High School Maryland Integrated Science Assessment

In 2013, the Maryland State Board of Education adopted the Next Generation Science Standards (NGSS) as the new Maryland Science Standards. Maryland's previous science standards took a traditional approach to science, emphasizing students "knowing" disconnected science facts and decontextualized, procedural skills. In contrast to standards that emphasized one aspect of science at a time, the new science standards are three-dimensional, and integrate disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCCs) into performance expectations that require students to demonstrate knowledge-in-use as they make sense of real-world phenomena and solve authentic problems.

The High School Maryland Integrated Science Assessment (HS MISA) is the final assessment in a series of science assessments that a student will take which are aligned to the NGSS. The HS MISA is a Maryland High School Assessment (MHSA). Passing the Maryland High School Assessments is a graduation requirement. The HS MISA was developed based on a subset of the High School NGSS standards. The subset was determined during a series of meetings involving a High School Test Committee and finalized by the Science Supervisors from the Maryland Local School Systems (LSS). Each LSS then developed science curricula, a course sequence, and plan for assessing based on this subset. This document highlights the Performance Expectations (PEs) that are used to develop the HS MISA.

In order to assess the three dimensions of the performance expectations found in the standards, a set of interrelated items is required. There are no single items on the HS MISA each item is part of an item set.

The HS MISA uses the item set as a subunit of the assessment. Specific items may focus on two of the dimensions, but together in a set, all three dimensions are addressed and inferences can be made regarding a student's three dimensional understanding.

The HS MISA is an integrated science assessment which addresses Earth and space science, life science, physical science, and engineering, technology, and applications of science. Each item set on the HS MISA has a stimulus that focuses on a specific real world phenomenon. The stimulus and items provide a storyline and includes multiple components that work together to partially or fully assess a bundle of chosen Performance Expectations (i.e., a group of related Performance Expectations from the NGSS). The intent is for students to explicitly use their understanding of the three dimensions to make sense of the information provided to them.

The SEPs include developing and using models, planning and conducting investigations, analyzing and interpreting data, using mathematical and computational thinking, constructing explanations, engaging in argument, and obtaining, evaluating, and communicating information. Students use these practices to demonstrate an understanding of the disciplinary core ideas.

Students in high school continue to make sense of the four core ideas in the physical sciences of the NGSS. 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 core 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 making sense of ideas across the science disciplines. In some of the physical science performance expectations at the high school level, students are also expected to demonstrate an understanding of several engineering practices including design and evaluation.

The performance expectations in **PS1: Matter and its interactions** help students formulate an answer to the question, "How can one explain the structure, properties, and interactions of matter?" The PS1 Disciplinary Core Idea on the High School MISA is broken down into two sub-ideas: the structure and properties of matter and chemical reactions. 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. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Using this expanded knowledge of chemical reactions, students are able to explain important biological and geophysical phenomena. The crosscutting concept of patterns is identified as the organizing concepts for these disciplinary core ideas. In the PS1 performance expectations, students are expected to demonstrate proficiency in constructing explanations and designing solutions; and to use these practices to demonstrate an understanding of the core ideas.

The performance expectation associated with **PS2: Motion and Stability: Forces and Interactions** support students' understanding of ideas related to why some objects will keep moving. 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 High School MISA for PS2 is the sub idea of Forces and Motion. The performance expectation in PS2 focus on students building understanding of forces and interactions and Newton's Second Law. The crosscutting concepts of cause and effect is called out as organizing concepts for this disciplinary core ideas. In the PS2 performance expectations, students are expected to demonstrate proficiency in analyzing data and using math to support claims to demonstrate an understanding of the core ideas.

The performance expectations associated with **PS3: Energy** help students formulate an answer to the question, "How is energy transferred and conserved?" The Core Idea expressed in the High School MISA for PS3 is broken down into three sub-core ideas: Definitions of Energy, Conservation of Energy and Energy Transfer, 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 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, using computational thinking and designing solutions; demonstrate proficiency in constructing explanations and designing solutions; and to use these practices to demonstrate an understanding of the core ideas.

The performance expectation associated with **PS4: Waves and Their Applications in Technologies for Information Transfer** are critical to understand how many new technologies work. As such, this 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, and Electromagnetic Radiation. Students are able to apply understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances and investigate nature on many scales. The crosscutting concept of cause and effect is highlighted as an organizing concepts for these disciplinary core ideas. In the PS4 performance expectation, students are expected to demonstrate proficiency in using mathematical thinking to demonstrate an understanding of the core ideas.

HS-PS Physical Science

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-PS1-5. 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-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-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]

HS-PS3-3. 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-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.]

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

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)
- Use mathematical representations of phenomena or

Disciplinary Core Ideas

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

PS1.B: Chemical Reactions
- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-5)
- 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. (HS-PS1-2)

PS2.A: Forces and Motion
- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

PS3.A: Definitions of Energy
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-1),(HS-PS3-2)
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2)
- 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

Crosscutting Concepts

Patterns
- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-2),(HS- PS1-5)

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1),(HS-PS4-1)

Systems and System Models
- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS- PS3-1)

Energy and Matter
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS- PS3-3)
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2)

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*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)

Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5)
- 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. (HS-PS1-2)
- 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. (HS-PS3-3)

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- Theories and laws provide explanations in science. (HS-PS2-1)
- Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1)

motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)

PS3.B: Conservation of Energy and Energy Transfer

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1)
- 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. (HS-PS3-1)
- The availability of energy limits what can occur in any system. (HS-PS3-1)

PS3.D: Energy in Chemical Processes

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

PS4.A: Wave Properties

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1)

ETS1.A: Defining and Delimiting Engineering Problems

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

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- 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. (HS-PS3-3)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS- PS3-1)

Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-PS3-2); **HS.PS1.B** (HS-PS3-1),(HS-PS3-2); **HS.PS2.B** (HS-PS3-2); **HS.PS3.A** (HS-PS1-5); **HS.PS3.C** (HS-PS2-1); **HS.LS1.C** (HS-PS1-2); **HS.LS2.B** (HS-PS3-1); **HS.ESS1.A** (HS-PS2-1), HS-PS3-1); **HS.ESS1.C** (HS-PS2-1); **HS.ESS2.A** (HS-PS3-1),(HS-PS3-2), (HS-PS4-1); **HS.ESS2.C** (HS-PS1-2), (HS-PS2-1); **HS.ESS3.A** (HS-PS3-3)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS1-2),(HS-PS1-5), (HS-PS3-2); **MS.PS1.B** (HS-PS1-2),(HS-PS1-5); **MS.PS2.A** (HS-PS2-1); **MS.PS2.B** (HS-PS1-5), (HS-PS3-2); **MS.PS3.A** (HS-PS1-5), (HS-PS3-1),(HS-PS3-2),(HS-PS3-3); **MS.PS3.B** (HS-PS1-5), (HS-PS3-1),(HS-PS3-2),(HS-PS3-3); **MS.PS3.C** (HS-PS2-1), (HS-PS3-2); **MS.PS4.A** (HS-PS4-1) **MS.PS4.B** (HS-PS4-1); **MS.ESS2.A** (HS-PS3-1),(HS-PS3-3)

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5), (HS-PS2-1),
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1), (HS-PS4-1)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2),(HS-PS1-5)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1)
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1),(HS-PS3-2)

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-PS1-5), (HS-PS2-1), (HS-PS3-1),(HS-PS3-2),(HS-PS3-3), (HS-PS4-1)
MP.4	Model with mathematics. (HS-PS2-1), (HS-PS3-1),(HS-PS3-2),(HS-PS3-3), (HS-PS4-1)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-5), (HS-PS2-1), (HS-PS3-1), (HS-PS3-3)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-1), (HS-PS3-1), (HS-PS3-3)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-5), (HS-PS2-1), (HS-PS3-1), (HS-PS3-3)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1), (HS-PS4-1)
HSA-SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1), (HS-PS4-1)
HSA-CED.A.1	Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1)
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1)
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1), (HS-PS4-1)
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. (HS-PS2-1)
HSS-ID.A.1	Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Students in high school develop understanding of key concepts that will help them make sense of life science. The ideas are built upon students' science understanding of disciplinary core ideas, science and engineering practices, and crosscutting concepts from earlier grades. There are four life science disciplinary core ideas in high school: 1) From Molecules to Organisms: Structures and Processes, 2) Ecosystems: Interactions, Energy, and Dynamics, 3) Heredity: Inheritance and Variation of Traits, 4) Biological Evolution: Unity and Diversity. The performance expectations for high school life science blend core ideas with scientific and engineering practices and crosscutting concepts to support students in developing usable knowledge that can be applied across the science disciplines.

The performance expectation in **LS1: From Molecules to Organisms: Structures and Processes** help students formulate an answer to the question, "How do organisms live and grow?" The LS1 Disciplinary Core Idea for the HS MISA is presented as Structure and Function. In this performance expectation, students understand the role of proteins as essential to the work of the cell and living systems. The cellular processes can be used as a model for understanding the hierarchical organization of organisms. Crosscutting concept of structure and function provide students with insights to the structures and processes of organisms.

The performance expectations in **LS2: Ecosystems: Interactions, Energy, and Dynamics** help students formulate an answer to the question, "How and why do organisms interact with their environment, and what are the effects of these interactions?" The LS2 Disciplinary Core Idea includes three sub-ideas: Interdependent Relationships in Ecosystems, Cycles of Matter and Energy Transfer in Ecosystems, and Ecosystem Dynamics. High school students can use mathematical reasoning and develop models to demonstrate an understanding of fundamental concepts of carrying capacity, factors affecting biodiversity and populations, and the cycling of matter and flow of energy among organisms in an ecosystem. Crosscutting concepts of systems and system models and scale, proportion, and quantity play a central role in students' understanding of science and engineering practices and core ideas of ecosystems.

The performance expectation in **LS3: Heredity: Inheritance and Variation of Traits** help students formulate answers to the questions: "How are the characteristics of one generation passed to the next? How can individuals of the same species and even siblings have different characteristics?" The LS3 Disciplinary Core Idea on the HS MISA includes the sub-idea: Variation of Traits. 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 cause and effect is called out as an organizing concept for this core idea.

The performance expectations in **LS4: Biological Evolution: Unity and Diversity** help students formulate an answer to the question, "What evidence shows that different species are related? The LS4 Disciplinary Core Idea involves three sub-ideas: Evidence of Common Ancestry and Diversity, Natural Selection, and Adaptation. Students can construct explanations for the processes of natural selection and evolution and communicate how multiple lines of evidence support these explanations. Students can evaluate evidence of the conditions that may result in new species and understand the role of genetic variation in natural selection. The crosscutting concepts of cause and effect and systems and patterns play an important role in students' understanding of the evolution of life on Earth.

HS-LS Life Science

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-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-LS2-5. 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-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-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-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]

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

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
- Develop a model based on evidence to illustrate the relationships between systems or components of a system. (HS-LS2-5)

Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
- 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. (HS-LS1-1), (HS-LS4-2)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed

Disciplinary Core Ideas

LS1.A: Structure and Function
- Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1-1)

LS2.A: Interdependent Relationships in Ecosystems
- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS- LS2-2)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2)

LS3.B: Variation of Traits

Crosscutting Concepts

Patterns
- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-1)

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-2), (HS-LS4-2),(HS-LS4-5)

Scale, Proportion, and Quantity
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2)

Systems and System Models
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions— including energy, matter, and information flows—within and between systems at different scales. (HS-LS2-5)

Structure and Function
- Investigating or designing new systems or structures requires a detailed examination of the

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world(s). Arguments may also come from current scientific or historical episodes in science.

- Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5)
- Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9-12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- 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). (HS-LS4-1)

Connections to Nature of Science

Scientific Knowledge is Open to Revision in Light of New Evidence

- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS- LS2-2)

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that 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. (HS-LS4-1)

- 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. (HS-LS3-2)
- 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. (HS-LS3-2)

LS4.A: Evidence of Common Ancestry and Diversity

- Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1)

LS4.B: Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-2)

LS4.C: Adaptation

- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2)
- 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. (HS-LS4-5)
- 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. (HS-LS4-5)

PS3.D: Energy in Chemical Processes

- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary to HS-LS2-5)

properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-LS1-1)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS- LS4-1)

Connections to other DCIs in this grade-band: **HS.PS1.B** (HS-LS2-5); **HS.LS2.A** (HS-LS4-2), (HS-LS4-5); **HS.LS2.D** (HS-LS4-2), (HS-LS4-5); **HS.LS3.A** (HS-LS1-1), (HS-LS4-1); **HS.LS3.B** (HS-LS4-1),(HS-LS4-2),(HS-LS4-5); **HS.ESS1.C** (HS-LS4-1); **HS.ESS2.D** (HS-LS2-5); **HS.ESS2.E** (HS-LS2-2), (HS-LS4-2),(HS-LS4-5); **HS.ESS3.A** (HS-LS2-2), (HS-LS4-2),(HS-LS4-5); **HS.ESS3.C** (HS-LS2-2); **HS.ESS3.D** (HS-LS2-2)

Articulation to DCIs across grade-bands: **MS.PS3.D** (HS-LS2-5); **MS.LS1.A** (HS- LS1-1); **MS.LS1.C** (HS-LS2-5); **MS.LS2.A** (HS-LS2-2), (HS-LS4-2), (HS-LS4-5); **MS.LS2.B** (HS-LS2-5); **MS.LS2.C** (HS-LS2-2), (HS-LS4-5); **MS.LS3.A** (HS-LS1-1), (HS-LS3-2), (HS-LS4-1); **MS.LS3.B** (HS-LS1-1), (HS-LS3-2), (HS-LS4-1), (HS-LS4-2); **MS.LS4.A** (HS-LS4-1); **MS.LS4.B** (HS-LS4-2), (HS-LS4-3); **MS.LS4.C** (HS-LS4-2), (HS-LS4-3), (HS-LS4-5); **MS.ESS1.C** (HS-LS4-1); **MS.ESS2.A** (HS-LS2-5); **MS.ESS3.C** (HS-LS2-2), (HS-LS4-5)

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-1), (HS-LS2-2), (HS-LS3-2), (HS-LS4-1), (HS-LS4-2)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS4-5)
WHST.9-12.1	Write arguments focused on discipline-specific content. (HS-LS3-2)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-1), (HS- LS2-2), (HS-LS4-1), (HS-LS4-2)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-1)
SL.11-12.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-LS4-1), (HS-LS4-2)

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-LS2-2), (HS-LS3-2), (HS-LS4-1), (HS-LS4-2), (HS-LS4-5)
MP.4	Model with mathematics. (HS-LS2-2), (HS-LS4-2)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-LS2-2)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-LS2-2)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-LS2-2)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Students in high school continue to develop their understanding of the three disciplinary core ideas in the Earth and Space Sciences. The high school performance expectations in Earth and Space 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 earth and space sciences, but to life and physical 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.

The performance expectation in **ESS1: Earth's Place in the Universe**, help students formulate an answer to the question: "What is the universe, and what is Earth's place in it?" The ESS1 Disciplinary Core Idea for the HS MISA is broken down into two sub-ideas: the universe and its stars and Earth and the solar system. Students examine the processes governing the formation, evolution, and workings of the solar system and the universe. 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. 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 the universe. The crosscutting concepts of energy and matter is called out as organizing concepts for these disciplinary core ideas. In the ESS1 performance expectation, students are expected to demonstrate proficiency in constructing explanations and designing solutions to use this practice to demonstrate an understanding of the core ideas.

The performance expectations in **ESS2: Earth's Systems**, help students formulate an answer to the question: "How and why is Earth constantly changing?" The ESS2 Disciplinary Core Idea for the HS MISA are broken down into four sub-ideas: Earth materials and systems, the roles of water in Earth's surface processes, weather and climate, and biogeology. For the purpose of the NGSS, most of biogeology has been addressed within the life science standards. Students develop 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, and the sun-driven surface systems that tear down the land through weathering and erosion. Students begin to examine the ways that human activities cause feedbacks that create changes to other systems. Students understand the system interactions that control weather and climate, with a major emphasis on the mechanisms and implications of climate change. Students model the flow of energy between different components of the weather system and how this affects chemical cycles such as the carbon cycle. The crosscutting concepts of cause and effect, energy and matter, structure and function and stability and change are called out as organizing concepts for these disciplinary core ideas. In the ESS2 performance expectations, students are expected to demonstrate proficiency in developing and using models, planning and carrying out investigations, analyzing and interpreting data, and engaging in argument; and to use these practices to demonstrate an understanding of the core ideas.

The performance expectations in **ESS3: Earth and Human Activity** help students formulate an answer to the question: "How do Earth's surface processes and human activities affect each other?" The ESS3 Disciplinary Core Idea on the HS MISA is broken down into two sub-ideas: human impact on Earth systems, and global climate change. Students understand the complex and significant interdependencies between humans and the rest of Earth's systems through the significant environmental impacts of human activities. Students use mathematical thinking and the analysis of geoscience data to examine and construct solutions to the many challenges facing long-term human sustainability on Earth. The crosscutting concepts of systems and system models, and stability and change are called out as organizing concepts for these disciplinary core ideas. In the ESS3 performance expectations, students are expected to demonstrate proficiency in developing and using analyzing and interpreting data, and mathematical and computational thinking to use these practices to demonstrate an understanding of the core ideas.

HS-ESS Earth Space Science

Students who demonstrate understanding can:

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-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth. [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.]

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]

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

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-6)
- Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4)

Planning and Carrying Out Investigations

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.

- 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. (HS-ESS2-5)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-2)
- 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. (HS-ESS1-2)
- 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. (HS-ESS1-2)

ESS1.B: Earth and the Solar System

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

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4)

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS3-6)

Energy and Matter

- The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6)
- Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. (HS-ESS1-2)

Structure and Function

- The functions and properties of natural and designed objects and systems can

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

High School Earth Space Science on the HS MISA

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-ESS2-2), (HS-ESS3-5)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
- 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. (HS-ESS1-2)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
- Construct an oral and written argument or counter-arguments based on data and evidence. (HS-ESS2-7)

Connections to Nature of Science

Scientific Investigations Use a Variety of Methods
- Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS- ESS3-5)
- New technologies advance scientific knowledge. (HS-ESS3-5)

Scientific Knowledge is Based on Empirical Evidence
- Science knowledge is based on empirical evidence. (HS- ESS3-5)
- Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4),(HS-ESS3-5)

ESS2-4)

ESS2.A: Earth Materials and Systems
- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-2)
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4)

ESS2.C: The Roles of Water in Earth's Surface Processes
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5)

ESS2.D: Weather and Climate
- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-2),(HS-ESS2-4)
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6),(HS-ESS2-7)
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4)

ESS2.E: Biogeology
- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7)

ESS2.D: Weather and Climate
- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary to HS- ESS3-6)

ESS3.D: Global Climate Change
- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)
- 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. (HS-ESS3-6)

PS4.B Electromagnetic Radiation
- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. (secondary to HS-ESS1-2)

be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-5)

Stability and Change
- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-7)
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-5)
- Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-2)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- 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-ESS1-2)

Influence of Engineering, Technology, and Science on Society and the Natural World
- 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-ESS2-2)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-ESS1-2)
- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2)

Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-ESS1-2),(HS-ESS2-5),(HS-ESS2-6); **HS.PS1.B** (HS-ESS2-5),(HS-ESS2-6); **HS.PS1.C** (HS-ESS1-2); **HS.PS3.A** (HS-ESS1-2),(HS-ESS2-4); **HS.PS3.B** (HS-ESS1-2), (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS3-5); **HS.PS3.D** (HS-ESS2-6),(HS-ESS3-5); **HS.PS4.A** (HS-ESS1-2); **HS.PS4.B** (HS-ESS2-2); **HS.LS1.C** (HS-ESS2-6),(HS-ESS3-5); **HS.LS2.A** (HS-ESS2-7); **HS.LS2.B** (HS-ESS2-2),(HS-ESS2-6),(HS-ESS3-6); **HS.LS2.C** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-7),(HS-ESS3-6); **HS.LS4.A** (HS-ESS2-7); **HS.LS4.B** (HS-ESS2-7); **HS.LS4.C** (HS-ESS2-7); **HS.LS4.D** (HS- ESS2-2),(HS-ESS2-7),(HS-ESS3-6); **HS.ESS1.C** (HS-ESS2-4); **HS.ESS2.A** (HS-ESS3-2),(HS-ESS3-6); **HS.ESS2.D** (HS-ESS3-5)**HS.ESS3.C** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6); **HS.ESS3.D** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-ESS1-2),(HS-ESS2-5),(HS-ESS2-6); **MS.PS3.A** (HS-ESS2-4); **MS.PS3.B** (HS-ESS2-4),(HS-ESS3-5); **MS.PS3.D** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6),(HS-ESS3-5); **MS.PS4.B** (HS-ESS1-2),(HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6); **MS.LS1.C** (HS-ESS2-4); **MS.LS2.A** (HS-ESS2-7); **MS.LS2.B** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6); **MS.LS2.C** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-7),(HS-ESS3-6); **MS.LS4.A** (HS-ESS2-7); **MS.LS4.B** (HS-ESS2-7); **MS.LS4.C** (HS-ESS2-2),(HS-ESS2-7); **MS.ESS1.A** (HS-ESS1-2); **MS.ESS1.C** (HS-ESS2-7); **MS.ESS2.A** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6),(HS-ESS2-7),(HS-ESS3-5),(HS-ESS3-6); **MS.ESS2.B** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6); **MS.ESS2.C** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6),(HS-ESS2-7),(HS-ESS3-6); **MS.ESS2.D** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS3-5); **MS.ESS3.C** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6),(HS-ESS2-7)**,**(HS-ESS3-5),(HS-ESS3-6); **MS.ESS3.D** (HS-ESS2-2),(HS- ESS2-4),(HS-ESS2-6)**,**(HS-ESS3-5),(HS-ESS3-6)

Common Core State Standards Connections:

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

ELA/Literacy –	
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS1-2),(HS-ESS2-2),(HS-ESS3-5)
RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-ESS2-2),(HS-ESS3-5)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ESS3-5)
WHST.9-12.1	Write arguments focused on discipline-specific content. (HS-ESS2-7)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-ESS1-2)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-ESS2-5)
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-ESS2-4)
Mathematics –	
MP.2	Reason abstractly and quantitatively. (HS-ESS1-2),(HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6),(HS-ESS3-5),(HS-ESS3-6)
MP.4	Model with mathematics. (HS-ESS2-4),(HS-ESS2-6),(HS-ESS3-6)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS1-2),(HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6), (HS-ESS3-5),(HS-ESS3-6)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS1-2),(HS-ESS2-4),(HS-ESS2-6),(HS-ESS3-5),(HS-ESS3-6)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS1-2),(HS-ESS2-2),(HS-ESS2-4),(HS- ESS2-5),(HS-ESS2-6),(HS-ESS3-5),(HS-ESS3-6)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-ESS1-2)
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-ESS1-2)
HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.(HS-ESS1-2)