and how do they seem to move?" First grade performance expectations include PS4, LS1, LS3, and ESS1

Disciplinary Core Ideas from the NRC Framework. 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 are also 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. Students are able to observe, describe, and predict some patterns of the movement of objects in the sky.

The crosscutting concepts of patterns; cause and effect; structure and function; and influence of engineering, technology, and science on society and the natural world are called out as organizing concepts for these disciplinary core ideas. In 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 understanding of the core ideas.

## 1. Waves: Light and Sound

**Students who demonstrate understanding can:**

**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 or a person making a hunting call.]

**1-PS4-2** **Make observations to construct an evidence-based account that objects in darkness 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.]

**1-PS4-3** **Plan and conduct investigations 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.*]

**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. Explain how the device works.] [*Assessment Boundary: Assessment does not include technological details for how communication devices work.*]

## 1-PS4-1

**Students who demonstrate understanding can:**
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 or a person making a hunting call.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Planning and Carrying Out Investigations<br>• Plan and conduct investigations collaboratively to produce evidence to answer a question.<br><br>Connections to Nature of Science<br><br>Scientific Investigations Use a Variety of Methods<br>• Science investigations begin with a question.<br>• Scientists use different ways to study the world. | **PS4.A: Wave Properties**<br>• Sound can make matter vibrate, and vibrating matter can make sound. | **Cause and Effect**<br>• Simple tests can be designed to gather evidence to support or refute student ideas about causes. |

## 1-PS4-2

**Students who demonstrate understanding can:**
Make observations to construct an evidence-based account that objects in darkness 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Constructing Explanations and Designing Solutions<br>• Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. | **PS4.B: Electromagnetic Radiation**<br>• Objects can be seen if light is available to illuminate them or if they give off their own light. | **Cause and Effect**<br>• Simple tests can be designed to gather evidence to support or refute student ideas about causes. |

## 1-PS4-3

**Students who demonstrate understanding can:**
Plan and conduct investigations 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Planning and Carrying Out Investigations<br>• Plan and conduct investigations collaboratively to produce evidence to answer a question. | **PS4.B: Electromagnetic Radiation**<br>• 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**<br>• Simple tests can be designed to gather evidence to support or refute student ideas about causes. |

## 1-PS4-4

**Students who demonstrate understanding can:**
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. Explain how the device works.

**Assessment Boundary:** Assessment does not include technological details for how communication devices work.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Constructing Explanations and Designing Solutions<br>• Use tools and materials provided to design a device that solves a specific problem. | **PS4.C: Information Technologies and Instrumentation**<br>• People also use a variety of devices to communicate (send and receive information) over long distances. | **Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Engineering, Technology, and Science, on Society and the Natural World**<br>• People depend on various technologies in their lives; human life would be very different without technology. |

# 1. Structure, Function, and Information Processing

**Students who demonstrate understanding can:**

**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 (e.g., protective helmets), acorn shells, mollusks, and animal scales; stabilizing structures by mimicking animal tails and roots on plants; keeping out intruders by mimicking thorns on branches and animal quills; detecting intruders by mimicking eyes and ears; use of camouflage, or tools such as snowshoes. Explain how the solution solves the problem described.]

**1-LS1-2** **Read texts and use media to determine patterns in behavior of parents and offspring that help offspring survive.** [Clarification Statement: Examples of patterns of behaviors could include the signals that offspring make (such as crying, cheeping, and other vocalizations) and the responses of the parents (such as feeding, comforting, and protecting the offspring).]

**1-LS3-1** **Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.** [Clarification Statement: Examples of patterns could include features plants or animals share. Examples of observations could include leaves from the same kind of plant are the same shape but can differ in size; and, a particular breed of dog looks like its parents but is not exactly the same.] [*Assessment Boundary: Assessment does not include inheritance or animals that undergo metamorphosis or hybrids.*]

## 1-LS1-1

**Students who demonstrate understanding can:**
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 (e.g., protective helmets), acorn shells, mollusks, and animal scales; stabilizing structures by mimicking animal tails and roots on plants; keeping out intruders by mimicking thorns on branches and animal quills; detecting intruders by mimicking eyes and ears; use of camouflage, or tools such as snowshoes. Explain how the solution solves the problem described.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Constructing Explanations and Designing Solutions<br>• Use materials to design a device that solves a specific problem or a solution to a specific problem. | **LS1.A: Structure and Function**<br>• 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.<br>**LS1.D: Information Processing**<br>• 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**<br>• The shape and stability of structures of natural and designed objects are related to their function(s).<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Science, Engineering and Technology on Society and the Natural World**<br>• Every human-made product is designed by applying some knowledge of the natural world and is built using materials derived from the natural world. |

# 1-LS1-2

**Students who demonstrate understanding can:**
Read texts and use media to determine patterns in behavior of parents and offspring that help offspring survive.

**Clarification Statement:** Examples of patterns of behaviors could include the signals that offspring make (such as crying, cheeping, and other vocalizations) and the responses of the parents (such as feeding, comforting, and protecting the offspring).

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Obtaining, Evaluating, and Communicating Information<br>• Read grade-appropriate texts and use media to obtain scientific information to determine patterns in the natural world.<br><br>Connections to Nature of Science<br><br>Scientific Knowledge is Based on Empirical Evidence<br>• Scientists look for patterns and order when making observations about the world. | **LS1.B: Growth and Development of Organisms**<br>• 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**<br>• Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. |

## 1-LS3-1

**Students who demonstrate understanding can:**
Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.

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

**Assessment Boundary**: Assessment does not include inheritance or animals that undergo metamorphosis or hybrids.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Constructing Explanations and Designing Solutions<br>• Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. | **LS3.A: Inheritance of Traits**<br>• Young animals are very much, but not exactly like, their parents. Plants also are very much, but not exactly, like their parents.<br>**LS3.B: Variation of Traits**<br>• Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways. | **Patterns**<br>• Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. |

# 1. Space Systems: Patterns and Cycles

**Students who demonstrate understanding can:**

**1-ESS1-1** **Use observations of the sun, moon, stars, and tides 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. Students not required to know the mechanisms that control tides*]

**1-ESS1-2** **Make and graph observations at different times of year to relate the amount of daylight to the time of year, and graph findings.** [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.*]

## 1-ESS1-1

**Students who demonstrate understanding can:**
Use observations of the sun, moon, stars, and tides 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. Students not required to know the mechanisms that control tides.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Analyzing and Interpreting Data<br>• 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**<br>• Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. | **Patterns**<br>• Patterns in the natural world can be observed, used to describe phenomena, and used as evidence.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Science assumes natural events happen today as they happened in the past.<br>• Many events are repeated. |

## 1-ESS1-2

**Students who demonstrate understanding can:**
Make and graph observations at different times of year to relate the amount of daylight to the time of year, and graph findings.

**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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Planning and Carrying Out Investigations<br>• Make observations (firsthand or from media) to collect data that can be used to make comparisons. | **ESS1.B: Earth and the Solar System**<br>• Seasonal patterns of sunrise and sunset can be observed, described, and predicted. | **Patterns**<br>• Patterns in the natural world can be observed, used to describe phenomena, and used as evidence. |

# SECOND GRADE

The performance expectations in second grade help students formulate answers to questions such as: "How does land change and what are some things that cause it to change? What are the different kinds of land and bodies of water? How are materials similar and different from one another, and how do the properties of the materials relate to their use? What do plants need to grow? How many types of living things live in a place?" Second grade performance expectations include PS1, LS2, LS4, ESS1, ESS2, and ETS1

Disciplinary Core Ideas from the NRC Framework. 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 are also 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 analysis and classification of different materials. Students are able to 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 are able to 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.

The crosscutting concepts of patterns; cause and effect; energy and matter; structure and function; stability and change; and influence of engineering, technology, and science on society and the natural world are called out as organizing concepts for these disciplinary core ideas. In the 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 understanding of the core ideas.

## 2. Structure and Properties of Matter

**Students who demonstrate understanding can:**

**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.]

**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.*]

**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.]

**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 burning wood.]

## 2-PS1-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Planning and Carrying Out Investigations<br>Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. | **PS1.A: Structure and Properties of Matter**<br>• 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**<br>• Patterns in the natural and human designed world can be observed. |

## 2-PS1-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Analyzing and Interpreting Data<br>• Analyze data from tests of an object or tool to determine if it works as intended. | **PS1.A: Structure and Properties of Matter**<br>• Different properties are suited to different purposes. | **Cause and Effect**<br>• Simple tests can be designed to gather evidence to support or refute student ideas about causes.<br><br>***Connections to Engineering, Technology, and Applications of Science***<br><br>**Influence of Engineering, Technology, and Science, on Society and the Natural World**<br>• Every human-made product is designed by applying some knowledge of the natural world and is built using materials derived from the natural world. |

## 2-PS1-3

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Constructing Explanations and Designing Solutions<br>• Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. | **PS1.A: Structure and Properties of Matter**<br>• Different properties are suited to different purposes.<br>• A great variety of objects can be built up from a small set of pieces. | **Energy and Matter**<br>• Objects may break into smaller pieces and be put together into larger pieces, or change shapes. |

## 2-PS1-4

**Students who demonstrate understanding can:**
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 burning wood.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Engaging in Argument from Evidence<br>• Construct an argument with evidence to support a claim.<br><br>Connections to Nature of Science<br><br>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena<br>• Science searches for cause and effect relationships to explain natural events. | **PS1.B: Chemical Reactions**<br>• 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**<br>• Events have causes that generate observable patterns. |

## 2. Interdependent Relationships in Ecosystems

**Students who demonstrate understanding can:**

**2-LS2-1** **Plan and conduct an investigation to determine if plants need sunlight and water to grow.** [*Assessment Boundary: Assessment is limited to testing one variable at a time.*]

**2-LS2-2** **Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants.*.** [Clarification Statement: Examples can include those components that mimic the natural structure of an animal that helps it disperse seeds (e.g., hair that snares seeds, squirrel cheek pouches that transport seeds) or that mimic the natural structure of an animal that helps it pollinate plants (e.g., bees have fuzzy bodies to which pollen sticks, hummingbirds have bills that transport pollen). Explain how the model disperses seeds or pollinates plants.]

**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.*]

## 2-LS2-1

**Students who demonstrate understanding can:**
Plan and conduct an investigation to determine if plants need sunlight and water to grow.

**Assessment Boundary***:* Assessment is limited to testing one variable at a time.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Planning and Carrying Out Investigations<br>• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. | **LS2.A: Interdependent Relationships in Ecosystems**<br>• Plants depend on water and light to grow. | **Cause and Effect**<br>• Events have causes that generate observable patterns. |

## 2-LS2-2

**Students who demonstrate understanding can:**
Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants.*.

**Clarification Statement:** Examples can include those components that mimic the natural structure of an animal that helps it disperse seeds (e.g., hair that snares seeds, squirrel cheek pouches that transport seeds) or that mimic the natural structure of an animal that helps it pollinate plants (e.g., bees have fuzzy bodies to which pollen sticks, hummingbirds have bills that transport pollen). Explain how the model disperses seeds or pollinates plants.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Developing and Using Models<br>• Develop a simple model based on evidence to represent a proposed object or tool. | **LS2.A: Interdependent Relationships in Ecosystems**<br>• Plants depend on animals for pollination or to move their seeds around.<br>**ETS1.B: Developing Possible Solutions**<br>• 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. *(secondary)* | **Structure and Function**<br>• The shape and stability of structures of natural and designed objects are related to their function(s). |

## 2-LS4-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| Planning and Carrying Out Investigations<br>• Make observations (firsthand or from media) to collect data which can be used to make comparisons.<br><br>Connections to Nature of Science<br><br>Scientific Knowledge is Based on Empirical Evidence<br>• Scientists look for patterns and order when making observations about the world. | **LS4.D: Biodiversity and Humans**<br>• There are many different kinds of living things in any area, and they exist in different places on land and in water. | |

## 2. Earth's Systems: Processes that Shape the Earth

**Students who demonstrate understanding can:**

**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, earthquakes, tsunamis, avalanches, and landslides, which happen quickly and events such as erosion of rocks and movement of glaciers, which occur slowly.] [*Assessment Boundary: Assessment does not include quantitative measurements of timescales.*]

**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. Discuss the solutions for controlling erosion.]

**2-ESS2-2** **Develop a model to represent the shapes and kinds of land and bodies of water in an area.** **[**Clarifying Statement: Discuss the features of the models.] [*Assessment Boundary: Assessment does not include quantitative scaling in models.*]

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

## 2-ESS1-1

**Students who demonstrate understanding can:**
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, earthquakes, tsunamis, avalanches, and landslides, which happen quickly and events such as erosion of rocks and movement of glaciers, which occur slowly.

**Assessment Boundary:** Assessment does not include quantitative measurements of timescales.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• Make observations from several sources to construct an evidence-based account for natural phenomena. | **ESS1.C: The History of Planet Earth**<br>• Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe. | **Stability and Change**<br>• Things may change slowly or rapidly. |

## 2-ESS2-1

**Students who demonstrate understanding can:**
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.  Discuss the solutions for controlling erosion.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• Compare multiple solutions to a problem. | **ESS2.A: Earth Materials and Systems**<br>• Wind and water can change the shape of the land.<br>**ETS1.C: Optimizing the Design Solution**<br>• Because there is always more than one possible solution to a problem, it is useful to compare and test designs. *(secondary)* | **Stability and Change**<br>• Things may change slowly or rapidly.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Engineering, Technology, and Science on Society and the Natural World**<br>• Developing and using technology has impacts on the natural world.<br><br>**Connections to Nature of Science**<br><br>**Science Addresses Questions About the Natural and Material World**<br>• Scientists study the natural and material world. |

## 2-ESS2-2

**Develop a model to represent the shapes and kinds of land and bodies of water in an area.** **[**Clarifying Statement: Discuss the features of the models.] [*Assessment Boundary: Assessment does not include quantitative scaling in models.*]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model to represent patterns in the natural world. | **ESS2.B: Plate Tectonics and Large-Scale System Interactions**<br>• Maps show where things are located. One can map the shapes and kinds of land and water in any area. | **Patterns**<br>• 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>• 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**<br>• Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. | **Patterns**<br>• Patterns in the natural world can be observed. |

# THIRD GRADE

The performance expectations in third grade help students formulate answers to questions such as: "What is typical weather in different parts of the world and during different times of the year? How can the impact of weather-related hazards be reduced? How do organisms vary in their traits? How are plants, animals, and environments of the past similar or different from current plants, animals, and environments? What happens to organisms when their environment changes? How do equal and unequal forces on an object affect the object? How can magnets be used?" Third grade performance expectations include PS2, LS1, LS2, LS3, LS4, ESS2, and ESS3

Disciplinary Core Ideas from the NRC Framework. Students are able to organize and use data to describe typical weather conditions expected during a particular season. By applying their understanding of weather-related hazards, students are able to make a claim about the merit of a design solution that reduces the impacts of such hazards. Students are expected to develop an understanding of the similarities and differences of organisms' life cycles. An understanding that organisms have different inherited traits, and that the environment can also affect the traits that an organism develops, is acquired by students at this level. In addition, students are able to construct an explanation using evidence for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing. Students are expected to develop an understanding of types of organisms that lived long ago and also about the nature of their environments. 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 are able to 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; cause and effect; scale, proportion, and quantity; systems and system models; interdependence of science, engineering, and technology; and influence of engineering, technology, and science on society and the natural world are called out as organizing concepts for these disciplinary core ideas. In 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 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 understanding of the core ideas.

## 3. Forces and Interactions

**Students who demonstrate understanding can:**

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

**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.*]

**3-PS2-3** **Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.** [Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [*Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.*]

**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.]

## 3-PS2-1

**Students who demonstrate understanding can:**
Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

**Clarification Statement:** Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.

**Assessment Boundary**: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. | **PS2.A: Forces and Motion**<br>Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.)<br>**PS2.B: Types of Interactions**<br>Objects in contact exert forces on each other. | **Cause and Effect**<br>Cause and effect relationships are routinely identified. |

## 3-PS2-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. | **PS2.A: Forces and Motion**<br>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**<br>Patterns of change can be used to make predictions. |

## 3-PS2-3

**Students who demonstrate understanding can:**
Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

**Clarification Statement:**
Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.

**Assessment Boundary**:
Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Asking Questions and Defining Problems**<br>Ask questions that can be investigated based on patterns such as cause and effect relationships. | **PS2.B: Types of Interactions**<br>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**<br>Cause and effect relationships are routinely identified, tested, and used to explain change. |

## 3-PS2-4

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Develop a model based on evidence to illustrate the relationships between systems or between components of a system. | **PS1.C: Nuclear Processes**<br>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**<br>In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. |

## 3. Interdependent Relationships in Ecosystems: Environmental Impacts on Organisms

**Students who demonstrate understanding can:**

**3-LS2-1** **Construct an argument that some animals form groups that help members survive.** [Clarification Statement: Alaska examples may include wolves, musk ox, caribou, and schools of fish.]

**3-LS4-1** **Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.** [Clarification Statement: Examples of data could include type, size, and 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.*]

**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.]

**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. Solution may be created or provided. Students evaluate the solution to the problem to determine the merit of the solution. Students describe how well the proposed solution meets the given criteria and constraints to reduce the impact of the problem created by the environmental change in the system.] [*Assessment Boundary: Assessment is limited to a single environmental change. Assessment does not include the greenhouse effect or climate change.*]

## 3-LS2-1

**Students who demonstrate understanding can:**
Construct an argument that some animals form groups that help members survive.

**Clarification Statement:**
Alaska examples may include wolves, musk ox, caribou, and schools of fish.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>Construct an argument with evidence, data, and/or a model. | **LS2.D: Social Interactions and Group Behavior**<br>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 *(Note: Moved from K–2).* | **Cause and Effect**<br>Cause and effect relationships are routinely identified and used to explain change. |

## 3-LS4-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>Analyze and interpret data to make sense of phenomena using logical reasoning. | **LS4.A: Evidence of Common Ancestry and Diversity**<br>Some kinds of plants and animals that once lived on Earth are no longer found anywhere. *(Note: moved from K-2)*<br>Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments. | **Scale, Proportion, and Quantity**<br>Observable phenomena exist from very short to very long time periods. |

# 3-LS4-3

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>Construct an argument with evidence. | **LS4.C: Adaptation**<br>For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. | **Cause and Effect**<br>Cause and effect relationships are routinely identified and used to explain change. |

## 3-LS4-4

**Students who demonstrate understanding can:**
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. Solution may be created or provided. Students evaluate the solution to the problem to determine the merit of the solution. Students describe how well the proposed solution meets the given criteria and constraints to reduce the impact of the problem created by the environmental change in the system.

**Assessment Boundary**:
Assessment is limited to a single environmental change. Assessment does not include the greenhouse effect or climate change.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>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**<br>When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. *(secondary)*<br>**LS4.D: Biodiversity and Humans**<br>Populations live in a variety of habitats, and change in those habitats affects the organisms living there. | **Systems and System Models**<br>A system can be described in terms of its components and their interactions. |

## 3. Inheritance and Variation of Traits: Life Cycles and Traits

**Students who demonstrate understanding can:**

**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, such as salmon, wooly bear caterpillar, frogs, 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.*]

**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.*]

**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 normally tall plants grown with insufficient water are stunted; a pet dog that is given too much food and little exercise may become overweight; and, comparison of plants and animals in Arctic regions versus non-Arctic regions.]

**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 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.]

## 3-LS1-1

**Students who demonstrate understanding can:**
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, such as salmon, wooly bear caterpillar, frogs, 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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Develop models to describe phenomena. | **LS1.B: Growth and Development of Organisms**<br>Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles. | **Patterns**<br>Patterns of change can be used to make predictions. |

## 3-LS3-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>Analyze and interpret data to make sense of phenomena using logical reasoning. | **LS3.A: Inheritance of Traits**<br>Many characteristics of organisms are inherited from their parents.<br>**LS3.B: Variation of Traits**<br>Different organisms vary in how they look and function because they have different inherited information. | **Patterns**<br>Similarities and differences in patterns can be used to sort and classify natural phenomena. |

## 3-LS3-2

**Students who demonstrate understanding can:**
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 normally tall plants grown with insufficient water are stunted; a pet dog that is given too much food and little exercise may become overweight; and, comparison of plants and animals in Arctic regions versus non-Arctic regions

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>Use evidence (e.g., observations, patterns) to support an explanation. | **LS3.A: Inheritance of Traits**<br>Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment.<br>**LS3.B: Variation of Traits**<br>The environment also affects the traits that an organism develops. | **Cause and Effect**<br>Cause and effect relationships are routinely identified and used to explain change. |

## 3-LS4-2

**Students who demonstrate understanding can:**
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 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>Use evidence (e.g., observations, patterns) to construct an explanation. | **LS4.B: Natural Selection**<br>Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing. | **Cause and Effect**<br>Cause and effect relationships are routinely identified and used to explain change. |

## 3. Weather and Climate

**Students who demonstrate understanding can:**

**3-ESS2-1** **Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.** [Clarification Statement: Examples of data at this grade level could include student-generated graphs of 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.*]

**3-ESS2-2** **Obtain and combine information to describe climates in different regions of the world.**

**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 storm erosion or flooding (e.g., from storm surges), or buildup of snow drifts; wind resistant roofs, lightning rods, and other weather hazards such as white-out conditions.]

## 3-ESS2-1

**Students who demonstrate understanding can:**
Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.

**Clarification Statement:**
Examples of data at this grade level could include student-generated graphs of 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships. | **ESS2.D: Weather and Climate**<br>Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. | **Patterns**<br>Patterns of change can be used to make predictions. |

# 3-ESS2-2

**Students who demonstrate understanding can:**
Obtain and combine information to describe climates in different regions of the world.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>Obtain and combine information from books and other reliable media to explain phenomena. | **ESS2.D: Weather and Climate**<br>Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. | **Patterns**<br>Patterns of change can be used to make predictions. |

## 3-ESS3-1

**Students who demonstrate understanding can:**
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 storm erosion or flooding (e.g., from storm surges), or buildup of snow drifts; wind resistant roofs, lightning rods, and other weather hazards such as white-out conditions.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>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**<br>A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. *(Note: This Disciplinary Core Idea is also addressed by 4-ESS3-2.)* | **Cause and Effect**<br>Cause and effect relationships are routinely identified, tested, and used to explain change. |

## 3-5.Engineering Design

**Students who demonstrate understanding can:**

**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.**

**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.**

**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.**

# FOURTH GRADE

The performance expectations in fourth grade help students formulate answers to questions such as: "What are waves and what are some things they can do? How can water, ice, wind and vegetation change the land? What patterns of Earth's features can be determined with the use of maps? How do internal and external structures support the survival, growth, behavior, and reproduction of plants and animals? What is energy and how is it related to motion? How is energy transferred? How can energy be used to solve a problem?" Fourth grade performance expectations include PS3, PS4, LS1, ESS1, ESS2, ESS3, and ETS1

Disciplinary Core Ideas from the NRC Framework. Students are able to use a model of waves to describe patterns of waves in terms of amplitude and wavelength, and that waves can cause objects to move. Students are expected to develop understanding of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. They apply their knowledge of natural Earth processes to generate and compare multiple solutions to reduce the impacts of such processes on humans. In order to describe patterns of Earth's features, students analyze and interpret data from maps. Fourth graders are expected to develop an understanding that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. By developing a model, they describe that an object can be seen when light reflected from its surface enters the eye. Students are able to use evidence to construct an explanation of the relationship between the speed of an object and the energy of that object. 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; cause and effect; energy and matter; systems and system models; interdependence of science, engineering, and technology; and influence of engineering, technology, and science on society and the natural world are called out as organizing concepts for these disciplinary core ideas. In 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 understanding of the core ideas.

# 4. Energy

**Students who demonstrate understanding can:**

**4-PS3-1** **Use evidence to construct an explanation relating the speed of an object to the energy of that object.** [*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.*

**4-PS3-2** **Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.** [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]

**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. Examples may be at different scales, such as bouncing balls, car crashes, and plate tectonics (e.g., collisions of land to land, ice to ice, and ice to land).] [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]

**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 electric energy or use stored energy to cause motion or produce light or sound.*]

**4-ESS3-1** **Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.** [Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, tidal, geothermal, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]

## 4-PS3-1

**Students who demonstrate understanding can:**
Use evidence to construct an explanation relating the speed of an object to the energy of that object.

**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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>Use evidence (e.g., measurements, observations, patterns) to construct an explanation. | **PS3.A: Definitions of Energy**<br>The faster a given object is moving, the more energy it possesses. | **Energy and Matter**<br>Energy can be transferred in various ways and between objects. |

# 4-PS3-2

**Students who demonstrate understanding can:**
Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Planning and Carrying Out Investigations**<br>Make observations 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**<br>Energy can be moved from place to place by moving objects or through sound, light, or electric currents.<br>**PS3.B: Conservation of Energy and Energy Transfer**<br>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.<br>Light also transfers energy from place to place.<br>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**<br>Energy can be transferred in various ways and between objects. |

## 4-PS3-3

**Students who demonstrate understanding can:**
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. Examples may be at different scales, such as bouncing balls, car crashes, and plate tectonics (e.g., collisions of land to land, ice to ice, and ice to land).

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Asking Questions and Defining Problems**<br>Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. | **PS3.A: Definitions of Energy**<br>Energy can be moved from place to place by moving objects or through sound, light, or electric currents.<br>**PS3.B: Conservation of Energy and Energy Transfer**<br>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.<br>**PS3.C: Relationship Between Energy and Forces**<br>When objects collide, the contact forces transfer energy so as to change the objects' motions. | **Energy and Matter**<br>Energy can be transferred in various ways and between objects. |

## 4-PS3-4

**Students who demonstrate understanding can:**
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 electric energy or use stored energy to cause motion or produce light or sound.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>Apply scientific ideas to solve design problems. | **PS3.B: Conservation of Energy and Energy Transfer**<br>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.<br>**PS3.D: Energy in Chemical Processes and Everyday Life**<br>The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use.<br>**ETS1.A: Defining Engineering Problems**<br>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. *(secondary)* | **Energy and Matter**<br>Energy can be transferred in various ways and between objects. |

# 4-ESS3-1

**Students who demonstrate understanding can:**
Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

**Clarification Statement:**
Examples of renewable energy resources could include wind energy, water behind dams, tidal, geothermal, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>Obtain and combine information from books and other reliable media to explain phenomena. | **ESS3.A: Natural Resources**<br>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**<br>Cause and effect relationships are routinely identified and used to explain change. |

# 4. Waves

**Students who demonstrate understanding can:**

**4-PS4-1** **Develop and use 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 using wire 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.*]

**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.]

## 4-PS4-1

**Students who demonstrate understanding can:**
Develop and use 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 using wire 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Developing and Using Models**<br>Develop a model using an analogy, example, or abstract representation to describe a scientific principle. | **PS4.A: Wave Properties**<br>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. *(Note: This grade band endpoint was moved from K–2.)*<br>Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). | **Patterns**<br>Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena. |

## 4-PS4-3

**Students who demonstrate understanding can:**

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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>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**<br>Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa.<br>**ETS1.C: Optimizing The Design Solution**<br>Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. *(secondary)* | **Patterns**<br>Similarities and differences in patterns can be used to sort and classify designed products. |

# 4. Structure, Function, and Information Processing

**Students who demonstrate understanding can:**

**4-PS4-2** **Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.** [*Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.*]

**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, skin, gills, scales, and bones.] [*Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.*]

**4-LS1-2** **Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.** [Clarification Statement: Emphasis is on systems of information transfer. Examples may include salmon homing, responses of marine invertebrates to sound and smell, and sonar communication among whales and other marine mammals.] [*Assessment Boundary: Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.*]

# 4-PS4-2

**Students who demonstrate understanding can:**
Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

**Clarification Statement:**
Emphasis is on systems of information transfer. Examples may include salmon homing, responses of marine invertebrates to sound and smell, and sonar communication among whales and other marine mammals.

**Assessment Boundary**:
Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Develop a model to describe phenomena. | **PS4.B: Electromagnetic Radiation**<br>An object can be seen when light reflected from its surface enters the eyes. | **Cause and Effect**<br>Cause and effect relationships are routinely identified. |

# 4-LS1-1

**Students who demonstrate understanding can:**
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, skin, gills, scales, and bones.

**Assessment Boundary**:
Assessment is limited to macroscopic structures within plant and animal systems.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

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

## 4-LS1-2

**Students who demonstrate understanding can:**
Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.

**Clarification Statement:**
Emphasis is on systems of information transfer. Examples may include salmon homing, responses of marine invertebrates to sound and smell, and sonar communication among whales and other marine mammals.

**Assessment Boundary**:
Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Use a model to test interactions concerning the functioning of a natural system. | **LS1.D: Information Processing**<br>Different sense receptors are specialized for particular kinds of information, which may be then processed by the animal's brain. Animals are able to use their perceptions and memories to guide their actions. | **Systems and System Models**<br>A system can be described in terms of its components and their interactions. |

## 4. Earth's Systems: Processes that Shape the Earth

**Students who demonstrate understanding can:**

**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; 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.*]

**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.*]

**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.]

**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 monitoring of volcanic activity.] [*Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.*]

## 4-ESS1-1

**Students who demonstrate understanding can:**
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; 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>Identify the evidence that supports particular points in an explanation. | **ESS1.C: The History of Planet Earth**<br>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**<br>Patterns can be used as evidence to support an explanation. |

# 4-ESS2-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. | **ESS2.A: Earth Materials and Systems**<br>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.<br>**ESS2.E: Biogeology**<br>Living things affect the physical characteristics of their regions. | **Cause and Effect**<br>Cause and effect relationships are routinely identified, tested, and used to explain change. |

# 4-ESS2-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

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

# 4-ESS3-2

**Students who demonstrate understanding can:**
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 monitoring of volcanic activity.

**Assessment Boundary**:
Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>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**<br>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. *(Note: This Disciplinary Core Idea can also be found in 3.WC.)*<br>**ETS1.B: Designing Solutions to Engineering Problems**<br>Testing a solution involves investigating how well it performs under a range of likely conditions. *(secondary)* | **Cause and Effect**<br>Cause and effect relationships are routinely identified, tested, and used to explain change. |

# FIFTH GRADE

The performance expectations in fifth grade help students formulate answers to questions such as: "When matter changes, does its weight change? How much water can be found in different places on Earth? Can new substances be created by combining other substances? How does matter cycle through ecosystems? Where does the energy in food come from and what is it used for? How do lengths and directions of shadows or relative lengths of day and night change from day to day, and how does the appearance of some stars change in different seasons?" Fifth grade performance expectations include PS1, PS2, PS3, LS1, LS2, ESS1, ESS2, and ESS3

Disciplinary Core Ideas from the NRC Framework. Students are able to describe that matter is made of particles too small to be seen through the development of a model. 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 are able to 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 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; cause and effect; scale, proportion, and quantity; energy and matter; and systems and systems models are called out as organizing concepts for these disciplinary core ideas. In 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; and to use these practices to demonstrate understanding of the core ideas.

## 5. Structure and Properties of Matter

**Students who demonstrate understanding can:**

**5-PS1-1** **Develop and use a model to describe that matter is made of particles too small to be seen.** [Clarification Statement: Examples of evidence supporting a model 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.*]

**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.*]

**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.] [Ass*essment Boundary: Assessment does not include density or distinguishing mass and weight.*]

**5-PS1-4** **Conduct an investigation to determine whether the mixing of two or more substances results in new substances.** [Clarifying Statement: Share finding from the investigation.]

## 5-PS1-1

**Students who demonstrate understanding can:**
Develop and use a model to describe that matter is made of particles too small to be seen.

**Clarification Statement:** Examples of evidence supporting a model 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Use models to describe phenomena. | **PS1.A: Structure and Properties of Matter**<br>• 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**<br>• Natural objects exist from the very small to the immensely large. |

## 5-PS1-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Measure and graph quantities such as weight to address scientific and engineering questions and problems. | **PS1.A: Structure and Properties of Matter**<br>• The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish.<br>**PS1.B: Chemical Reactions**<br>• 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**<br>• Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.<br><br>***Connections to Nature of Science***<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Science assumes consistent patterns in natural systems. |

## 5-PS1-3

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. | **PS1.A: Structure and Properties of Matter**<br>• 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**<br>• Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume. |

# 5-PS1-4

**Students who demonstrate understanding can:**
Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

**Clarifying Statement**: Share finding from the investigation.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. | **PS1.B: Chemical Reactions**<br>• When two or more different substances are mixed, a new substance with different properties may be formed. | **Cause and Effect**<br>• Cause and effect relationships are routinely identified and used to explain change. |

# 5. Matter and Energy in Organisms and Ecosystems

**Students who demonstrate understanding can:**

**5-PS3-1** **Use models to describe that energy in animals' food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun.** [Clarification Statement: Examples of models could include diagrams, and flow charts.]

**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.]

**5-LS2-1** **Develop and describe a model that describes 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.]

## 5-PS3-1

**Students who demonstrate understanding can:**
Use models to describe that energy in animals' food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun.

**Clarification Statement:** Examples of models could include diagrams, and flow charts.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Use models to describe phenomena. | **PS3.D: Energy in Chemical Processes and Everyday Life**<br>• 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).<br>**LS1.C: Organization for Matter and Energy Flow in Organisms**<br>• 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. *(secondary)* | **Energy and Matter**<br>• Energy can be transferred in various ways and between objects. |

# 5-LS1-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• Support an argument with evidence, data, or a model. | **LS1.C: Organization for Matter and Energy Flow in Organisms**<br>• Plants acquire their material for growth chiefly from air and water. | **Energy and Matter**<br>• Matter is transported into, out of, and within systems. |

# 5-LS2-1

**Students who demonstrate understanding can:**
Develop and describe a model that describes 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.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model to describe phenomena.<br><br>***Connections to the Nature of Science***<br><br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>• Science explanations describe the mechanisms for natural events. | **LS2.A: Interdependent Relationships in Ecosystems**<br>• The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. | **Systems and System Models**<br>• A system can be described in terms of its components and their interactions. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| | **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**<br>• Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. | |

# 5. Earth's Systems

**Students who demonstrate understanding can:**

**5-ESS2-1** **Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere (water), cryosphere (ice), 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, cryosphere, atmosphere, and biosphere are each a system.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*]

**5-ESS2-2** **Describe and graph the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.** [Classification Statement: Examples could include lakes, rivers, glaciers, sea ice, oceans, groundwater, and polar ice caps. Represent and interpret the data represented by the graphical displays.] [*Assessment Boundary: Assessment is limited to oceans, lakes, rivers, glaciers, ground water, and polar ice caps, and does not include the atmosphere.*]

**5-ESS3-1** **Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.**

# 5-ESS2-1

**Students who demonstrate understanding can:**
Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere (water), cryosphere (ice), 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, cryosphere, atmosphere, and biosphere are each a system.

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model using an example to describe a scientific principle. | **ESS2.A: Earth Materials and Systems**<br>• 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**<br>• A system can be described in terms of its components and their interactions. |

## 5-ESS2-2

**Students who demonstrate understanding can:**
Describe and graph the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.

**Classification Statement:** Examples could include lakes, rivers, glaciers, sea ice, oceans, groundwater, and polar ice caps. Represent and interpret the data represented by the graphical displays.

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Describe and graph quantities such as area and volume to address scientific questions. | **ESS2.C: The Roles of Water in Earth's Surface Processes**<br>• 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**<br>• Standard units are used to measure and describe physical quantities such as weight and volume. |

## 5-ESS3-1

**Students who demonstrate understanding can:**
Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Obtaining, Evaluating, and Communicating Information**<br>• 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**<br>• Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. | **Systems and System Models**<br>• A system can be described in terms of its components and their interactions.<br><br>**Connections to Nature of Science**<br><br>**Science Addresses Questions About the Natural and Material World.**<br>• Science findings are limited to questions that can be answered with empirical evidence. |

# 5. Space Systems: Stars and the Solar System

**Students who demonstrate understanding can:**

**5-PS2-1** **Support an argument that the gravitational force exerted by Earth on objects is directed toward the center of the Earth.** [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.*]

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

**5-ESS1-2** **Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, daily appearance of the moon, 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 causes of seasons.*]

# 5-PS2-1

**Students who demonstrate understanding can:**
Support an argument that the gravitational force exerted by Earth on objects is directed toward the center of the Earth.

**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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• Support an argument with evidence, data, or a model. | **PS2.B: Types of Interactions**<br>• The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. | **Cause and Effect**<br>• Cause and effect relationships are routinely identified and used to explain change. |

## 5-ESS1-1

**Students who demonstrate understanding can:**
Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from the Earth.

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• Support an argument with evidence, data, or a model. | **ESS1.A: The Universe and its Stars**<br>• 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**<br>• Natural objects exist from the very small to the immensely large. |

## 5-ESS1-2

**Students who demonstrate understanding can:**
Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, daily appearance of the moon, 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 causes of seasons.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Analyzing and Interpreting Data**<br>• 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**<br>• 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**<br>• Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena. |

# MIDDLE SCHOOL PHYSICAL SCIENCES

Students in middle school continue to develop understanding of four core ideas in the physical sciences. The middle school performance expectations in the Physical Sciences build on the K – 5 ideas and capabilities to allow learners to explain phenomena central to the physical sciences but also to the life sciences and earth and space science. The performance expectations in physical science blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge to explain real world phenomena in the physical, biological, and earth and space sciences. In the physical sciences, performance expectations at the middle school level focus on students developing understanding of several scientific practices. These include developing and using models, planning and conducting investigations, analyzing and interpreting data, using mathematical and computational thinking, and constructing explanations; and to use these practices to demonstrate understanding of the core ideas. Students are also expected to demonstrate understanding of several of engineering practices including design and evaluation.

The performance expectations in the topic **Structure and Properties of Matter** help students to formulate an answer to the questions: "How can particles combine to produce a substance with different properties? How does thermal energy affect particles?" by building understanding of what occurs at the atomic and molecular scale. By the end of middle school, students will be able to apply understanding that pure substances have characteristic properties and are made from a single type of atom or molecule. They will be able to provide molecular level accounts to explain states of matters and changes between states. The crosscutting concepts of cause and effect; scale, proportion and quantity; structure and function; interdependence of science, engineering, and technology; and influence of science, engineering and technology on society and the natural world are called out as organizing concepts for these disciplinary core ideas. In these performance expectations, students are expected to demonstrate proficiency in developing and using models, and obtaining, evaluating, and communicating information. Students use these scientific and engineering practices to demonstrate understanding of the core ideas.

The performance expectations in the topic **Chemical Reactions** help students to formulate an answer to the questions: "What happens when new materials are formed? What stays the same and what changes?" by building understanding of what occurs at the atomic and molecular scale during chemical reactions. By the end of middle school, 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 are also able to apply an understanding of the design and the process of optimization in engineering to chemical reaction systems. The crosscutting concepts of patterns and energy and matter are called out as organizing concepts for these disciplinary core ideas. In these performance expectations, students are expected to demonstrate proficiency in developing and using models, analyzing and interpreting data, and designing solutions. Students use these scientific and engineering practices to demonstrate understanding of the core ideas.

The performance expectations in the topic **Forces and Interactions** focus on helping students understand ideas related to why some objects will keep moving, why objects fall to the ground and why some materials are attracted to each other while others are not. Students answer the question, “How can one describe physical interactions between objects and within systems of objects?” At the middle school level, the PS2 Disciplinary Core Idea from the NRC Framework is broken down into two sub-ideas: Forces and Motion and Types of interactions. By the end of September 2017 ©2013 Achieve, Inc. All rights reserved. 33 of 102 middle school, 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 other repel. In particular, students will develop 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 are also able to apply an engineering practice and concept to solve a problem caused when objects collide. The crosscutting concepts of cause and effect; system and system models; stability and change; and the influence of science, engineering, and technology on society and the natural world serve as organizing concepts for these disciplinary core ideas. In these performance expectations, students are expected to demonstrate proficiency in asking questions, planning and carrying out investigations, and designing solutions, and engaging in argument; and to use these practices to demonstrate understanding of the core ideas.

The performance expectations in the topic **Energy** help students formulate an answer to the question, “How can energy be transferred from one object or system to another?” At the middle school level, the PS3 Disciplinary Core Idea from the NRC Framework is broken down into four sub-core ideas: Definitions of Energy, Conservation of Energy and Energy Transfer, the Relationship between Energy and Forces, and Energy in Chemical Process and Everyday Life. 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 that that 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 may also contain stored (potential) energy, depending on their relative positions. Students will also come to know the difference between energy and temperature, and begin to develop an understanding of the relationship between force and energy. Students are also able to apply an understanding of design to the process of energy transfer. The crosscutting concepts of scale, proportion, and quantity; systems and system models; and energy are called out as organizing concepts for these disciplinary core ideas. These performance expectations expect students to demonstrate proficiency in developing and using models, planning investigations, analyzing and interpreting data, and designing solutions, and engaging in argument from evidence; and to use these practices to demonstrate understanding of the core ideas in PS3.

The performance expectations in the topic **Waves and Electromagnetic Radiation** help students formulate an answer to the question, “What are the characteristic properties of waves and how can they be used?” At the middle school level, the PS4 Disciplinary Core Idea from the NRC Framework is broken down into Wave Properties, Electromagnetic Radiation, and Information Technologies and Instrumentation. Students are able to describe and predict 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. The crosscutting concepts of patterns and structure and function are used as organizing concepts for these disciplinary core ideas. These performance expectations focus on students demonstrating proficiency in developing and using models, using mathematical thinking, and obtaining, evaluating and communicating information; and to use these practices to demonstrate understanding of the core ideas.

## MS. Structure and Properties of Matter

**Students who demonstrate understanding can:**

**MS-PS1-1** **Develop models to describe the atomic composition of simple molecules and extended structures.** [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [*Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or extended structure is not required.*]

**MS-PS1-3** **Collect information that supports the idea that synthetic materials come from the use of natural resources, and analyze the positive and negative effects of use and development of synthetics on society.** [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [*Assessment Boundary: Assessment is limited to qualitative information.*]

**MS-PS1-4** **Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.** [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawing and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]

## MS-PS1-1

**Students who demonstrate understanding can**:
Develop models to describe the atomic composition of simple molecules and extended structures.

**Clarification Statement:**
Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.

**Assessment Boundary:**
Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or extended structure is not required.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Develop a model to predict and/or describe phenomena. | **PS1.A: Structure and Properties of Matter**<br>• 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.<br>• Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.<br>• Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). | **Scale, Proportion, and Quantity**<br>• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. |

# MS-PS1-3

**Students who demonstrate understanding can**:
Collect information that supports the idea that synthetic materials come from the use of natural resources, and analyze the positive and negative effects of use and development of synthetics on society**.**

**Clarification Statement:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>• 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 now supported by evidence. (MS-PS1-3) | **PS1.B: Chemical Reactions**<br>• 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 | **Structure and Function**<br>• Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Interdependence of Science, Engineering, and Technology**<br>• Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.<br>**Influence of Science, Engineering and Technology on Society and the Natural World**<br>• The uses of technologies and any limitation on their use are driven by individual or societal needs, desires, and values; by the findings of scientific |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| | | research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-PS1-3) |

# MS-PS1-4

**Students who demonstrate understanding can**:
Develop models to describe the atomic composition of simple molecules and extended structures**.**

**Clarification Statement:**
Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawing and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>• Develop a model to predict and/or describe phenomena. | **PS1.A: Structure and Properties of Matter**<br>• Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.<br>• 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.<br>• The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.<br>**PS3.A: Definitions of Energy**<br>• 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 | **Cause and Effect**<br>• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4) |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| | this second meaning; it refers to the energy transferred due to the temperature difference between two objects.<br>• 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. | |

# MS. Chemical Reactions

**Students who demonstrate understanding can:**

**MS-PS1-2** **Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.** [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [*Assessment boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.*]

**MS-PS1-5** **Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.** [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms that represent atoms.] [*Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.*]

**MS-PS1-6** **Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.** [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of chemical process designs could involve dissolving ammonium chloride or calcium chloride and chemical heat packs. Examples of physical process designs could involve a plastic bag and hot water. Alaskan physical examples could include: countercurrent exchange in the limbs and surfaces of Arctic animals and the DIFFERENCE IN THE albedo effect of open ocean water vs. sea ice.] [*Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.*]

## MS-PS1-2

**Students who demonstrate understanding can:**
Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

**Clarification Statement**:
Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.

**Assessment Boundary**: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>• Analyze and interpret data to determine similarities and differences in findings.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is based on Empirical Evidence**<br>• Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2) | **PS1.A: Structure and Properties of Matter**<br>• Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.<br>**PS1.B: Chemical Reactions**<br>• 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**<br>• Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2) |

# MS-PS-5

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model to describe unobservable mechanisms<br><br>**Connections to Nature of Science**<br><br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>• Laws are regularities or mathematical descriptions of natural phenomena. | **PS1.B: Chemical Reactions**<br>• 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.<br>• The total number of each type of atom is conserved, and thus the mass does not change. | **Energy and Matter**<br>• Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5) |

## MS-PS-6

**Students who demonstrate understanding can:**
Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

**Clarification Statement:**
Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of chemical process designs could involve dissolving ammonium chloride or calcium chloride and chemical heat packs. Examples of physical process designs could involve a plastic bag and hot water. Alaskan physical examples could include: countercurrent exchange in the limbs and surfaces of Arctic animals and the DIFFERENCE IN THE albedo effect of open ocean water vs. sea ice.

**Assessment Boundary:**
Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• Some chemical reactions release energy, others store energy.<br>**ETS1.B: Developing Possible Solutions**<br>• A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.<br>**ETS1.C: Optimizing the Design Solution**<br>• 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.<br>• The iterative process of testing the most promising solutions and modifying what is | **Energy and Matter**<br>• The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-6) |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| | proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. | |

# MS. Forces and Interactions

**Students who demonstrate understanding can:**

**MS-PS2-1** **Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*** [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [*Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.*]

**MS-PS2-2** **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [*Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.*]

**MS-PS2-3** **Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.** [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, the effect of increasing the number or strength of magnets on the speed of an electric motor, or a change in the range and intensity of the aurora over time.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]

**MS-PS2-4** **Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.** [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [*Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.*]

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

# MS-PS2-1

**Students who demonstrate understanding can:**
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.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | **PS2.A: Forces and Motion**<br>• 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**<br>• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Science, Engineering, and Technology on Society and the Natural World**<br>• The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. |

## MS-PS2-2

**Students who demonstrate understanding can**:
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.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• 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**<br>• 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.<br>• All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. | **Stability and Change**<br>• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. |

## MS-PS2-3

**Students who demonstrate understanding can:**
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, the effect of increasing the number or strength of magnets on the speed of an electric motor, or a change in the range and intensity of the aurora over time.

**Assessment Boundary**: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Asking Questions and Defining Problems**<br>• 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**<br>• 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**<br>• Cause and effect relationships may be used to predict phenomena in natural or designed systems. |

# MS-PS2-4

**Students who demonstrate understanding can:**
Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

**Clarification Statement**:
Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.

**Assessment Boundary**: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Engaging in Argument from Evidence**<br>• 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**<br>• Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. 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 changed object, or a ball, respectively). | **Systems and System Models**<br>• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems. |

# MS-PS2-5

**Students who demonstrate understanding can:**
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.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• 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**<br>• 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 changed object, or a ball, respectively). | **Cause and Effect**<br>• Cause and effect relationships may be used to predict phenomena in natural or designed systems. |

# MS. Energy

**Students who demonstrate understanding can:**

**MS-PS3-1** **Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.** [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]

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

**MS-PS3-3** **Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.** [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, a Styrofoam cup, or traditional seasonal clothing or dwellings.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

**MS-PS3-4** **Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.** [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

**MS-PS3-5** **Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.** [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [*Assessment Boundary: Assessment does not include calculations of energy.*]

## MS-PS3-1

**Student who demonstrate understanding:**
Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

**Clarification Statement**:
Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Analyzing and Interpreting Data**<br>• Construct and interpret graphical displays of data to identify linear and nonlinear relationships. | **PS3.A: Definitions of Energy**<br>• 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**<br>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. |

## MS-PS3-2

**Students who demonstrate understanding:**
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.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model to describe unobservable mechanisms. | **PS3.A: Definitions of Energy**<br>• A system of objects may also contain stored (potential) energy, depending on their relative positions.<br>**PS3.C: Relationship Between Energy and Forces**<br>• 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**<br>• Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. |

## MS-PS3-3

**Students who demonstrate understanding:**
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, a Styrofoam cup, or traditional seasonal clothing or dwellings.

**Assessment Boundary**: Assessment does not include calculating the total amount of thermal energy transferred.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3) | **PS3.A: Definitions of Energy**<br>• 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.<br>• Energy is spontaneously transferred out of hotter regions or objects and into colder ones.<br>**ETS1.A: Defining and Delimiting an Engineering Problem**<br>• 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. (secondary to MS-PS3-3)<br>**ETS1.B: Developing Possible Solutions** | **Scale, Proportion, and Quantity**<br>• 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.<br>**Energy and Matter**<br>• The transfer of energy can be tracked as energy flows through a designed or natural system. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | • 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. (secondary to MS-PS3-3) | |

## MS-PS3-4

**Students who demonstrate understanding**:
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• 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**<br>• 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.<br>**PS3.B: Conservation of Energy and Energy Transfer**<br>• 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**<br>• 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 |

# MS-PS3-5

**Students who demonstrate understanding:**
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.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• 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. (MS-PS3-5) | ***PS3.B: Conservation of Energy and Energy Transfer***<br>• *When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)* | **Energy and Matter**<br>• Energy may take different forms (e.g. energy in fields, thermal energy, and energy of motion). |

# MS. Waves and Electromagnetic Radiation

**Students who demonstrate understanding can:**

**MS-PS4-1** Qualitatively and quantitatively describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave**.** [Clarification Statement: Examples can include waves modeled with a jump rope, slinky, water, seismic activity, and sound.] [*Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.*]

**MS-PS4-2** **Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.** [Clarification Statement: Emphasis is on both light and mechanical waves (including sound). Examples of models could include drawings, simulations, and written descriptions. Alaskan examples include whale echolocation, or use of sonar projection of the sea floor and fish populations.] [*Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.*]

**MS-PS4-3** Integrated with HS PS4-2

## MS-PS4-1

**Students who demonstrate understanding:**
Qualitatively and quantitatively describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave**.**

**Clarification Statement:** Examples can include waves modeled with a jump rope, slinky, water, seismic activity, and sound.

**Assessment Boundary:** Assessment does not include electromagnetic waves and is limited to standard repeating waves.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Use mathematical representations to describe and/or support scientific conclusions and design solutions.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Based on Empirical Evidence**<br>• Science knowledge is based upon logical and conceptual connections between evidence and explanations. | **PS4.A: Wave Properties**<br>• A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. | **Patterns**<br>• Graphs and charts can be used to identify patterns in data. |

## MS-PS4-2

**Students who demonstrate understanding:**
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 (including sound). Examples of models could include drawings, simulations, and written descriptions. Alaskan examples include whale echolocation, or use of sonar projection of the sea floor and fish populations.

**Assessment Boundary:** Assessment is limited to qualitative applications pertaining to light and mechanical waves.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Developing and Using Models**<br>• Develop and use a model to describe a phenomena | **PS4.A: Wave Properties**<br>• A sound wave needs a medium through which it is transmitted.<br>**PS4.B: Electromagnetic Radiation**<br>• 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.<br>• The path that light travels can be traced as straight lines, except at surfaces between different transparent materials<br>• (e.g., air and water, air and glass) where the light path bends.<br>• A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.<br>• However, because light can travel through space, it cannot be a matter wave, like sound or water waves. | **Structure and Function**<br>• Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. |

## MS-PS4-3

Integrated with HS PS4-2

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>**Obtaining, Evaluating, and Communicating Information**<br>• Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. (MS-PS4-3) | **PS4.C: Information Technologies and Instrumentation**<br>• Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3) | **Structure and Function**<br>• Structures can be designed to serve particular functions. (MS-PS4-3)<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Science, Engineering, and Technology on Society and the Natural World**<br>• Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3)<br><br>**Connections to Nature of Science**<br><br>**Science is a Human Endeavor**<br>• Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-3) |

# MIDDLE SCHOOL LIFE SCIENCES

Students in middle school develop understanding of key concepts to help them make sense of the life sciences. These ideas build upon students' science understanding from earlier grades and from the disciplinary core ideas, science and engineering practices, and crosscutting concepts of other experiences with physical and earth sciences. There are five life science topics in middle school: 1) Structure, Function, and Information Processing, 2) Growth, Development, and Reproduction of Organisms, 3) Matter and Energy in Organisms and Ecosystems, 4) Interdependent Relationships in Ecosystems, and 5) Natural Selection and Adaptations. The performance expectations in middle school blend core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge across the science disciplines. While the performance expectations in middle school life science couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many science and engineering practices integrated in the performance expectations. The concepts and practices in the performance expectations are based on the grade-band endpoints described in A Framework for K-12 Science Education (NRC, 2012).

The Performance Expectations in **Structure, Function, and Information Processing** help students formulate an answer to the question, "How do the structures of organisms contribute to life's functions?" Middle school students can plan and carry out investigations to develop evidence that living organisms are made of cells and to determine the relationship of organisms to the environment. Students can use understanding of cell theory to develop physical and conceptual models of cells. They can construct explanations for the interactions of systems in cells and organisms and how organisms gather and use information from the environment. By the end of their studies, students understand that all organisms are made of cells, that special structures are responsible for particular functions in organisms, and that for many organisms the body is a system of multiple interacting subsystems that form a hierarchy from cells to the body. Crosscutting concepts of cause and effect, structure and function, and matter and energy are called out as organizing concepts for these core ideas.

The Performance Expectations in **Growth, Development, and Reproduction of Organisms** help students formulate an answer to the question, "How do organisms grow, develop, and reproduce?" Students understand how the environment and genetic factors determine the growth of an individual organism. They also demonstrate understanding of the genetic implications for sexual and asexual reproduction. Students can develop evidence to support their understanding of the structures and behaviors that increase the likelihood of successful reproduction by organisms. They have a beginning understanding of the ways humans can select for specific traits, the role of technology, genetic modification, and the nature of ethical responsibilities related to selective breeding. At the end of middle school, students can explain how selected structures, functions, and behaviors of organisms change in predictable ways as they progress from birth to old age. Students can use the practices of analyzing and interpreting data, using models, conducting investigations and communicating information. Crosscutting concepts of structure and function, change and stability, and matter and energy flow in organisms support understanding across this topic.

The Performance Expectations in **Matter and Energy in Organisms and Ecosystems** help students formulate answers to the questions: "How do organisms obtain and use matter and energy? How do matter and energy move through an ecosystem?" Middle school students can use conceptual and physical models to explain the transfer of energy and cycling of matter as they construct explanations for the role of photosynthesis in cycling matter in ecosystems. They can construct explanations for the cycling of matter in organisms and the interactions of organisms to obtain the matter and energy from the ecosystem to survive and grow. Students have a grade-appropriate understanding and use of the practices of investigations, constructing arguments based on evidence, and oral and written communication. They understand that sustaining life requires substantial energy and matter inputs and the structure and functions of organisms contribute to the capture, transformation, transport, release, and elimination of matter and energy. Adding to these crosscutting concepts is a deeper understanding of systems and system models that ties the performances expectations in this topic together.

The Performance Expectations in **Interdependent Relationships in Ecosystems** help students formulate an answer to the question, "How do organisms interact with other organisms in the physical environment to obtain matter and energy? To answer the question, middle school students construct explanations for the interactions in ecosystems and the scientific, economic, political, and social justifications used in making decisions about maintaining biodiversity in ecosystems. Students can use models, construct evidence-based explanations, and use argumentation from evidence. Students understand that organisms and populations of organisms are dependent on their environmental interactions both with other organisms and with nonliving factors. They also understand the limits of resources influence the growth of organisms and populations, which may result in competition for those limited resources. Crosscutting concepts of matter and energy, systems and system models, and cause and effect are used by students to support understanding the phenomena they study.

The Performance Expectations in **Natural Selection and Adaptations** help students formulate answers to the questions: "How does genetic variation among organisms in a species affect survival and reproduction? How does the environment influence genetic traits in populations over multiple generations?" Middle school students can analyze data from the fossil record to describe evidence of the history of life on Earth and can construct explanations for similarities in organisms. They have a beginning understanding of the role of variation in natural selection and how this leads to speciation. They have a grade-appropriate understanding and use of the practices of analyzing graphical displays; using mathematical models; and gathering, reading, and communicating information. The crosscutting concept of cause and effect is central to this topic.

# MS. Structure, Function, and Information Processing

**Students who demonstrate understanding can:**

**MS-LS1-1.** **Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.** [Clarification Statement: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living things, and understanding that living things may be made of one cell or many and varied cells.]

**MS-LS1-2.** **Develop and use a model to describe the function of a cell as a whole and ways 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.*]

**MS-LS1-3.** **Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.** [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [*Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.*]

**MS-LS1-8.** **Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.** [*Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.*]

# MS-LS1-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>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**<br>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**<br>• Phenomena that can be observed at one scale may not be observable at another scale.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Interdependence of Science, Engineering, and Technology**<br>• Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. |

# MS-LS1-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Develop and use a model to describe phenomena. | **LS1.A: Structure and Function**<br>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**<br>• 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. |

## MS-LS1-3

**Students who demonstrate understanding can:**
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.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon. | In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. | **Systems and System Models**<br>• Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Science is a Human Endeavor**<br>• Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. (MS-LS1-3) |

## MS-LS1-8

**Students who demonstrate understanding can:**
Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

**Assessment Boundary:** Assessment does not include mechanisms for the transmission of this information.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>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**<br>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**<br>• Cause and effect relationships may be used to predict phenomena in natural systems. (MS-LS1-8) |

## MS. Matter and Energy in Organisms and Ecosystems

**Students who demonstrate understanding can:**

**MS-LS1-6.** **Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.** [Clarification Statement: Emphasis is on tracing the role of vegetation in movement of matter and flow of energy. Alaskan examples include: caribou eating lichen through the winter, forests and other ecosystems thriving with contribution of decaying salmon, and phytoplankton and seaweed in marine food chain.] [*Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.*]

**MS-LS1-7.** **Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.** [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [*Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.*]

**MS-LS2-1.** **Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.** [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources. This emphasis should include local ecosystem processes and traditional native ways of knowing.]

**MS-LS2-3.** **Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.** [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system. Examples should include: food web, energy pyramid, cycles of water, oxygen, nitrogen, and carbon. Alaska references could include animal droppings contributing nutrients to tundra and other ecosystems.] [*Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.*]

**MS-LS2-4.** **Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.** [Clarification Statement: Emphasis is on recognizing patterns in data, evaluating the validity of and analyzing the evidence, and making logical inferences that explain or predict changes in population based on physical or biological changes.]

# MS-LS1-6

**Students who demonstrate understanding can:**

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 the role of vegetation in movement of matter and flow of energy. Alaskan examples include: caribou eating lichen through the winter, forests and other ecosystems thriving with contribution of decaying salmon, and phytoplankton and seaweed in marine food chain.

**Assessment Boundary**: Assessment does not include the biochemical mechanisms of photosynthesis.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Based on Empirical Evidence**<br>Science knowledge is based upon logical connections between evidence and explanations. | **LS1.C: Organization for Matter and Energy Flow in Organisms**<br>• Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.<br>**PS3.D: Energy in Chemical Processes and Everyday Life**<br>• The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary to MS-LS1-6) | **Energy and Matter**<br>• Within a natural system, the transfer of energy drives the motion and/or cycling of matter. |

# MS-LS1-7

**Students who demonstrate understanding can:**

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

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

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model to describe unobservable mechanisms. (MS-LS1-7) | **LS1.C: Organization for Matter and Energy Flow in Organisms**<br>• Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. (MS-LS1-7)<br><br>**PS3.D: Energy in Chemical Processes and Everyday Life**<br>• 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. (secondary to MS-LS1-7) | **Cause and Effect**<br>• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-1)<br>**Energy and Matter**<br>• Matter is conserved because atoms are conserved in physical and chemical processes. (MS-LS1-7) |

# MS-LS2-1

**Students that demonstrate understanding can:**
Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

**Clarification Statement:** Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources. This emphasis should include local ecosystem processes and traditional native ways of knowing.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>• Analyze and interpret data to provide evidence for phenomena. (MS-LS2-1)<br>• Science disciplines share common rules of obtaining and evaluating empirical evidence. (MS-LS2-4) | **LS2.A: Interdependent Relationships in Ecosystems**<br>• Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1)<br>• 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. (MS-LS2-1)<br>• Growth of organisms and population increases are limited by access to resources. (MS-LS2-1) | **Cause and Effect**<br>• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-1) |

# MS-LS2-3

**Students who demonstrate understanding can:**
Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

**Clarification Statement:** Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system. Examples should include: food web, energy pyramid, cycles of water, oxygen, nitrogen, and carbon. Alaska references could include animal droppings contributing nutrients to tundra and other ecosystems.

**Assessment Boundary:** Assessment does not include the use of chemical reactions to describe the processes.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model to describe phenomena. (MS-LS2-3) | **LS2.B: Cycle of Matter and Energy Transfer in Ecosystems**<br>• Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3) | **Energy and Matter**<br>• The transfer of energy can be tracked as energy flows through a natural system.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-LS2-3) |

## MS-LS2-4

**Students who demonstrate understanding can:**
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, evaluating the validity of and analyzing the evidence, and making logical inferences that explain or predict changes in population based on physical or biological changes.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• 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.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Based on Empirical Evidence**<br>Science disciplines share common rules of obtaining and evaluating empirical evidence. | **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**<br>• Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. | **Stability and Change**<br>• Small changes in one part of a system might cause large changes in another part. |

# MS. Interdependent Relationships in Ecosystems

**Students who demonstrate understanding can:**

**MS-LS2-2.** **Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.** [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.]

**MS-LS2-5.** **Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*** [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

## MS-LS2-2

**Students who demonstrate understanding can:**
Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

**Clarification Statement**: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena. | **LS2.A: Interdependent Relationships in Ecosystems**<br>• Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. | **Patterns**<br>• Patterns can be used to identify cause and effect relationships. |

## MS-LS2-5

**Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*** [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. | **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**<br>• 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. (MS-LS2-5)<br>**LS4.D Biodiversity and Humans**<br>• 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. (MS- LS2-5)<br>**ETS1.B: Developing Possible Solutions**<br>• There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. | **Stability and Change**<br>• Small changes in one part of a system might cause large changes in another part.(MS-LS2-5)<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Science, Engineering, and Technology on Society and the Natural World**<br>• The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS- LS2-5)<br><br>**Connections to Nature of Science**<br><br>**Science Addresses Questions About the Natural and Material World**<br>• Scientific knowledge can describes consequence of actions but does not make the decisions that society takes. (MS-LS2-5) |

# MS. Growth, Development, and Reproduction of Organisms

**Students who demonstrate understanding can:**

**MS-LS1-4.** **Use an evidence-based argument to support an explanation for how characteristic behaviors and/or structures of organisms affect the probability of their successful reproduction.** [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building and burrowing 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 pollinators, and hard shells on nuts that squirrels bury.]

**MS-LS1-5.** **Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds. Alaskan examples include fish sizes/population in fresh vs. salt water or of varying water temperatures, deer size and color (Sitka blacktail deer), bear size and color.] [*Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.*]

**MS-LS3-1.** **Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.** [Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins and that the changes can have far-reaching effects.] [*Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.*]

**MS-LS3-2.** **Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.** [Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]

**MS-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.]

## MS-LS1-4

**Students who demonstrate understanding can:**
Use an evidence-based argument to support an explanation for how characteristic behaviors and/or structures of organisms affect the probability of their successful reproduction.

**Clarification Statement**: Examples of behaviors that affect the probability of animal reproduction could include nest building and burrowing 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 pollinators, and hard shells on nuts that squirrels bury.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• 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. (MS-LS1-4) | **LS1.B: Growth and Development of Organisms**<br>• Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-4)<br>• Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4) | **Cause and Effect**<br>• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS1-4),(MS-LS1-5),(MS-LS4-5) |

# MS-LS1-5

**Students who demonstrate understanding can:**
**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. Alaskan examples include fish sizes/population in fresh vs. salt water or of varying water temperatures, deer size and color (Sitka blacktail deer), bear size and color.

**Assessment Boundary**: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• Genetic factors as well as local conditions affect the growth of the adult plant. | • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. |

# MS-LS3-1

**Students who demonstrate understanding can:**
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 and that the changes can have far-reaching effects.

**Assessment Boundary:** Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop and use a model to describe phenomena. | **LS3.A: Inheritance of Traits**<br>• 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.<br>**LS3.B: Variation of Traits**<br>• 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**<br>• Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. |

## MS-LS3-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop and use a model to describe phenomena. (MS- LS3-1),(MS-LS3-2) | **LS1.B: Growth and Development of Organisms**<br>• Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2)<br>**LS3.A: Inheritance of Traits**<br>• Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.<br>**LS3.B: Variation of Traits**<br>• 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**<br>• Cause and effect relationships may be used to predict phenomena in natural systems. |

# MS-LS4-5

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>• 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. (MS-LS4-5) | **LS4.B: Natural Selection**<br>• 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. (MS-LS4-5) | **Cause and Effect**<br>• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Interdependence of Science, Engineering, and Technology**<br>• Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-LS4-5)<br><br>**Connections to Nature of Science**<br><br>**Science Addresses Questions About the** |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | | **Natural and Material World**<br>• Science knowledge can describe consequences of actions but does not make the decisions that society takes. |

# MS. Natural Selection and Adaptations

**Students who demonstrate understanding can:**

**MS-LS4-1.** **Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.**[Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]

**MS-LS4-2.** **Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.** [Clarification Statement: Emphasis is on comparing anatomical differences, such as field experiences using dichotomous and other types of keys, in order to explain evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]

**MS-LS4-3.** **Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.** [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]

**MS-LS4-4.** **Construct and present an evidence-based explanation of how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.** [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]

**MS-LS4-6.** **Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.** [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [*Assessment Boundary: Assessment does not include Hardy Weinberg calculations.*]

# MS-LS4-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Analyzing and Interpreting Data**<br>• Analyze and interpret data to determine similarities and differences in findings.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Based on Empirical Evidence**<br>• Science knowledge is based upon logical and conceptual connections between evidence and explanations. | **4.A: Evidence of Common Ancestry and Diversity**<br>• 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**<br>• Graphs, charts, and images can be used to identify patterns in data.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. |

## MS-LS4-2

**Students who demonstrate understanding can:**
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 comparing anatomical differences, such as field experiences using dichotomous and other types of keys, in order to explain evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events. | **LS4.A: Evidence of Common Ancestry and Diversity**<br>• 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**<br>• Patterns can be used to identify cause and effect relationships.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. |

# MS-LS4-3

**Students who demonstrate understanding can:**
Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.

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

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

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Analyzing and Interpreting Data**<br>• Analyze displays of data to identify linear and nonlinear relationships. | **LS4.A: Evidence of Common Ancestry and Diversity**<br>• Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. | **Patterns**<br>• Graphs, charts, and images can be used to identify patterns in data. |

## MS-LS4-4

**Students who demonstrate understanding can:**
Construct and present an evidence-based explanation of 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• Construct an explanation that includes qualitative or quantitative relationships between variables s that describe phenomena. | **LS4.B: Natural Selection**<br>• Natural selection leads to the predominance of certain traits in a population, and the suppression of others. | **Cause and Effect**<br>• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. |

# MS-LS4-6

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Use mathematical representations to support scientific conclusions and design solutions. | **LS4.C: Adaptation**<br>• 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**<br>• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. |

# MIDDLE SCHOOL EARTH AND SPACE SCIENCES

Students in middle school develop understanding of a wide range of topics in Earth and space science (ESS) that build upon science concepts from elementary school through more advanced content, practice, and crosscutting themes. There are six ESS standard topics in middle school: Space Systems, History of Earth, Earth's Interior Systems, Earth's Surface Systems, Weather and Climate, and Human Impacts. The content of the performance expectations are based on current community-based geoscience literacy efforts such as the Earth Science Literacy Principles (Wysession et al., 2012), and is presented with a greater emphasis on an Earth Systems Science approach. The performance expectations strongly reflect the many societally relevant aspects of ESS (resources, hazards, environmental impacts) as well as related connections to engineering and technology.

**Space Systems**: Middle school students can examine the Earth's place in relation to the solar system, Milky Way galaxy, and universe. There is a strong emphasis on a systems approach, using models of the solar system to explain astronomical and other observations of the cyclic patterns of eclipses, tides, and seasons. There is also a strong connection to engineering through the instruments and technologies that have allowed us to explore the objects in our solar system and obtain the data that support the theories that explain the formation and evolution of the universe.

**History of Earth**: Students can examine geoscience data in order to understand the processes and events in Earth's history. Important concepts in this topic are "Scale, Proportion, and Quantity" and "Stability and Change," in relation to the different ways geologic processes operate over the long expanse of geologic time. An important aspect of the history of Earth is that geologic events and conditions have affected the evolution of life, but different life forms have also played important roles in altering Earth's systems.

**Earth's Systems**: Students understand how Earth's geosystems operate by modeling the flow of energy and cycling of matter within and among different systems. Students can investigate the controlling properties of important materials and construct explanations based on the analysis of real geoscience data. Of special importance in both topics are the ways that geoscience processes provide resources needed by society but also cause natural hazards that present risks to society; both involve technological challenges, for the identification and development of resources and for the mitigation of hazards.

**Weather and Climate**: Students can analyze data, including maps, and construct and use models to develop understanding of the factors that control weather and climate. A systems approach is also important here, examining the feedbacks between systems as energy from the sun is transferred between systems and circulates though the ocean and atmosphere.

**Human Impacts**: Students understand the ways that human activities impacts Earth's other systems. Students can use many different practices to understand the significant and complex issues surrounding human uses of land, energy, mineral, and water resources and the resulting impacts of their development.

## MS. Space Systems

**Students who demonstrate understanding can:**

**MS-ESS1-1a** **Develop and use a model to explain how the positions of the Earth-Sun-Moon in a system and the cyclic patterns of each cause lunar phases and eclipses of the sun and moon.** [Clarification Statement: Examples of models can be physical, graphical, or conceptual.]

**MS-ESS1-1b** **Develop and use a model to explain how the seasons occur.** [Clarification statement: Reference Alaskan community latitudes and how position on the Earth affects the severity of the seasons for the different regions of AK. Compare and describe the seasons of the northern hemisphere and the southern hemisphere.] [*Assessment Boundary: Assessment limited to qualitative and spatial explanations for seasons.*]

**MS-ESS1-2** **Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.** [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state.)] [*Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.*]

**MS-ESS1-3** **Analyze data to determine scale properties of objects in the solar system.** [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [*Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.*]

# MS-ESS1-1a

**Students who demonstrate understanding can:**
Develop and use a model to explain how the positions of the Earth-Sun-Moon in a system and the cyclic patterns of each cause lunar phases and eclipses of the sun and moon.

**Clarification Statement:** Examples of models can be physical, graphical, or conceptual.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop and use a model to describe phenomena. | **ESS1.A The Universe and its Stars**<br>• Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.<br>**ESS1.B: Earth and the Solar System**<br>• 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**<br>• Patterns can be used to identify cause and effect relationships.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. |

# MS-ESS1-1b

**Students who demonstrate understanding can:**
Develop and use a model to explain how the seasons occur.

**Clarification statement**: Reference Alaskan community latitudes and how position on the Earth affects the severity of the seasons for the different regions of AK. Compare and describe the seasons of the northern hemisphere and the southern hemisphere.

**Assessment Boundary:** Assessment limited to qualitative and spatial explanations for seasons.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop and use a model to describe phenomena. | **ESS1.A The Universe and its Stars**<br>• Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.<br>**ESS1.B: Earth and the Solar System**<br>• 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**<br>• Patterns can be used to identify cause and effect relationships.<br>**Connections to Nature of Science**<br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. |

# MS-ESS1-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop and use a model to describe phenomena. | **ESS1.A The Universe and its Stars**<br>• Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.<br>**ESS1.B: Earth and the Solar System**<br>• 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<br>• The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. | **Systems and System Models**<br>• Models can be used to represent systems and their interactions.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. |

# MS-ESS1-3

**Students who demonstrate understanding can:**
Analyze data to determine scale properties of objects in the solar system.

**Clarification Statement:** Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.

**Assessment Boundary:** Assessment does not include recalling facts about properties of the planets and other solar system bodies.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>• Analyze and interpret data to determine similarities and differences in findings. | **ESS1.B: Earth and the Solar System**<br>• 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**<br>• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Interdependence of Science, Engineering, and Technology**<br>• Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. |

# MS. History of Earth

**Students who demonstrate understanding can:**

**MS-ESS1-4** **Construct and explain, using evidence from rock strata, how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.** [Clarification Statement: Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of Earth's major events could range from being very recent (such as the last Ice Age or the earliest fossils of homo sapiens) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant volcanic eruptions.] [*Assessment Boundary: Assessment does not include recalling the names of specific periods or epochs and events within them.*]

**MS-ESS2-2** **Construct and present an evidence-based explanation of how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate. Alaskan examples should include locally significant landforms including coastal or ocean sea floor structures.]

**MS-ESS2-3** **Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.** [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [*Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.*]

# MS-ESS1-4

**Students who demonstrate understanding can:**
Construct and explain, using evidence from rock strata, 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• 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.<br>**ESS2.B: Plate Tectonics and Large-Scale System Interactions**<br>• 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. | **Scale Proportion and Quantity**<br>• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. |

## MS-ESS2-2

**Students who demonstrate understanding can:**
Construct and present an evidence-based explanation of how geoscience processes have changed Earth's surface at varying time and spatial scales.

**Clarification Statement**: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate. Alaskan examples should include locally significant landforms including coastal or ocean sea floor structures.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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. | **ESS2.A: Earth's Materials and Systems**<br>• 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<br>**ESS2.C: The Roles of Water in Earth's Surface Processes**<br>• Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. | **Scale Proportion and Quantity**<br>• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. |

# MS-ESS2-3

**Students who demonstrate understanding can:**
Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

**Clarification Statement:** Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).

**Assessment Boundary:** Paleomagnetic anomalies in oceanic and continental crust are not assessed.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>• Analyze and interpret data to provide evidence for phenomena. (MS-ESS2-3)<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Open to Revision in Light of New Evidence**<br>• Science findings are frequently revised and/or reinterpreted based on new evidence. (MS-ESS2-3) | **ESS1.C: The History of Planet Earth**<br>• Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. (HS.ESS1.C GBE)(secondary to MS-ESS2-3)<br>**ESS2.B: Plate Tectonics and Large-Scale System Interactions**<br>• Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. (MS-ESS2-3) | **Patterns**<br>• Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. (MS-ESS2-3) |

# MS. Earth's Systems

**Students who demonstrate understanding can:**

**MS-ESS2-1** **Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.** [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [*Assessment Boundary: Assessment does not include the identification and naming of minerals.*]

**MS-ESS2-4** **Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.** [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.] [*Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.*]

**MS-ESS3-1** **Construct an evidence-based explanation for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.** [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]

## MS-ESS2-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop and use a model to describe phenomena. (MS- ESS2-1) | **ESS2.A: Earth's Materials and Systems**<br>• 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. (MS-ESS2-1) | **Stability and Change**<br>• 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. (MS- ESS2-1) |

# MS-ESS2-4

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model to describe unobservable mechanisms. (MS-ESS2-4) | **ESS2.C: The Roles of Water in Earth's Surface Processes**<br>• Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. (MS-ESS2-4)<br>• Global movements of water and its changes in form are propelled by sunlight and gravity. (MS-ESS2-4) | **Energy and Matter**<br>• Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-ESS2-4) |

# MS-ESS3-1

**Students who demonstrate understanding can:**
Construct an evidence-based explanation 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).

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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. (MS-ESS3-1) | **ESS3.A: Natural Resources**<br>• 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. (MS-ESS3-1) | **Cause and Effect**<br>• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-1)<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Science, Engineering, and Technology on Society and the Natural World**<br>• All human activity draws on natural resources and has both short and long- term consequences, positive as well a negative, for the health of people and the natural environment. (MS-ESS3-1) |

# MS. Weather and Climate

**Students who demonstrate understanding can:**

**MS-ESS2-5 Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.** [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]

**MS-ESS2-6 Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*]

**MS-ESS3-5 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 and chemistry (both ocean and land surface), sea ice cover, permafrost, glacial change, atmospheric levels of gases such as carbon dioxide and methane, food availability locally and worldwide, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]

# MS-ESS2-5

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Asking Questions and Defining Problems**<br>• Ask questions to identify and clarify evidence of an argument. (MS-ESS3-5)<br>**Planning and Carrying Out Investigations**<br>• 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. (MS-ESS2-5) | **ESS2.C: The Roles of Water in Earth's Surface Processes**<br>• 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. (MS-ESS2-5)<br>**ESS2.D: Weather and Climate**<br>• Because these patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-5)<br>• 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. (MS-ESS2-6)<br>**ESS3.D: Global Climate Change** | **Cause and Effect**<br>• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS2-5)<br><br>**Stability and Change**<br>• Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (MS-ESS3-5) |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | • 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. (MS-ESS3-5) | |

## MS-ESS2-6

**Students who demonstrate understanding can:**
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.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop and use a model to describe phenomena. | **ESS2.C: The Roles of Water in Earth's Surface Processes**<br>• Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.<br>**ESS2.D: Weather and Climate**<br>• 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.<br>• 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**<br>• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. |

# MS-ESS3-5

**Students who demonstrate understanding can:**
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 and chemistry (both ocean and land surface), sea ice cover, permafrost, glacial change, atmospheric levels of gases such as carbon dioxide and methane, food availability locally and worldwide, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Asking Questions and Defining Problems**<br>• Ask questions to identify and clarify evidence of an argument. | **ESS3.D: Global Climate Change**<br>• 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**<br>• Stability might be disturbed either by sudden events or gradual changes that accumulate over time. |

# MS. Human Impacts

**Students who demonstrate understanding can:**

**MS-ESS3-2 Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.** [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts). Alaskan examples should include but are not limited to tsunamis, storm surges, landslides, and earthquakes.]

**MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.***[Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

**MS-ESS3-4 Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.** [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

## MS-ESS3-2

**Students who demonstrate understanding can:**
Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

**Clarification Statement:** Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts). Alaskan examples should include but are not limited to tsunamis, storm surges, landslides, and earthquakes.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>• Analyze and interpret data to determine similarities and differences in findings. | **ESS3.B: Natural Hazards**<br>• 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**<br>• Graphs, charts, and images can be used to identify patterns in data.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Science, Engineering, and Technology on Society and the Natural World**<br>• The uses of technologies and limitations on their use are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. |

# MS-ESS3-3

**Students who demonstrate understanding can:**
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).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• Apply scientific principles to design an object, tool, process or system. | **ESS3.C: Human Impacts on Earth Systems**<br>• 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.<br>• 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**<br>• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.<br>• The uses of technologies and limitations on their use are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. |

# MS-ESS3-4

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• 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**<br>• 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**<br>• Cause and effect relationships may be used to predict phenomena in natural or designed systems.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Science, Engineering, and Technology on Society and the Natural World**<br>• All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.<br><br>**Connections to Nature of Science**<br><br>**Science Addresses Questions About the Natural and Material World**<br>• Science knowledge can describe consequences of actions but does not make the decisions that society takes. |

# MS. Engineering Design

**Students who demonstrate understanding can:**

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

**MS-ETS1-2** **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**

**MS-ETS1-3** **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.**

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

# HIGH SCHOOL PHYSICAL SCIENCES

Students in high school continue to develop their understanding of the four core ideas in the physical sciences. These ideas include the most fundamental concepts from chemistry and physics, but are intended to leave room for expanded study in upper-level high school courses. The high school performance expectations in Physical Science build on the middle school ideas and skills and allow high school students to explain more in-depth phenomena central not only to the physical sciences, but to life and earth and space sciences as well. These performance expectations blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge to explain ideas across the science disciplines. In the physical science performance expectations at the high school level, there is a focus on several scientific practices. These include developing and using models, planning and conducting investigations, analyzing and interpreting data, using mathematical and computational thinking, and constructing explanations; and to use these practices to demonstrate understanding of the core ideas. Students are also expected to demonstrate understanding of several engineering practices, including design and evaluation.

The performance expectations in the topic **Structure and Properties of Matter** help students formulate an answer to the question, "How can one explain the structure and properties of matter?" Two sub-ideas from the *NRC Framework* are addressed in these performance expectations: the structure and properties of matter, and nuclear processes. Students are expected to develop understanding of the substructure of atoms and provide more mechanistic explanations of the properties of substances. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Phenomena involving nuclei are also important to understand, as they explain the formation and abundance of the elements, radioactivity, the release of energy from the sun and other stars, and the generation of nuclear power. The crosscutting concepts of patterns, energy and matter, and structure and function are called out as organizing concepts for these disciplinary core ideas. In these performance expectations, students are expected to demonstrate proficiency in developing and using models, planning and conducting investigations, and communicating scientific and technical information; and to use these practices to demonstrate understanding of the core ideas.

The performance expectations in the topic **Chemical Reactions** help students formulate an answer to the questions: "How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?" Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Using this expanded knowledge of chemical reactions, students are able to explain important biological and geophysical phenomena. Students are also able to apply an understanding of the process of optimization in engineering design to chemical reaction systems. The crosscutting concepts of patterns, energy and matter, and stability and change are called out as organizing concepts for these disciplinary core ideas. In these performance expectations, students are expected to demonstrate proficiency in developing and using models, using mathematical thinking, constructing explanations, and designing solutions; and to use these practices to demonstrate understanding of the core ideas.

The Performance Expectations associated with the topic **Forces and Interactions** supports students' understanding of ideas related to why some objects will keep moving, why objects fall to the ground, and why some materials are attracted to each other while others are not. Students should be able to answer the question, "How can one explain and predict interactions between objects and within systems of objects?" The disciplinary core idea expressed in the Framework for PS2 is broken down into the sub ideas of Forces and Motion and Types of Interactions. The performance expectations in PS2 focus on students building understanding of forces and interactions and Newton's Second Law. Students also develop understanding that the total momentum of a system of objects is conserved when there is no net force on the system. Students are able to use Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. Students are able to apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. The crosscutting concepts of patterns, cause and effect, and systems and system models are called out as organizing concepts for these disciplinary core ideas. In the PS2 performance expectations, students are expected to demonstrate proficiency in planning and conducting investigations, analyzing data and using math to support claims, and applying scientific ideas to solve design problems; and to use these practices to demonstrate understanding of the core ideas.

The Performance Expectations associated with the topic **Energy** help students formulate an answer to the question, "How is energy transferred and conserved?" The disciplinary core idea expressed in the Framework for PS3 is broken down into four sub-core ideas: Definitions of Energy, Conservation of Energy and Energy Transfer, the Relationship between Energy and Forces, and Energy in Chemical Process and Everyday Life. Energy is understood as quantitative property of a system that depends on the motion and interactions of matter and radiation within that system, and the total change of energy in any system is always equal to the total energy transferred into or out of the system. Students develop an understanding that energy at both the macroscopic and the atomic scale can be accounted for as either motions of particles or energy associated with the configuration (relative positions) of particles. In some cases, the energy associated with the configuration of particles can be thought of as stored in fields. Students also demonstrate their understanding of engineering principles when they design, build, and refine devices associated with the conversion of energy. The crosscutting concepts of cause and effect; systems and system models; energy and matter; and the influence of science, engineering, and technology on society and the natural world are further developed in the performance expectations associated with PS3. In these performance expectations, students are expected to demonstrate proficiency in developing and using models, planning and carry out investigations, using computational thinking, and designing solutions; and to use these practices to demonstrate understanding of the core ideas.

The Performance Expectations associated with the topic **Waves and Electromagnetic Radiation** are critical to understand how many new technologies work. As such, this disciplinary core idea helps students answer the question, "How are waves used to transfer energy and send and store information?" The disciplinary core idea in PS4 is broken down into Wave Properties, Electromagnetic Radiation, and Information

Technologies and Instrumentation. Students are able to apply understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances, store information, and investigate nature on many scales. Models of electromagnetic radiation as either a wave of changing electric and magnetic fields or as particles are developed and used. Students understand that combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Students also demonstrate their understanding of engineering ideas by presenting information about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. The crosscutting concepts of cause and effect; systems and system models; stability and change; interdependence of science, engineering, and technology; and the influence of engineering, technology, and science on society and the natural world are highlighted as organizing concepts for these disciplinary core ideas. In the PS3 performance expectations, students are expected to demonstrate proficiency in asking questions, using mathematical thinking, engaging in argument from evidence, and obtaining, evaluating and communicating information; and to use these practices to demonstrate understanding of the core ideas.

# HS. Structure and Properties of Matter

**Students who demonstrate understanding can:**

**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 (valence electrons).** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [*Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*]

**HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [*Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.*]

**HS-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. Example applications include dating of rocks, carbon dating of artifacts, paleoclimate studies, medical imaging, tracking animal migrations via diet, age dating meteorites, tracking ground water flow.] [*Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*]

**HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of natural and designed materials.** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [*Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.*]

# HS-PS1-1

**Students who demonstrate understanding can:**
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 (valence electrons).

**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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Use a model to predict the relationships between systems or between components of a system. | **PS1.A: Structure and Properties of Matter**<br>• Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.<br>• The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. | **Patterns**<br>• 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

**Students who demonstrate understanding can:**
Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

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

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

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.<br>• 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**<br>• The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.<br>**PS2.B: Types of Interactions**<br>• 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. *(secondary)* | **Patterns**<br>• 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-PS1-8

**Students who demonstrate understanding can:**
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. Example applications include dating of rocks, carbon dating of artifacts, paleoclimate studies, medical imaging, tracking animal migrations via diet, age dating meteorites, tracking ground water flow.

**Assessment Boundary**: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model based on evidence to illustrate the relationships between systems or between components of a system. | **PS1.C: Nuclear Processes**<br>• 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**<br>• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. |

# HS-PS2-6

**Students who demonstrate understanding can:**
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of natural and 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>• 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). | **PS2.B: Types of Interactions**<br>• 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**<br>• 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. Chemical Reactions

**Students who demonstrate understanding can:**

**HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]

**HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [*Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*]

**HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [*Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*]

**HS-PS1-6. Make arguments based on kinetic molecular theory to explain how altering conditions affects the forward and reverse rates of a reaction 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.*]

**HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [*Assessment Boundary: Assessment does not include complex chemical reactions.*]

## HS-PS1-2

**Students who demonstrate understanding can:**
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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model based on evidence to illustrate the relationships between systems or between components of a system. | **PS1.C: Nuclear Processes**<br>• 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**<br>• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. |

## HS-PS1-4

**Students who demonstrate understanding can:**
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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• 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**<br>• 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.<br>**PS1.B: Chemical Reactions**<br>• 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**<br>• 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

**Students who demonstrate understanding can:**
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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• 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**<br>• 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

**Students who demonstrate understanding can:**
Make arguments based on kinetic molecular theory to explain how altering conditions affects the forward and reverse rates of a reaction 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• 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.<br><br>**ETS1.C: Optimizing the Design Solution**<br>• 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. *(secondary)* | **Stability and Change**<br>• Much of science deals with constructing explanations of how things change and how they remain stable. |

## HS-PS1-7

**Students who demonstrate understanding can:**
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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Use mathematical representations of phenomena to | **PS1.B: Chemical Reactions**<br>• 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**<br>• The total amount of energy and matter in closed systems is conserved. |

## HS. Forces and Interactions

**Students who demonstrate understanding can:**

**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.*]

**HS-PS2-2.** **Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.** [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [*Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.*]

**HS-PS2-3.** **Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*** [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [*Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]

**HS-PS2-4.** **Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [*Assessment Boundary: Assessment is limited to systems with two objects.*]

**HS-PS2-5.** **Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.** [*Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.*]

## HS-PS2-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Analyzing and Interpreting Data**<br>• 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**<br>• Newton's second law accurately predicts changes in the motion of macroscopic objects. | **Cause and Effect**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

## HS-PS2-2

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>Use mathematical representations of phenomena to describe explanations. | **PS2.A: Forces and Motion**<br>Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.<br>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**<br>When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. |

## HS-PS2-3

**Students who demonstrate understanding can:**
Apply science 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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Constructing Explanations and Designing Solutions**<br>Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. | **PS2.A: Forces and Motion**<br>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.<br>**ETS1.A: Defining and Delimiting an Engineering Problem**<br>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. *(secondary)*<br>**ETS1.C: Optimizing the Design Solution**<br>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. *(secondary)* | **Cause and Effect**<br>Systems can be designed to cause a desired effect. |

## HS-PS2-4

**Students who demonstrate understanding can:**
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.*

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Use mathematical representations of phenomena to describe explanations. | **PS2.B: Types of Interactions**<br>• 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.<br>• 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**<br>• 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

**Students who demonstrate understanding can:**
Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

**Assessment Boundary**: *Assessment is limited to designing and conducting investigations with provided materials and tools.*

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• 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**<br>• 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. (HS-PS2-4)<br>• 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.<br>**PS3.A: Definitions of Energy**<br>• "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. *(secondary)* | **Cause and Effect**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

# HS. Energy

**Students who demonstrate understanding can:**

**HS-PS3-1** **Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model. Examples of models could include different insulation types or windows.] [*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]

**HS-PS3-2** **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 positions of particles (objects).** [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]

**HS-PS3-3** **Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*** [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [*Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*]

**HS-PS3-4** **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]

**HS-PS3-5** **Develop and use a model of two objects interacting through electrical or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction (Coulomb's Law).** [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [*Assessment Boundary: Assessment is limited to systems containing two objects.*]

## HS-PS3-1

**Students who demonstrate understanding can:**
Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

**Clarification Statement:** Emphasis is on explaining the meaning of mathematical expressions used in the model.

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

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Create a computational model or simulation of a phenomenon, designed device, process, or system. | **PS3.A: Definitions of Energy**<br>• 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.<br><br>**PS3.B: Conservation of Energy and Energy Transfer**<br>• 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.<br>• Energy cannot be created or destroyed, but it can be transported from one place | **Systems and System Models**<br>• 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.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Science assumes the universe is a vast single system in which basic laws are consistent. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | to another and transferred between systems.<br>• 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.<br>• The availability of energy limits what can occur in any system. | |

## HS-PS3-2

**Students who demonstrate understanding can:**
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 positions 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.

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• 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**<br>• 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.<br>• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.<br>• 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 | **Energy and Matter**<br>• Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | 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. | |

## HS-PS3-3

**Students who demonstrate understanding can:**
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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.<br><br>**PS3.D: Energy in Chemical Processes**<br>• Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.<br><br>**ETS1.A: Defining and Delimiting Engineering Problems**<br>• 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 | **Energy and Matter**<br>• 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.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Science, Engineering, and Technology on Society and the Natural World**<br>• Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | way that one can tell if a given design meets them. | |

## HS-PS3-4

**Students who demonstrate understanding can:**
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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• 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**<br>• Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.<br>• 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).<br><br>**PS3.D: Energy in Chemical Processes**<br>• 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**<br>• 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

**Students who demonstrate understanding can:**
Develop and use a model of two objects interacting through electrical or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction (Coulomb's Law).

**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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| **Developing and Using Models**<br>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**<br>When two objects interacting through a field change relative position, the energy stored in the field is changed. | **Cause and Effect**<br>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. Waves and Electromagnetic Radiation

**Students who demonstrate understanding can:**

**HS-PS4-1.** **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [*Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.*]

**HS-PS4-2.** **Evaluate questions about the advantages and disadvantages of using digital transmission and storage of information with respect to that of forms other than digital, including analog.** [Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]

**HS-PS4-3.** **Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.** [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [*Assessment Boundary: Assessment does not include using quantum theory.*]

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

**HS-PS4-5.** **Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*** [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [*Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.*]

## HS-PS4-1

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. | **PS4.A: Wave Properties**<br>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**<br>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

## HS-PS4-2

**Students who demonstrate understanding can:**
Evaluate questions about the advantages and disadvantages of using digital transmission and storage of information with respect to that of forms other than digital, including analog.

**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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Asking Questions and Defining Problems**<br>• 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**<br>• 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**<br>• Systems can be designed for greater or lesser stability. |

## HS-PS4-3

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. | **PS4.A: Wave Properties**<br>• [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.)<br>**PS4.B: Electromagnetic Radiation**<br>• 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**<br>• 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

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>• 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**<br>• 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**<br>• 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

**Students who demonstrate understanding can:**
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.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>• 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**<br>• Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. *(secondary)*<br>**PS4.A: Wave Properties**<br>• 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.<br>**PS4.B: Electromagnetic Radiation**<br>• Photoelectric materials emit electrons when they absorb light of a high-enough frequency.<br>• PS4.C: Information Technologies and Instrumentation<br>• Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern | **Cause and Effect**<br>• Systems can be designed to cause a desired effect. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| | world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. | |

# HIGH SCHOOL LIFE SCIENCES

Students in high school develop understanding of key concepts that help them make sense of life science. The ideas are building upon students' science understanding of disciplinary core ideas, science and engineering practices, and crosscutting concepts from earlier grades. There are five life science topics in high school: *1) Structure and Function, 2) Inheritance and Variation of Traits, 3) Matter and Energy in Organisms and Ecosystems, 4) Interdependent Relationships in Ecosystems, and 5) Natural Selection and Evolution.* The performance expectations for high school life science blend core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge that can be applied across the science disciplines. While the performance expectations in high school life science couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices underlying the performance expectations. The performance expectations are based on the grade-band endpoints described in *A Framework for K-12 Science Education* (NRC, 2012).

The performance expectations in the topic **Structure and Function** help students formulate an answer to the question: "How do the structures of organisms enable life's functions?" High school students are able to investigate explanations for the structure and function of cells as the basic units of life, the hierarchical systems of organisms, and the role of specialized cells for maintenance and growth. Students demonstrate understanding of how systems of cells function together to support the life processes. Students demonstrate their understanding through critical reading, using models, and conducting investigations. The crosscutting concepts of structure and function, matter and energy, and systems and system models in organisms are called out as organizing concepts.

The performance expectations in the topic **Inheritance and Variation of Traits** help students in pursuing an answer to the question: "How are the characteristics from one generation related to the previous generation?" High school students demonstrate understanding of the relationship of DNA and chromosomes in the processes of cellular division that pass traits from one generation to the next. Students can determine why individuals of the same species vary in how they look, function, and behave. Students can develop conceptual models for the role of DNA in the unity of life on Earth and use statistical models to explain the importance of variation within populations for the survival and evolution of species. Ethical issues related to genetic modification of organisms and the nature of science can be described. Students can explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expression. Crosscutting concepts of structure and function, patterns, and cause and effect developed in this topic help students to generalize understanding of inheritance of traits to other applications in science.

The performance expectations in the topic **Matter and Energy in Organisms and Ecosystems** help students answer the questions: "How do organisms obtain and use energy they need to live and grow? How do matter and energy move through ecosystems?" High school students can construct explanations for the role of energy in the cycling of matter in organisms and ecosystems. They can apply mathematical concepts to develop evidence to support explanations of the interactions of photosynthesis and cellular respiration and develop models to communicate

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these explanations. They can relate the nature of science to how explanations may change in light of new evidence and the implications for our understanding of the tentative nature of science. Students understand organisms' interactions with each other and their physical environment, how organisms obtain resources, change the environment, and how these changes affect both organisms and ecosystems. In addition, students can utilize the crosscutting concepts of matter and energy and Systems and system models to make sense of ecosystem dynamics.

The performance expectations in the topic **Interdependent Relationships in Ecosystems** help students answer the question, "How do organisms interact with the living and non-living environment to obtain matter and energy?" This topic builds on the other topics as high school students demonstrate an ability to investigate the role of biodiversity in ecosystems and the role of animal behavior on survival of individuals and species. Students have increased understanding of interactions among organisms and how those interactions influence the dynamics of ecosystems. Students can generate mathematical comparisons, conduct investigations, use models, and apply scientific reasoning to link evidence to explanations about interactions and changes within ecosystems.

The performance expectations in the topic **Natural Selection and Evolution** help students answer the questions: "How can there be so many similarities among organisms yet so many different plants, animals, and microorganisms? How does biodiversity affect humans?" High school students can investigate patterns to find the relationship between the environment and natural selection. Students demonstrate understanding of the factors causing natural selection and the process of evolution of species over time. They demonstrate understanding of how multiple lines of evidence contribute to the strength of scientific theories of natural selection and evolution. Students can demonstrate an understanding of the processes that change the distribution of traits in a population over time and describe extensive scientific evidence ranging from the fossil record to genetic relationships among species that support the theory of biological evolution. Students can use models, apply statistics, analyze data, and produce scientific communications about evolution. Understanding of the crosscutting concepts of patterns, scale, structure and function, and cause and effect supports the development of a deeper understanding of this topic.

## HS. Structure and Function

**Students who demonstrate understanding can:**

**HS-LS1-1.** **Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.** [*Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.*]

**HS-LS1-2.** **Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.** [Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [*Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.*]

**HS-LS1-3.** **Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.** [Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [*Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.*]

## HS-LS1-1

**Students who demonstrate understanding can:** 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:**

**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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• Systems of specialized cells within organisms help them perform the essential functions of life.<br>• 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**<br>• 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

**Students who demonstrate understanding can:** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

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

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

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• 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**<br>• Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. | **Systems and System Models**<br>• 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

**Students who demonstrate understanding can:** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

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

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

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• 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.<br><br>**Connections to Nature of Science**<br><br>**Scientific Investigations Use a Variety of Methods**<br>• Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. | **LS1.A: Structure and Function**<br>• 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. | **Stability and Change**<br>• Feedback (negative or positive) can stabilize or destabilize a system. |

## HS. Matter and Energy in Organisms and Ecosystems

**Students who demonstrate understanding can:**

**HS-LS1-5.** **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [*Assessment Boundary: Assessment does not include specific biochemical steps.*]

**HS-LS1-6.** **Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.** [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [*Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.*]

**HS-LS1-7.** **Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.** [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [*Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.*]

**HS-LS2-3.** **Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.** [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.] [*Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.*]

**HS-LS2-4.** **Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.** [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [*Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.*]

**HS-LS2-5.** **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** [Clarification Statement: Examples of models could include simulations and mathematical models.] [*Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.*]

## HS-LS1-5

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• 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**<br>• 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**<br>• 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

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• 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.<br>• 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**<br>• 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

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• 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**<br>• As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.<br>• 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**<br>• Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. |

# HS-LS2-3

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Open to Revision in Light of New Evidence**<br>• Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. | **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**<br>• Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. | **Energy and Matter**<br>• Energy drives the cycling of matter within and between systems. |

## HS-LS2-4

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Use mathematical representations of phenomena or design solutions to support claims. | **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**<br>• 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**<br>• 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

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• 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**<br>• 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.<br><br>**PS3.D: Energy in Chemical Processes**<br>• 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**<br>• 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. Interdependent Relationships in Ecosystems

**Students who demonstrate understanding can:**

**HS-LS2-1.** **Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.** [Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [*Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.*]

**HS-LS2-2.** **Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.** [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [*Assessment Boundary: Assessment is limited to provided data.*]

**HS-LS2-6.** **Evaluate 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 hunting and fishing harvests, predation, flooding, sea ice variation, erosion, volcanic eruptions, land level changes due to earthquakes, tsunamis, changes in ocean current patterns or ocean chemistry, or sea-level rise.]

**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, pollution, building dams and roads, and dissemination of invasive species. Example lessons can include applications of Tragedy of the Commons.]

**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.]

**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 testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]

## HS-LS2-1

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

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

# HS-LS2-2

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Use mathematical representations of phenomena or design solutions to support and revise explanations.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Open to Revision in Light of New Evidence**<br>• Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. | **LS2.A: Interdependent Relationships in Ecosystems**<br>• 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.<br><br>**LS2.C: Ecosystem Dynamics, Functioning, and Resilience**<br>• A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant | **Scale, Proportion, and Quantity**<br>• Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | 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. | |

# HS-LS2-6

**Students who demonstrate understanding can:** 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 hunting and fishing harvests, predation, flooding, sea ice variation, erosion, volcanic eruptions, land level changes due to earthquakes, tsunamis, changes in ocean current patterns or ocean chemistry, or sea-level rise.

**Assessment Boundary***:*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Open to Revision in Light of New Evidence**<br>• Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. | **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**<br>• 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**<br>• Much of science deals with constructing explanations of how things change and how they remain stable. |

## HS-LS2-7

**Students who demonstrate understanding can:** 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, pollution, building dams and roads, and dissemination of invasive species. Example lessons can include applications of Tragedy of the Commons.

**Assessment Boundary***:*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.<br><br>**LS4.D: Biodiversity and Humans**<br>• Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).<br>• 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 | **Stability and Change**<br>• Much of science deals with constructing explanations of how things change and how they remain stable. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| | 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.<br><br>**ETS1.B: Developing Possible Solutions**<br>• 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-LS2-8

**Students who demonstrate understanding can:** 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***:*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Open to Revision in Light of New Evidence**<br>• Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. | **LS2.D: Social Interactions and Group Behavior**<br>• Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. | **Cause and Effect**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

## HS-LS4-6

**Students who demonstrate understanding can:** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*

**Clarification Statement:** Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.

**Assessment Boundary***:*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Create or revise a simulation of a phenomenon, designed device, process, or system. | **LS4.C: Adaptation**<br>• 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.<br><br>**LS4.D: Biodiversity and Humans**<br>• 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 | **Cause and Effect**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.<br><br>**ETS1.B: Developing Possible Solutions**<br>• 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.<br>• 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 | |

## HS. Inheritance and Variation of Traits

**Students who demonstrate understanding can:**

**HS-LS1-4.** **Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.** [*Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.*]

**HS-LS3-1.** **Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.** [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

**HS-LS3-2.** **Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.** [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]

**HS-LS3-3.** **Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.** [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [*Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.*]

# HS-LS1-4

**Students who demonstrate understanding can:** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

**Clarification Statement:**

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

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• 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**<br>• 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**<br>• 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-LS3-1

**Students who demonstrate understanding can:** 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:**

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

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Asking Questions and Defining Problems**<br>• Ask questions that arise from examining models or a theory to clarify relationships. | **LS1.A: Structure and Function**<br>• 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.<br><br>**LS3.A: Inheritance of Traits**<br>• 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**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

# HS-LS3-2

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• 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**<br>• 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.<br>• 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**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

# HS-LS3-3

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>• 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**<br>• 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**<br>• 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).<br><br>**Connections to Nature of Science**<br><br>**Science is a Human Endeavor**<br>• Technological advances have influenced the progress of science and science has influenced advances in technology.<br>• Science and engineering are influenced by society and society is influenced by science and engineering. |

## HS. Natural Selection and Evolution

**Students who demonstrate understanding can:**

**HS-LS4-1.** **Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.** [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]

**HS-LS4-2.** **Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [*Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.*]

**HS-LS4-3.** **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.** [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [*Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.*]

**HS-LS4-4.** **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]

**HS-LS4-5.** **Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, pollution, erosion, permafrost thawing, changes in sea ice, invasive species, land level changes due to earthquakes, changes in ocean chemistry, sea level change, volcanic eruptions, drought, flood and the rate of change of the environment affect the distribution or disappearance of traits in species.]

## HS-LS4-1

**Students who demonstrate understanding can:** 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***:*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Obtaining, Evaluating, and Communicating Information**<br>• 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).<br><br>**Connections to Nature of Science**<br><br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>• A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. | **LS4.A: Evidence of Common Ancestry and Diversity**<br>• Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. | **Patterns**<br>• 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.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. |

## HS-LS4-2

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• 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.<br>**LS4.C: Adaptation**<br>• 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**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

# HS-LS4-3

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>• 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**<br>• 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.<br>• The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.<br><br>**LS4.C: Adaptation**<br>• 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 | **Patterns**<br>• 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. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
| --- | --- | --- |
| | 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.<br>• Adaptation also means that the distribution of traits in a population can change when conditions change. | |

# HS-LS4-4

**Students who demonstrate understanding can:** 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***:*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• 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**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. |

## HS-LS4-5

**Students who demonstrate understanding can:** 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, pollution, erosion, permafrost thawing, changes in sea ice, invasive species, land level changes due to earthquakes, changes in ocean chemistry, sea level change, volcanic eruptions, drought, flood and the rate of change of the environment affect the distribution or disappearance of traits in species.

**Assessment Boundary**:

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. | **LS4.C: Adaptation**<br>• 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.<br>• 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**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

# HIGH SCHOOL EARTH AND SPACE SCIENCES

Students in high school develop understanding of a wide range of topics in Earth and space science (ESS) that build upon science concepts from middle school through more advanced content, practice, and crosscutting themes. There are five ESS standard topics in middle school: Space Systems, History of Earth, Earth's Systems, Weather and Climate, and Human Sustainability. The content of the performance expectations are based on current community-based geoscience literacy efforts such as the Earth Science Literacy Principles (Wysession et al., 2012), and is presented with a greater emphasis on an Earth Systems Science approach. There are strong connections to mathematical practices of analyzing and interpreting data. The performance expectations strongly reflect the many societally relevant aspects of ESS (resources, hazards, environmental impacts) with an emphasis on using engineering and technology concepts to design solutions to challenges facing human society.

**Space Systems**: High school students can examine the processes governing the formation, evolution, and workings of the solar system and universe. Some concepts studied are fundamental to science, such as understanding how the matter of our world formed during the Big Bang and within the cores of stars. Others concepts are practical, such as understanding how short-term changes in the behavior of our sun directly affect humans. Engineering and technology play a large role here in obtaining and analyzing the data that support the theories of the formation of the solar system and universe.

**History of Earth**: Students can construct explanations for the scales of time over which Earth processes operate. An important aspect of Earth and space science involves making inferences about events in Earth's history based on a data record that is increasingly incomplete that farther you go back in time. A mathematical analysis of radiometric dating is used to comprehend how absolute ages are obtained for the geologic record. A key to Earth's history is the coevolution of the biosphere with Earth's other systems, not only in the ways that climate and environmental changes have shaped the course of evolution but also in how emerging life forms have been responsible for changing Earth.

**Earth's Systems**: Students can develop models and explanations for the ways that feedbacks between different Earth systems control the appearance of Earth's surface. Central to this is the tension between internal systems, which are largely responsible for creating land at Earth's surface (e.g., volcanism and mountain building), and the sun- driven surface systems that tear down the land through weathering and erosion. Students understand the role that water plays in affecting weather. Students understand chemical cycles such as the carbon cycle. Students can examine the ways that human activities cause feedbacks that create changes to other systems.

**Weather and Climate**: Students understand the system interactions that control weather and climate, with a major emphasis on the mechanisms and implications of climate change. Students understand the analysis and interpretation of different kinds of geoscience data allow students to construct explanations for the many factors that drive climate change over a wide range of time scales.

**Human Impacts**: Students understand the complex and significant interdependencies between humans and the rest of Earth's systems through the impacts of natural hazards, our dependencies on natural resources, and the environmental impacts of human activities.

# HS. Space Systems

**Students who demonstrate understanding can:**

**HS-ESS1-1.** **Develop a model based on evidence to illustrate that the life span of the Sun is a function of nuclear fusion in its core, and that stars, through nuclear fusion over their life cycle, produce elements and release energy that eventually reaches Earth in the form of radiation.** [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. Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Example applications include solar flares, auroras, 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 nuclear fusion, or details of the many different nucleosynthesis pathways for stars of differing masses.*]

**HS-ESS1-2.** **Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]

**HS-ESS1-4.** **Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [*Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.*]

## HS-ESS1-1

**Students who demonstrate understanding can:** Develop a model based on evidence to illustrate that the life span of the Sun is a function of nuclear fusion in its core, and that stars, through nuclear fusion over their life cycle, produce elements and release energy that eventually reaches Earth in the form of radiation.

**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. Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Example applications include solar flares, auroras, 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 nuclear fusion, or details of the many different nucleosynthesis pathways for stars of differing masses.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model based on evidence to illustrate the relationships between systems or components of a system.<br><br>**Obtaining, Evaluating, and Communicating Information**<br>• 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**<br>• The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.<br>• The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.<br>• 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.<br><br>**PS3.D: Energy in Chemical Processes and Everyday Life**<br>• Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. | **Scale, Proportion, and Quantity**<br>• The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.<br><br>**Energy and Matter**<br>• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. |

# HS-ESS1-2

**Students who demonstrate understanding can:** 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***:*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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.<br><br>**Connections to Nature of Science**<br><br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>• A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through | **ESS1.A: The Universe and Its Stars**<br>• The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.<br>• 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.<br>• 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 | **Energy and Matter**<br>• Energy cannot be created or destroyed– only moved between one place and another place, between objects and/or fields, or between systems.<br><br>**Connection to Engineering, Technology, and Applications of Science**<br><br>**Interdependence of Science, Engineering, and Technology**<br>• Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.<br><br>**Connection to Nature of Science** |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. | are produced when certain massive stars achieve a supernova stage and explode.<br><br>**PS4.B Electromagnetic Radiation**<br>• 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. | **Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>• Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.<br>• Science assumes the universe is a vast single system in which basic laws are consistent. |

# HS-ESS1-4

**Students who demonstrate understanding can:** Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

**Clarification Statement:** Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.

**Assessment Boundary**: *Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematical and Computational Thinking**<br>• Use mathematical or computational representations of phenomena to describe explanations. | **ESS1.B: Earth and the Solar System**<br>• 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**<br>• 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).<br><br>**Connection to Engineering, Technology, and Applications of Science**<br><br>**Interdependence of Science, Engineering, and Technology**<br>• Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. |

## HS. History of Earth

**Students who demonstrate understanding can:**

**HS-ESS1-5.** **Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.** [Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).]

**HS-ESS1-6.** **Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.** [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

**HS-ESS2-1.** **Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.** [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [*Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.*]

# HS-ESS1-5

**Students who demonstrate understanding can:** Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.

**Clarification Statement:** Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).

**Assessment Boundary***:*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. | **ESS1.C: The History of Planet Earth**<br>• 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.<br>**ESS2.B: Plate Tectonics and Large-Scale System Interactions**<br>• 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.<br>**PS1.C: Nuclear Processes**<br>• 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**<br>• Empirical evidence is needed to identify patterns. |

# HS-ESS1-6

**Students who demonstrate understanding can:** 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.

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.<br><br>**Connections to Nature of Science**<br><br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>• A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.<br>• Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. | **ESS1.C: The History of Planet Earth**<br>• 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.<br><br>**PS1.C: Nuclear Processes**<br>• 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**<br>• Much of science deals with constructing explanations of how things change and how they remain stable. |

## HS-ESS2-1

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model based on evidence to illustrate the relationships between systems or between components of a system. | **ESS2.A: Earth Materials and Systems**<br>• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts.<br>**ESS2.B: Plate Tectonics and Large-Scale System Interactions**<br>• 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.<br>• 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**<br>• 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. Earth's Systems

**Students who demonstrate understanding can:**

**HS-ESS2-2.** **Analyze geoscience data to evaluate claims that one change to Earth's surface creates 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 temperature that melts glacial and sea 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 feedbacks due to the effects of permafrost thawing; how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge and decrease sediment transport, and how the loss of wetlands causes a decrease in local humidity that further reduces wetland extent.]

**HS-ESS2-3.** **Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]

**HS-ESS2-5.** **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 evidence for the 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, beach erosion and deposition patterns in relation to substrate type and size, erosion using variations in soil moisture content, and frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering, and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

**HS-ESS2-6.** **Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.** [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, permafrost, and biosphere (including humans), providing the foundation for living organisms.]

**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.*]

## HS-ESS2-2

**Students who demonstrate understanding can:** Analyze geoscience data to evaluate claims that one change to Earth's surface creates 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 temperature that melts glacial and sea 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 feedbacks due to the effects of permafrost thawing; how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge and decrease sediment transport, and how the loss of wetlands causes a decrease in local humidity that further reduces wetland extent.

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>• 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**<br>• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.<br>**ESS2.D: Weather and Climate**<br>• 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**<br>• Feedback (negative or positive) can stabilize or destabilize a system.<br><br>**Connections to Engineering, Technology and Applications of Science**<br><br>**Influence of Engineering, Technology, and Science on Society and the Natural World**<br>• New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. |

## HS-ESS2-3

**Students who demonstrate understanding can:** 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.

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Based on Empirical Evidence**<br>• Science knowledge is based on empirical evidence.<br>• Science disciplines share common rules of evidence used to evaluate explanations about natural systems.<br>• Science includes the process of coordinating patterns of evidence with current theory. | **ESS2.A: Earth Materials and Systems**<br>• 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.<br>**ESS2.B: Plate Tectonics and Large-Scale System Interactions**<br>• 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 | **Energy and Matter**<br>• Energy drives the cycling of matter within and between systems.<br><br>**Connections to Engineering, Technology and Applications of Science**<br><br>**Interdependence of Science, Engineering, and Technology**<br>• Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | tectonics can be viewed as the surface expression of mantle convection.<br>**PS4.A: Wave Properties**<br>• Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. | |

## HS-ESS2-5

**Students who demonstrate understanding can:** 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 evidence for the 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, beach erosion and deposition patterns in relation to substrate type and size, erosion using variations in soil moisture content, and 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).

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Planning and Carrying Out Investigations**<br>• 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**<br>• 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**<br>• 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

**Students who demonstrate understanding can:** 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, permafrost, and biosphere (including humans), providing the foundation for living organisms.

**Assessment Boundary***:*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model based on evidence to illustrate the relationships between systems or between components of a system. | **ESS2.D: Weather and Climate**<br>• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.<br>• Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. | **Energy and Matter**<br>• The total amount of energy and matter in closed systems is conserved. |

## HS-ESS2-7

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

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

# HS. Weather and Climate

**Students who demonstrate understanding can:**

**HS-ESS2-4.** **Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.** [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [*Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.*]

**HS-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, and physical and chemical characteristics of atmosphere and ocean.] [*Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.*]

## HS-ESS2-4

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Use a model to provide mechanistic accounts of phenomena.<br><br>**Connections to Nature of Science**<br><br>**Scientific Knowledge is Based on Empirical Evidence**<br>• Science arguments are strengthened by multiple lines of evidence supporting a single explanation. | **ESS1.B: Earth and the Solar System**<br>• 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.<br><br>**ESS2.A: Earth Materials and Systems**<br>• 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 | **Cause and Effect**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| | (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.<br>**ESS2.D: Weather and Climate**<br>• 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.<br>**ESS2.D: Weather and Climate**<br>• Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. | |

## HS-ESS3-5

**Students who demonstrate understanding can:** 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, and physical and chemical characteristics of atmosphere and ocean.

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

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>• Analyze data using computational models in order to make valid and reliable scientific claims.<br><br>**Connections to Nature of Science**<br><br>**Scientific Investigations Use a Variety of Methods**<br>• Science investigations use diverse methods and do not always use the same set of procedures to obtain data.<br>• New technologies advance scientific knowledge.<br><br>**Scientific Knowledge is Based on Empirical Evidence**<br>• Science knowledge is based on empirical evidence.<br>• Science arguments are strengthened by multiple lines of evidence supporting a single explanation. | **ESS3.D: Global Climate Change**<br>• 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**<br>• Change and rates of change can be quantified and modeled over very short or very long period of time. Some system changes are irreversible. |

## HS. Human Sustainability

**Students who demonstrate understanding can:**

**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, wildlife, fish, trees, 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, storm surge, lightning strike fires, 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, changes in stream or ocean water temperatures and/or chemistry, and the types of food that can be raised, hunted, fished, harvested, or gathered.]

**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, all types of mining, extracting of fossil fuels, and collecting renewable resources. Scientific knowledge indicates what can happen in natural systems--not what should happen.]

**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.*]

**HS-ESS3-4.** **Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

**HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.** [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [*Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*]

# HS-ESS3-1

**Students who demonstrate understanding can:** 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, wildlife, fish, trees, 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, storm surge, lightning strike fires, 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, changes in stream or ocean water temperatures and/or chemistry, and the types of food that can be raised, hunted, fished, harvested, or gathered.

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• Resource availability has guided the development of human society.<br><br>**ESS3.B: Natural Hazards**<br>• 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**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Engineering, Technology, and Science on Society and the Natural World**<br>• Modern civilization depends on major technological systems. |

## HS-ESS3-2

**Students who demonstrate understanding can:** 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, all types of mining, extracting of fossil fuels, and collecting renewable resources. Scientific knowledge indicates what can happen in natural systems--not what should happen.

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| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Engaging in Argument from Evidence**<br>• 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**<br>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.<br><br>**ETS1.B. Designing Solutions to Engineering Problems**<br>• 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. | **Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Engineering, Technology, and Science on Society and the Natural World**<br>• Engineers continuously modify these systems to increase benefits while decreasing costs and risks.<br>Analysis of costs and benefits is a critical aspect of decisions about technology.<br><br>**Connections to Nature of Science**<br><br>**Science Addresses Questions About the Natural and Material World**<br>• Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.<br>• Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.<br>• Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. |

## HS-ESS3-3

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Create a computational model or simulation of a phenomenon, designed device, process, or system. | **ESS3.C: Human Impacts on Earth Systems**<br>• The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. | **Stability and Change**<br>• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Engineering, Technology, and Science on Society and the Natural World**<br>• Modern civilization depends on major technological systems.<br>• New technologies can have deep impacts on society and the environment, including some that were not anticipated.<br><br>**Connections to Nature of Science**<br><br>**Science is a Human Endeavor**<br>• Scientific knowledge is a result of human endeavors, imagination, and creativity. |

## HS-ESS3-4

**Students who demonstrate understanding can:** 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).

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Constructing Explanations and Designing Solutions**<br>• 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**<br>• Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.<br><br>**ETS1.B. Designing Solutions to Engineering Problems**<br>• 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**<br>• Feedback (negative or positive) can stabilize or destabilize a system.<br><br>**Connections to Engineering, Technology, and Applications of Science**<br><br>**Influence of Engineering, Technology, and Science on Society and the Natural World**<br>• Engineers continuously modify these systems to increase benefits while decreasing costs and risks. |

## HS-ESS3-6

**Students who demonstrate understanding can:** 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.*

*The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.*

| Science and Engineering Practices | Disciplinary Core Concepts | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>• Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. | **ESS2.D: Weather and Climate**<br>• 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.<br><br>**ESS3.D: Global Climate Change**<br>• 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**<br>• 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. |

# Appendix F: Science and Engineering Practices

# Appendix G: Crosscutting Concepts

Place holder for Crosscutting Concepts