<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model to predict the relationships between systems or between components of a system.</td><td>PS1.A: Structure and Properties of Matter
• Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
• The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment is limited to main group elements.
• Assessment does not include quantitative understanding of ionization energy beyond relative trends.
• <u>Students do not need to know:</u> Properties of individual elements, names of groups, anomalous electron configurations (Chromium and Copper)</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-1:
• Potassium chloride (KCl) tastes similar to table salt (sodium chloride (NaCl)).
• Balloons are filled with helium gas instead of hydrogen gas.
• Scientists work with silicate substrates in chambers filled with Argon instead of air.
• Diamond, graphene, and fullerene are different molecules/materials that are only made of carbon.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of periodic table components (periods, groups, etc.), including distractors, the components needed to model the phenomenon.</td></tr>
<tr><td colspan="4">2. Make predictions about the properties of elements based on the number of valence electrons. Predictions can be made by completing illustrations or selecting from lists with distractors.</td></tr>
<tr><td colspan="4">3. Identify missing components, relationships, or other limitations of the model. (Hydrogen similar to Alkali metals, one valence electron, and Halogens, missing only one valence electron).</td></tr>
<tr><td colspan="4">4. Describe, select, or identify the relationships among components of the periodic table that describe the properties of valence electrons, or explains the properties of elements.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing explanations and designing solutions
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>PS1.A: Structure and Properties of Matter
• The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

PS1.B: Chemical Reactions
• The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.

Content Limits
• Assessment is limited to chemical reactions involving main group elements and combustion reactions.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-2:
• A coal oven without proper ventilation produces billows of dark smoke.
• Two metals are placed in water. One bubbles and fizzes, while the other gives off a yellow flame and white smoke.
• Carlsbad Caverns is a large cave in New Mexico. Inside, large pointy structures appear to be growing from the ceiling.
• A shiny metallic solid is combined with a green gas, resulting in a white crystalline solid.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Use relationships identified in the data to predict properties of other chemical compounds/elements/mixtures.</td></tr>
<tr><td colspan="4">2. Identify patterns or evidence in the data that supports inferences about the properties of other chemical compounds/elements/mixtures.</td></tr>
<tr><td colspan="4">3. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations.</td></tr>
<tr><td colspan="4">4. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
</table>

5. Use an explanation to predict the properties of other chemical compounds/elements/mixtures given a change in reagents or conditions.
6. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations relating to the periodic table. This may include sorting out distractors.
7. Select, articulate, or construct an explanation about a chemical reaction. This may include identifying/selecting the products of the reaction as part of an explanation.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.</td><td>PS1.A Structure and Properties of Matter
• The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on understanding the strength 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.

Content Limits
• Assessment does not include Raoult’s law, nor calculations of vapor pressure.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-3:
• Two neighbors apply different salt treatments to their driveways the night before a freeze is predicted. The next morning, no ice formed on one of their driveways. However, the other driveway was covered with a thin layer of ice.
• A chef makes salad dressing by completely mixing oil, water, and vinegar in a large container. Afterwards, he pours the mixed dressing from the large container into individual containers and places one container on each of the restaurant’s tables before leaving for the night. In the morning, the chef finds a layer of oil floating on top of a liquid layer in each of the containers on the tables.
• After working with painting oils, an artist finds that she must wash her hands with soap and water to remove the oil from her hands, as rinsing with water alone does not remove the oil.
• A glass is completely filled with water. When coins are added to the full glass of water, the surface of the water rises above the rim of the glass without spilling.
• A thin layer of oil is applied to one sheet of plastic wrap and the second sheet of plastic wrap remains untreated. After water droplets are dropped onto each plastic sheet, the water droplets form a sphere on the oiled plastic, while the water droplets spread into a sheet of water on the untreated plastic.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify from a list, including distractors, the materials/tools needed for an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.</td></tr>
</table>

2. Identify the outcome data that should be collected in an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.
3. Evaluate the sufficiency and limitations of collected data about the physical properties/interactions of substances at the bulk scale to explain the phenomenon.
4. Make and/or record observations about the physical properties/interactions of substances at the bulk scale that provide evidence to support inferences about the relative strengths of the electrostatic attractions between the particles of those substances.
5. Interpret, summarize, and/or communicate the data from an investigation concerning the physical properties/interactions of substances at the bulk scale.
6. Explain or describe the causal processes that lead to the observed data.
7. Select, describe, or illustrate a prediction concerning the physical properties of or interactions between additional substance(s), and/or the strength of electrostatic attractions between the particles of additional substance(s), made by applying the findings from an investigation.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>PS1.A: Structure and Properties of Matter
• A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

PS1.B: Chemical Reactions
• Chemical processes, their rates, and whether or not e1nergy 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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawing and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.

Content Limits
• Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS1-4:
• Scientists gather samples of rock from the ocean floor. One sample looks and feels like ice, but burns and produces a flame when ignited.
• Wet cement is left sitting outside. After one day, the cement becomes hard and stiff.
• A temperature of a sample of tin is lowered from room temperature to 0 °C. The tin changes color from silver to gray, becomes brittle, and starts developing cracks on its surface.
• Baking soda is added to a container of citric acid at room temperature. The resulting solution becomes cold, and returns back to room temperature after 2 minutes.
• An oil lamp is lit by a match. The resulting flame lasts for several hours.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include models of bonds breaking and forming, heat absorbed or released, or aspects of a chemical reaction.</td></tr>
<tr><td colspan="4">2. Assemble or complete, from a collection of potential model components, an illustration or flow chart that is capable of representing a release or absorption of energy from a chemical reaction. This <u>does not</u> include labeling an existing diagram.</td></tr>
<tr><td colspan="4">3. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon.</td></tr>
<tr><td colspan="4">4. Make predictions about the effects of changes in bond energies. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.</td></tr>
</table>

5. Describe, select, or identify the relationships among components of a model that describes a release or absorption in energy, or explains why a release or absorption in energy is dependent on total bond energy.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.</td><td>PS2.A: Forces and Motion
• Newton's second law accurately predicts changes in the motion of macroscopic objects.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.
Content Limits
Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.
Stating the law or naming the law is not part of this PE.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">The phenomenon for these PEs are the given data. Samples of phenomena should describe the data set(s) to be given in terms of patterns or relationships to be found in the data, and the columns and rows of a hypothetical table presenting the data, even if the presentation is not tabular. The description of the phenomenon should describe the presentation format of the data (e.g., maps, tables, graphs, etc).

Some example phenomena for HS-PS2-1:
Force is removed from two vehicles' accelerator pedals. The vehicles' positions over time are given.
A water tank railcar is pulled by a train engine at constant speed and develops a leak allowing water to escape. The position and velocities of the water tank and train over time are given.
A heavy model rocket rises a shorter distance than a lighter model rocket using the same type of engine. The position of each rocket over time is given.
A falling skydiver's velocity increases for several minutes and then reaches a maximum speed. The velocity of the skydiver over time is given.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), make calculations or summarize data to highlight trends, patterns, or correlations.</td></tr>
<tr><td colspan="4">2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends or relationships in the motion of a macroscopic object. This may include sorting out distractors.</td></tr>
<tr><td colspan="4">3. Construct, state, or select a claim or propose a design solution based on the relationships identified in the data.</td></tr>
<tr><td colspan="4">4. Use relationships identified in the data to predict the motion of and changes in the motion of macroscopic objects.</td></tr>
</table>

5. Identify patterns or evidence in the data that supports inferences about the motion of and changes in the motion of macroscopic objects.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena to describe explanations</td><td>PS2.A: Forces and Motion
• Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
• If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.</td><td>Systems and System Models
• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle
• Students should not be deriving formulas but can be using and manipulating them

Content Limits
• Assessment is limited to systems of no more than two macroscopic bodies moving in one dimension.
• <u>Students do not need to know:</u>
o How to use a derivation to show that momentum is conserved only when there is no net force.
o How to derive formulas regarding conservation of momentum.
o How to resolve vectors and apply the understanding that momentum must be conserved in all directions.
o Newton’s Laws by name</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS2-2:
• A pool player hits a cue ball towards a stationary 8-ball. The cue ball collides with the 8-ball, causing the 8-ball to move. The 8-ball slows down until it comes to a rest 5 seconds after the collision.
• Two pool balls collide with each other and two soccer balls collide with each other. After the collision, the soccer balls come to a stop quicker than the pool balls.
• A pool player hits a cue ball towards a stationary 8-ball. The cue ball collides with the 8-ball. The velocity of the 8-ball 1 second after the collision is greater than the velocity of the 8-ball 2 seconds after the collision.
• Two hockey pucks collide during an ice hockey practice. A player realizes that the two pucks take a long time to come to rest on the ice. After practice, he makes two street hockey pucks collide on pavement. The pucks come to a stop more quickly than the ones on the ice did.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Make simple calculations using given data to calculate or estimate the total momentum in the system OR the momentum of individual objects within the system.</td></tr>
<tr><td colspan="4">2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate the total momentum in the system OR the momentum of individual objects within the system.</td></tr>
</table>

3.	Calculate or estimate properties or relationships between momentum and other forces based on data from one or more sources.
4.	Identify data or compile from given information, the information needed to support inferences about net force and/or how momentum is conserved within a system. This can include sorting out the relevant data from the given information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS2-3
Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.</td><td>PS2.A: Forces and Motion
• If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

ETS1.A: Defining and Delimiting an Engineering Problem
• 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)

ETS1.C: Optimizing the Design Solution
• Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary)</td><td>Cause and Effect
• Systems can be designed to cause a desired effect.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Limited to qualitative evaluations and/or algebraic manipulations</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Engineering Standards are built around meaningful design problems rather than phenomena. For this Standard, the design problem and solutions replace phenomena.

Some example design problems for HS-PS2-3:
• Bikers need to be both protected and have total visibility when riding. Design a helmet that protects the biker from collisions while maintaining awareness for his surroundings.
• Phone screens can be easily broken if dropped on the ground. Design a phone case that protects the phone from collisions while maintaining functionality.
• Design a material that can be implemented on a pool table, athletic field turf (fake grass), or miniature golf green to prevent wear and tear on the playing surface.
• Design an instrument case so that the instrument will still be in good condition even if the case is subject to being dropped or rolled around.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify or assemble from a collection, including distractors, the relevant aspects of the problem, that with the given design solutions, if implemented, will resolve/improve the device by minimizing impact force.</td></tr>
<tr><td colspan="4">2. Using the given information, select or identify the criteria against which the device or solution should be judged.</td></tr>
</table>

3. Using given data, propose/illustrate/assemble a potential device (prototype) or solution in order to minimize impact forces.
4. Using given information, select or identify constraints that the device or solution must meet.
5. Using a simulator, test a proposed prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS3-1
Create a computational model to calculate the change in 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.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Create a computational model or simulation of a phenomenon, designed device, process or system</td><td>PS3.A: Definitions of Energy
• Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.B: Conservation of Energy and Energy Transfer
• Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
• Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
• Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
• The availability of energy limits what can occur in any system.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on explaining the meaning of mathematical expressions used in the model.

Content Limits
• Assessment is limited to
    o Basic algebraic expressions or computations
    o Systems of two or three components
    o Thermal energy, kinetic energy, and/or the energies in gravitational, magnetic and electric fields.
• <u>Students do not need to know:</u>
    o A detailed understanding of circuits or thermodynamics</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS3-1:
• A block is attached to a spring and laid down on a table. The spring is stretched by pulling the block a certain distance. The spring is then released. As the block oscillates back and forth, the amplitude of each successive oscillation gets smaller until the block stops moving.
• A light bulb is hooked up to an energy source. When a resistor is added in series to the circuit, the brightness of the light bulb dims.</td></tr>
</table>

	• Two metal pots are placed on a stove top. Pot 1 has a metal handle while Pot 2 has a rubber handle. The stove is turned on and the pots heat up. After 10 minutes, the handle on Pot 1 is much hotter than the handle on Pot 2. • A toy truck is placed at the top of a frictionless ramp. When it travels down the ramp it collides with a stationary toy truck sitting on a horizontal surface (with friction) at the bottom of the ramp. The truck at the bottom of the ramp then begins to move.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Make simple calculations using given data to calculate or estimate the amount of energy in certain components of the system.
2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate how energy changes in one component of the system affect the energy changes in another component of the system OR how the flow of energy into and out of the system affects the energy change of each component within the system.
3. Calculate or estimate properties for, or the relationships between, each component of the system based on data from one or more sources.
4. Compile, from given information, the particular data needed for a particular inference about how energy changes in one component of the system affects the energy changes in another component of the system. This can include sorting out the relevant data from the given information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS3-2
Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects)</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system</td><td>PS3.A: Definitions of Energy
• Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
• At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light and thermal energy.
• These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields movers across space.</td><td>Energy and Matter
• Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of phenomena at the macroscopic scale could include:
  o The conversion of kinetic energy to thermal energy
  o The energy stored due to position of an object above the Earth
  o The energy stored between two electrically-charged plates.
• Examples of models could include diagrams, drawings, descriptions, and computer simulations

Content Limits
• <u>Students do not need to know:</u>
  o Thermodynamics in detail
  o Gravitational fields
  o Thermonuclear fusion</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS3-2:
• Two electrically charged plates, one with a positive charge and one with a negative charge, are placed a certain distance apart. Electron 1 is placed in the middle of the two plates. It accelerates to the positive plate and hits it with a certain velocity. Electron 2 is then placed closer to the negative plate. This electron gains more speed before reaching the positive plate.
• A gas is placed inside a container and sealed with a piston. The outside of the container is heated up. The piston begins to move upwards.
• A person rubs their hands together. Afterwards their hands feel warm.</td></tr>
</table>

	• A block is attached to a spring and placed on a horizontal table. When the spring is un-stretched, the spring and block do not move. When the spring is stretched to a certain distance (x), the block oscillates back and forth. • A ball is raised to a height (h) above Earth. When it is dropped it hits the ground with a certain velocity (v). The ball is then raised to twice the previous height. When it is dropped, the ball hits the ground with a greater velocity than it did previously.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Select or identify from a collection of potential model components, including distractors, the components needed to model the phenomenon. Components might include equations used to calculate energy or objects used to set up the experimental model. The model can be a conceptual model (flow chart).
2. Manipulate the components of a model to demonstrate how energy at the macroscopic scale can be accounted for as a combination of energy associated with the workings of particles at the microscopic scale, result in the observation of the phenomenon.
3. Make predictions about the effects of changes in the motion or relative position of objects in the model. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.
4. Identify missing components, relationships, or other limitations of the model showing how energy at the macroscopic scale is affected by the motion and positioning of particles at the microscopic scale.
5. Describe, select, or identify the relationships among components of a model that describes, or explains, how energy is related to the motion and relative position of objects.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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).</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.</td><td>PS3.B: Conservation of Energy and Energy Transfer
• Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
• Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

PS3.D: Energy in Chemical Processes
• Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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 is limited to investigations based on materials and tools provided to students.</td></tr>
<tr><td>Science Vocabulary Students are Expected to Know</td><td colspan="3">Specific heat, specific heat capacity, store, transfer, kinetic energy, conservation of energy, microscopic scale, macroscopic scale, thermal energy, molecular energy, heat conduction, heat radiation, Law of Conservation of Energy, Kelvin, Second Law of Thermodynamics, Joules, calorimetry</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Entropy, root mean velocity, Boltzmann’s constant, gravitational fields, fusion, fission</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS3-4:
• The temperature of a can of soda decreases when the can is placed in a container of ice.
• Hot coffee cools down after cold cream is added to the cup.
• A scoop of ice cream begins to melt when added to cold soda in a glass.
• A foam cup has 200 grams of room temperature water after 100 grams of hot water are mixed with 100 grams of cold water.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify, make, plan, and/or record observations/outcome data concerning changes in substances’ properties in order to provide evidence of transfer of thermal energy within a closed system.</td></tr>
</table>

2.	Organize, arrange, and/or generate/construct graphs, flowcharts, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations among observations and data concerning transfer of thermal energy within a closed system, and/or the boundaries of a closed system in which thermal energy is transferred.
3.	Describe, analyze, and/or summarize data (e.g., using illustrations and/or labels), to identify/highlight trends, perform calculations and other mathematical analyses, and identify patterns or correlations among observations and data concerning the transfer of thermal energy within a closed system.
4.	Use evidence to identify the boundaries of a closed system in which thermal energy is transferred.
5.	Identify patterns or evidence in the data that support inferences related to the transfer of thermal energy within a closed system.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-PS4-1
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.</td><td>PS4.A: Wave properties
• The wavelength and frequency of a wave are related to each other by the speed of travel of the wave, which depends on the type of wave and the media through which it is passing.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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 Earth.

Content Limits
• Assessment is limited to algebraic relationships and describing those relationships qualitatively.
• Students are not expected to produce equations from memory, like Snell's Law, but the concepts and relationships should be assessed.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-PS4-1:
• A person uses their car horn in an effort to attract the attention of their friend who is swimming in a pool a short distance away. The friend hears only muffled noises.
• A person opens their curtains so that the sun shines in the window. A diamond in their necklace begins to sparkle brightly.
• An earthquake occurs in Japan. The vibrations are recorded in Brazil, but not in Miami.
• A person sees a fish through the glass wall of a rectangular fish tank. The person moves and looks through the end of the tank. The fish appears to be in a different place.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Make calculations using given data to calculate or estimate relationships among the frequency, wavelength, speed of waves, and the media that they travel in.</td></tr>
<tr><td colspan="4">2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate relationships among the frequency, wavelength, speed of waves, and the media that they travel in.</td></tr>
<tr><td colspan="4">3. Calculate or estimate properties or relationships among the frequency, wavelength, and speed of waves in various media based on data from one or more sources.</td></tr>
<tr><td colspan="4">4. Compile, from given information, the particular data needed for a particular inference about a relationship among the frequency, wavelength, speed of waves, and the media they travel in. This can include sorting out the relevant data from the given information.</td></tr>
<tr><td colspan="4">5. Use quantitative or abstract reasoning to support a claim/explanation about a particular relationship between the velocity, wavelength, and frequency.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS1.A: Structure and Function
• Systems of specialized cells within organisms help them perform the essential functions of life.
• All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.</td><td>Structure and Function
• Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and the connections of these components in order to solve problems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Content Limits
• 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.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Sample phenomena for HS-LS1-1:
• Sweat glands cool the body by releasing sweat onto the skin's surface. A protein transports salt to help carry the water to the skin's surface. In some individuals, the salt is not reabsorbed and is left on the skin.
• When a blood vessel is cut, several proteins act to form a blood clot. This blood clot helps to stop the loss of blood from the body. In some individuals, when a blood vessel is cut, a blood clot does not form.
• During cell division, a copy of DNA in the cell is made. Sometimes mistakes are made in the DNA copy that are corrected by specific proteins. In some cells, when those mistakes in the DNA are not corrected, uncontrolled cellular division results.
• After a person eats, sugars from food are absorbed from the bloodstream into the body's cells. Insulin—a polypeptide hormone—allows those cells to absorb glucose from the bloodstream. In some individuals, sugars are not absorbed into the body's cells and are left in the bloodstream.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe the cause and effect relationship between a DNA sequence and the structure/function of a protein. This may include indicating the directions of causality in a model or completing a cause and effect chain.</td></tr>
<tr><td colspan="4">2. Describe, identify, or select evidence that supports or contradicts a claim about the role of DNA in causing the phenomenon. The evidence may be obtained from valid source(s) or might be generated by students using a simulation.</td></tr>
<tr><td colspan="4">3. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes to a DNA sequence in protein structure and function. Predictions may be selected from a collection of possibilities, including distractors, or they might be illustrated or described in writing.</td></tr>
<tr><td colspan="4">4. Use evidence to construct an explanation of how protein structure and subsequent function depend on a DNA sequence.</td></tr>
<tr><td colspan="4">5. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-2
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>LS1.A: Structure and Function
▪ Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.</td><td>Systems and System Models
• Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment does not include interactions and functions at the molecular or chemical reaction level (e.g., hydrolysis, oxidation, reduction, etc.).
• Assessment does not include mutations in genes that could contribute to modified bodily functions.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-2:
• After a healthy person eats a large meal, both their blood pressure and heart rate increase.
• When a normal adult male exercises, both his breathing rate and heart rate increase.
• The area around a person’s skin where a small scab has formed feels warm to the touch.
• Skin surface capillaries dilate when a person feels hot.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete an illustration or flow chart that is capable of representing how structures in two (or more) body systems interact to carry out normal, necessary bodily functions. This <u>does not</u> include labeling an existing diagram. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">2. Using the developed model, identify and describe the relationships between the structures and their coordinated functions in two (or more) body systems.</td></tr>
<tr><td colspan="4">3. Using the developed model, show that interacting systems have a hierarchical organization and provide specific functions within the body at those specific levels or organization. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">4. Make predictions about, or generate explanations for, how additions/substitutions/removal of certain components in the model can interrupt or change the relationships between those components and, thus, the bodily functions carried out by those structures in two (or more) body systems.</td></tr>
<tr><td colspan="4">5. Given models or diagrams of hierarchical organization of interacting systems, identify the components and the mechanism in each level of the hierarchy OR identify the properties of the components that allow those functions to occur.</td></tr>
</table>

6. Identify missing components, relationships, or other limitations of the model.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-3
Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</td></tr>
<tr><td>Dimensions</td><td>Planning and Carrying Out Investigations
• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence. 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.</td><td>LS1.A: Structure and Function
• Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.</td><td>Stability and Change
• Feedback (negative or positive) can stabilize or destabilize a system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.

Content Limits
• Assessment does not include the cellular processes involved in the feedback mechanism.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-3:
• Fruit ripeness (positive feedback loop):
o In nature, a tree or bush will suddenly ripen all of its fruits or vegetables without any visible signal.
• Human blood sugar concentration (negative feedback loop):
o The liver both stores and produces sugar in response to blood glucose concentration.
o The pancreas releases either glucagon or insulin in response to blood glucose concentration.
• Water content of plant cells (negative feedback loop):
o Stomata are generally open during the daytime when photosynthesis is active and are closed at night. However, scientists observe that stomata may even close during the day under hot, dry conditions.
o Guard cells surrounding the stomata expand and dilate in response to turgor/water pressure.
• Human digestion (positive feedback loop):
o Once digestion begins, it becomes a self-accelerating process.
• Dragonfly posture (negative feedback loop):
o Dragonfly's obelisk posture is an adaptation that minimizes the amount of body surface exposed to the sun. Posture helps reduce heat gain by radiation.
• Sunning lizards (negative feedback loop):
o Lizards sun on a warm rock to regulate body temperature.
• Thermoregulation in dolphins due to counter-current arrangement of veins around arteries (negative feedback loop):
o The counter-current system minimizes the loss of heat incurred when blood travels to the different parts of dolphins' bodies.
• Hawk-moths shiver as a preflight warm up (includes both negative and positive feedback):
o Hawk-moths shiver to contract and warm up their thoracic muscles before flight.</td></tr>
</table>

	• Incubation of Burmese pythons' eggs (negative feedback loop):
	  ○ A Burmese python wraps herself around her eggs and contracts her muscles to keep the eggs warm.
	• Ectotherms vs Endotherms (negative feedback loop):
	  ○ Cold-blooded fish use the environmental temperature to control their internal temperatures and therefore cannot maintain a constant metabolic rate. In contrast, warm-blooded whales use homeostasis to maintain their internal temperatures and therefore can maintain a constant metabolic rate.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Identify the outcome data that should be collected in an investigation to provide evidence that feedback mechanisms maintain homeostasis. This could include measurements and/or identifications of changes in the external environment, the response of the living system, stabilization/destabilization of the system's internal conditions, and/or the number of systems for which data are collected.
2. Make and/or record observations about the external factors affecting systems interacting to maintain homeostasis, responses of living systems to external conditions, and/or stabilization/destabilization of the systems' internal conditions. ***(SEP/DCI/CCC)**
3. Identify or describe the relationships, interactions, and/or processes that contribute to and/or participate in the feedback mechanisms maintaining homeostasis that lead to the observed data.
4. Using the collected data, express or complete a causal chain explaining how the components of (a) mechanism(s) interact in response to a disturbance in equilibrium in order to maintain homeostasis. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains. ***(SEP/DCI/CCC)**
5. Evaluate the sufficiency and limitations of data collected to explain the cause and effect mechanism(s) maintaining homeostasis.

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Performance Expectation	**HS-LS1-4** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.		
Dimensions	**Developing and Using Models** • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.B: Growth and Development of Organisms** • In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
Clarifications and Content Limits	**Clarification Statements** • Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis. **Content Limits** • <u>Students do not need to know</u>: Specific stages of mitosis (Interphase, G1 phase, S phase, G2 phase, prophase, metaphase, anaphase, telophase, cytokinesis).		
Phenomena			
Context/ Phenomena	Some example phenomena for HS-LS1-4: • Genomic sequencing of a parent cell and one of its daughter cells reveals that both have the same genetic makeup. • At the end of an hour, approximately 30,000 skin cells were shed by a person, but a loss of mass was not noticeable. • Ears and noses can be grown from stem cells in laboratory. • Plant cells in a root tip longitudinal cross section are different sizes and shapes.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			
1. Assemble or complete an illustration or flow chart that is capable of representing how a parent (somatic) cell is formed through fertilization, undergoes cellular division, forming daughter cells, and how those daughter cells contain all genetic material from the parent cells but differentiate via gene expression necessary. This does **not** include labeling an existing diagram.*(**SEP/DCI/CCC)**			
2. Using the model, identify and describe the relationship between the amount and composition of the genetic material that daughter cells receive from parent cells.			
3. Using the model, show that in multicellular organisms, different cell types arise from differential gene expression, not because of dissimilar genetic material within the cell's nucleus.			
4. Use a model of cellular division and differentiation to explain/illustrates the relationships between components that allow multicellular organisms to grow and carry out specific and necessary functions. *(**SEP/DCI/CCC)**			
5. Given models or diagrams of cellular division and differentiation, show that cells form tissues and organs that have specific structures and interact to carry out specific and necessary functions.			

6. Identify missing components, relationships, or other limitations of the model.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS1-5
Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model based on evidence to illustrate the relationship between systems or between components of a system.</td><td>LS1.C: Organization for Matter and Energy Flow in Organisms
• The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment does not include specific biochemical steps or cell signaling pathways.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-5:
• A maple tree in Washington state survives in the winter after losing all of its leaves.
• The waters of the Laguna Grande lagoon in Puerto Rico give off a bluish-green glow at night when disturbed.
• On the sill of a stained glass window, a soy plant behind the red glass panel grew taller than a soy plant behind the green glass panel.
• In a parking lot in the city of Bordeaux, France a tank filled with algae produces a green light.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete, from a collection of potential model components and distractors, an illustration or flow chart that is capable of representing the transformation of light energy into stored chemical energy.</td></tr>
<tr><td colspan="4">2. Use a model to identify and describe the relationships in terms of matter and/or energy between the reactants and the products of photosynthesis. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">3. Use a model to show the transfer of matter and flow of energy between an organism and its environment during photosynthesis. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">4. Make predictions about how additions/substitutions/removals of model components affect the transformation of light energy into stored chemical energy. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">5. Sort relevant from irrelevant information to support a model that demonstrates how sugar and oxygen are produced by carbon dioxide and water through the process of photosynthesis.</td></tr>
<tr><td colspan="4">6. Given models or diagrams of photosynthesis, identify the components and the mechanism in each scenario OR identify the properties of the components that allow photosynthesis to occur. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">7. Identify missing components, relationships, or other limitations of a model intended to show how photosynthesis transforms light energy into stored chemical energy.</td></tr>
</table>

8. Describe changes of energy and matter that occur in a system due to photosynthesis.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS1.C: Organization for Matter and Energy Flow in Organisms
• Sugar molecules formed contain carbon, hydrogen, and oxygen. Their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used, for example, to form new cells.
• As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.</td><td>Energy and Matter
• Changes of energy and matter in a system can be described as energy and matter flowing into, out of, and within that system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using evidence from models and simulations to support explanations.

Content Limits
• Assessment does not include the details of the specific chemical reactions or identification of macromolecules.
• <u>Students do not need to know:</u> Specific biochemical pathways and processes. Specific enzymes, oxidation-reduction</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-6:
• Hagfish produce and are covered in a thick layer of protective slime.
• The black widow spider's silk is several times as strong as any other known spider silk, making it about as durable as Kevlar.
• The female silk moth, releases a pheromone that is sensed by the male's feather-like antennae, inducing his excited fluttering behavior.
• The bombardier beetle release a boiling, noxious, pungent spray that can repel potential predators.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe, identify, or select evidence supporting or contradicting a claim that sugar molecules containing organic elements (e.g., carbon, hydrogen, and oxygen) that are ingested by an organism are broken down and rearranged via chemical reactions to form proteins, lipids, and nucleic acids.</td></tr>
<tr><td colspan="4">2. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.</td></tr>
<tr><td colspan="4">3. Express or complete a description of the flow of energy and/or matter within and between living systems. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.*(DCI/CCC)</td></tr>
</table>

4.	Articulate, describe, or select the relationships, interactions, reactions and/or processes to be explained. This may entail sorting relevant from irrelevant information or features of the reactants and products**.* (SEP/DCI/CCC)**
5.	Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in the amount and types of organic molecules ingested and the amount and type of products formed within a living system.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>LS1.C: Organization for Matter and Energy Flow in Organisms
• As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products
• As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.</td><td>Energy and Matter
• Energy cannot be created or destroyed—it only moves between one place and another, between objects and/or fields, or between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statement
• Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.

Content Limits
• Students aren’t expected to identify the steps or specific processes involved in cellular respiration.
• Assessment does not include mechanisms of cellular respiration (enzymatic activity, oxidation, molecular gradients, etc.).
• <u>Students do not need to know:</u> enzymes, ATP synthase, metabolism, biochemical pathways, redox reactions, molecular transport.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS1-7:
• A young plant is grown in a bowl of sugar water. As it grows, the amount of sugar in the water decreases.
• A bacterial colony in a petri dish is continually provided with sugar water. Over the course of a few days, the bacteria grow larger. When sugar water is no longer provided, the colonies shrink and some disappear.
• Fungus grows on a damp piece of tree bark on the ground. When the tree bark is completely gone, the fungus stops growing and eventually dies.
• Mushrooms grow on a rotting tree stump. While the number of mushrooms increases, the tree stump slowly decays.
• A person feels tired and weak before eating lunch. After eating some fruit, the person feel more energetic and awake.
• An athlete completing difficult training feels that her muscles recover and repair faster when she eats more food in a day, compared to when she ate less food in a day.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
</table>

1. Assemble or complete an illustration or flow chart that is capable of representing the transformation of food plus oxygen into energy and/or new compounds. This *does not* include labeling an existing diagram.
2. Using the developed model, identify and describe the relationships between the reactants of the transformation and the products of the transformation.*** (SEP; DCI; CCC)**
3. Using the developed model, show that matter and energy are only rearranged during cellular respiration, but never created or destroyed.
4. Make predictions about how additions/substitutions/removals of certain components can maintain/destroy the balance of the food plus oxygen → energy/new compounds reaction.*** (SEP; DCI; CCC)**
5. Given models or diagrams of cellular respiration, identify the components and the mechanism in each scenario OR identify the properties of the components that allow cellular respiration to occur.
6. Identify missing components, relationships, or other limitations of the model.
7. Describe, select, or identify the relationships among components of a model that describe or explain cellular respiration.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-1
Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematical and Computational Thinking
• Use mathematical and/or computational representations of phenomena or design solutions to support explanations</td><td>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 challenges such as predation, competition and disease. Organisms would have the capacity to produce populations of greater 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.</td><td>Scale, Proportion, and Quantity
• The significance of a phenomenon is dependent on the scale, proportion, and quantity involved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.
• Examples of mathematical representations include finding the average, determining trends, and using graphic comparisons of multiple sets of data.

Content Limits
• Assessment does not include deriving mathematical equations to make comparisons.
• <u>Students do not need to know:</u> Calculus/advanced mathematics (e.g., exponential growth and decay).</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-1:
• On Ngorogoro Crater in Tanzania in 1963, a scientist sees that there are much fewer lions than there were on previous visits.
• On St. Matthew Island, reindeer were introduced in 1944, but today no reindeer can be found on the island.
• In Washington State, more harbor seals are present today than in the past.
• In Alaska, you can see many more brown bears in Lake Clark National Park than in Denali National Park.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Make calculations using given data to calculate or estimate factors affecting the carrying capacity of an ecosystem. *(SEP/DCI)</td></tr>
<tr><td colspan="4">2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate factors affecting the carrying capacity of ecosystems of different scales. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">3. Calculate or estimate properties of or relationships between factors affecting the carrying capacity of an ecosystem based on data from one or more sources.</td></tr>
</table>

4.	Compile, from given information, the data needed for a particular inference about factors affecting the carrying capacity of an ecosystem. This can include sorting out the relevant data from the given information and representing the data through graphs, charts, and/or histograms.
5.	Use quantitative or abstract reasoning to make a claim about the factors that affect the carrying capacity of an ecosystem.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematical and Computational Thinking
• Use mathematical representations of phenomena or design solutions to support and revise explanations.</td><td>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 results from factors such 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 greater size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
• A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient) as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of mathematical representations include finding the average, determining trends, and using graphic comparisons of multiple sets of data.

Content Limits
• Assessment is limited to provided data.
• <u>Students do not need to know</u>: Calculus/advanced mathematics (e.g., exponential growth and decay)</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-2:
• After brown tree snakes were accidentally introduced to Guam in the 1950s, 11 native bird species went extinct.
• When European settlers decreased the wolf population for safety, deer populations thrived and overconsumed native plant species.
• California’s Central Valley can support fewer waterfowl in the winter during drought.
• The cones of Lodgepole pines do not release their seeds until a fire melts the resin that keeps them sealed.</td></tr>
</table>

	• Advancements in agriculture allowed the human population growth rate to drastically increase.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Make simple calculations using given data to calculate or estimate factors affecting biodiversity and populations in ecosystems.
2. Illustrate, graph, or identify relevant features or data that can be used to calculate or estimate factors affecting biodiversity and populations in ecosystems of different scales.
3. Calculate or estimate properties of or relationships between factors affecting biodiversity and populations in ecosystems based on data from one or more sources.
4. Compile, from given information, the data needed for a particular inference about factors affecting biodiversity and populations in ecosystems. This can include sorting out the relevant data from given information.
5. Construct an explanation regarding the relationship between biodiversity and populations in ecosystems of different scales using the given, calculated, or compiled information.
6. Revise or evaluate a given explanation of the relationship between biodiversity and populations in ecosystems of different scales based on the given, calculated, or compiled information.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, and peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
• Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for the processes.</td><td>Energy and Matter
• Energy drives the cycling of matter within and between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.
• Emphasis is on conceptual understanding that the supply of energy and matter restricts a system’s operation; for example, without inputs of energy (sunlight) and matter (carbon dioxide and water), a plant cannot grow.

Content Limits
• Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.
• Students do not need to know: lactic acid vs. alcoholic fermentation, chemical equations for photosynthesis, cellular respiration, or fermentation.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-3:
• After running for a long period of time, human muscles develop soreness and a burning sensation, and breathing rate increases.
• Bread baked with yeast looks and tastes differently than bread that is baked without yeast.
• A plant that is watered too much will have soft, brown patches on their leaves and will fail to grow.
• Cyanobacteria differ from other bacteria in that cyanobacteria appear blue-green in color and also lack flagella.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe, identify, or select evidence supporting or contradicting a claim about the role of photosynthesis and aerobic and anaerobic respiration in the cycling of matter and energy in an ecosystem.</td></tr>
<tr><td colspan="4">2. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.</td></tr>
<tr><td colspan="4">3. Express or complete a description of the flow of energy and/or matter between organisms. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.</td></tr>
<tr><td colspan="4">4. Articulate, describe, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features of the reactants and products.</td></tr>
<tr><td colspan="4">5. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the flow of matter and energy between organisms.</td></tr>
</table>

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-4
Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematical and Computational Thinking
• Use mathematical representations of phenomena, or design solutions to support claims.</td><td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
▪ Plants or algae from 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.</td><td>Energy and Matter
• Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.
• <u>Students do not need to know</u>: the specific biochemical mechanisms or thermodynamics of cellular respiration to produce ATP or of photosynthesis to convert sunlight energy into glucose.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-4:
• In the 6,000-hectare rainforest of San Lorenzo, Panama, there are 312 arthropods for every mammal, including humans.
• In Silver Springs, Florida, the biomass of plants is 809 g/m^2, while the biomass of large fish is 5 g/m^2.
• A herd of grazing caribou in the Seward Peninsula of Alaska are seen eating the leaves of birch trees in July. In December, they are seen eating tree lichen.
• A pine tree growing in a forest remains in one location throughout its lifetime. A fox in the same forest moves around every day of its life.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Calculate or estimate changes or differences in matter and energy between trophic levels of an ecosystem. **</td></tr>
</table>

2. Illustrate, graph, or identify a mathematical model describing changes in stored energy through trophic levels of an ecosystem.**
3. Compile and interpret data from given information to establish the relationship between organisms at different trophic levels.***(SEP/DCI/CCC)**
4. Use quantitative or abstract reasoning to make a claim about the cycling of matter and flow of energy through the trophic levels of an ecosystem. This may include sorting relevant from irrelevant information. ***(SEP/DCI/CCC)**
5. Identify and describe the components of a mathematical representation of an ecosystem that could include relative quantities related to organisms, matter, energy, and the food web of that ecosystem.

*denotes those task demands which are deemed appropriate for use in stand-alone item development
**TDs 1 and 2 may be used for stand-alones in combination with TD3 and TD4.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or components of a system.</td><td>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
▪ Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

PS3.D: Energy in Chemical Processes
▪ The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary)</td><td>Systems and System Models
• Models (e.g., physical, mathematical, or computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of models could include simulations and mathematical models.

Content Limits
• Assessment does not include the specific chemical steps of photosynthesis and respiration.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-5:
• A herd of cows grazing in a field wear balloon-like backpack devices on their backs.
• A piece of coal preserving a fossil leaf imprint is burned within the furnace of a coal-fired electrical power plant. Smoke generated from the fire escapes out of a smoke stack
• Several acres of trees are cut down and burned, generating clouds of smoke.
• Two mice die in the woods in November, one in Massachusetts and one in Florida. The Florida mouse decomposes much more quickly than the Massachusetts mouse.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Assemble or complete an illustration or flow chart that is capable of representing how the processes of photosynthesis and cellular respiration cycle carbon by various chemical, physical, geological, and biological processes through two or more spheres (biosphere, atmosphere, hydrosphere, geosphere). This does not include labeling an existing diagram.</td></tr>
<tr><td colspan="4">2. Using the developed model, identify and describe the relationships between the processes of photosynthesis and cellular respiration, and the coordinated functions of transferring carbon among two or more spheres (biosphere, atmosphere, hydrosphere, geosphere).</td></tr>
<tr><td colspan="4">3. Using the developed model, show that photosynthesis and cellular respiration are important parts of the overall carbon cycle that transfers carbon through two or more spheres (biosphere, atmosphere, hydrosphere, geosphere).</td></tr>
<tr><td colspan="4">4. Make predictions about, or generate explanations for, how substitutions of certain components in the model can interrupt or change the relationships between, or functions of, those components, thus effecting the cycling of carbon through the various spheres (biosphere, atmosphere, hydrosphere, geosphere).</td></tr>
</table>

5. Given models or diagrams* of the processes of photosynthesis and cellular respiration, identify the components and the mechanisms in each process that cycle carbon OR identify the properties of the components that allow those functions to occur.
6. Identify missing components, relationships, or other limitations of the model.
7. Modify/augment/add to the model to change or add steps that can alter the cycling of carbon through the various spheres (biosphere, atmosphere, hydrosphere, and/or geosphere).

*Labeled diagrams by themselves are not usually sufficient to serve as models.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-6
Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.</td><td>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.</td><td>Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of changes in ecosystem conditions could include modest biological or physical changes—such as moderate hunting or a seasonal flood—and extreme changes, such as volcanic eruption or sea-level rise.
• To show full comprehension of the PE, the student must demonstrate an understanding that, in a stable ecosystem, the average activity by the nutrients, decomposers, producers, primary consumers, secondary consumers, and tertiary consumers remains relatively consistent. When each of these levels has high levels of diversity, the ecosystem is stable because the group as a whole is better able to respond to pressures. However, even a healthy, diverse ecosystem is subject to extreme changes when faced with enough pressure.

Content Limits
• Assessment does not include Hardy-Weinberg equilibrium calculations.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-6:
• The populations of rabbits and deer in the Florida Everglades significantly decreased with the introduction of the Burmese python.
• Biodiversity of an area of the Amazon rainforest is affected differently in sustainable and non-sustainable lumber farms.
• After a fire, the biodiversity of a forest immediately decreases but eventually increases.
• An increase in mouse populations are observed the year after a flood but return to pre-flood numbers the following year.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Based on the provided data or information, identify the explanation that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.</td></tr>
<tr><td colspan="4">2. Identify and/or explain the claims, evidence, and reasoning supporting the explanation that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.</td></tr>
</table>

3.	Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the complex interactions in ecosystems, factors that affect biodiversity, relationships between species and the environment, and changes in numbers of species and organisms in a stable or changing ecosystem.
4.	Evaluate the strengths and weaknesses of a claim to explain the relationship of biodiversity and the environment in an ecosystem based on the evidence or data provided. ***(SEP/DCI/CCC)**
5.	Analyze and/or interpret evidence and its ability to support the explanation of the resiliency of an ecosystem in response to different levels of change. ***(SEP/DCI/CCC)**
6.	Provide and/or evaluate reasoning to support the explanation that an ecosystem remains relatively consistent when faced with modest disturbances, but it may experience extreme changes or fluctuations in biodiversity when faced with extreme disturbances. ***(SEP/DCI/CCC)**

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-7
Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.</td><td>LS2.C: Ecosystem Dynamics, Functioning, and Resilience
• Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

LS4.D: Biodiversity and Humans
• Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary)

ETS1.B: Developing Possible Solutions
• When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary)</td><td>Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of human activities can include urbanization, building dams, and dissemination of invasive species.

Content Limits
• Assessment does not include physical equations describing mechanics of solutions or mechanics of engineered structures.
• <u>Students do not need to know</u>: quantitative statistical analysis, specific conditions required for failure, specifics of constructing the solution.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example of phenomena for HS-LS2-7:
• The spread of cities through urbanization has destroyed wildlife habitats across the planet.
• Air pollution from driving cars has made the air unsafe to breathe in many areas.
• Dams have led to flooding of large areas of land, destroying animal habitats.
• Fishing has drastically changed marine ecosystems, removing certain predators or certain prey.
• Intensive farming and overgrazing have led to deforestation and desertification.
• Logging for wood/timber has led to deforestation and the destruction of wildlife habitats.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Express or complete a causal chain explaining how human activity impacts the environment. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause-and-effect chains.</td></tr>
</table>

3. Identify evidence supporting the inference of causation that is expressed in a causal chain.
4. Use an explanation to predict the environmental outcome, given a change in the design of human technology.
5. Describe, identify, and/or select information needed to support an explanation.
6. Identify or describe relevant aspects of the problem that given design solutions for reducing the impacts of human activities on the environment and biodiversity, if implemented, will resolve or improve.
7. Using given information about the effects of human activities on the environment and biodiversity, select or identify criteria against which the solution should be judged.
8. Using given information about the effects of human activities on the environment and biodiversity, select or identify constraints that the solution must meet.
9. Evaluate the criteria and constraints, along with trade-offs, for a proposed or given solution to resolve or improve the impact of human activities on the environment and biodiversity.
10. Using given data, propose a potential solution to resolve or improve the impact of human activities on the environment and biodiversity.
11. Using a simulator, test a proposed solution to resolve or improve the impact of human activities on the environment and biodiversity and evaluate the outcomes.
12. Evaluate and/or revise a solution to resolve or improve the impact of human activities on the environment and biodiversity and evaluate the outcomes

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS2-8
Evaluate the evidence for the role of group behavior on individual and species’ chances to survive and reproduce.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.</td><td>LS2.D: Social Interactions and Group Behavior
• Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• <u>Students do not need to know:</u>
o How to develop or analyze computer simulations and mathematical models that emulate the flocking behavior of animals.
o Individual genes or complex gene interactions determining individual animal behavior.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS2-8:
• Several hundred naked mole rats are observed living together in a colony. However, only one large naked mole rat is observed reproducing, while the others in the colony bring her food.
• A worker bee is observed flying away from its colony. Upon returning many other worker bees crowd around him while he moves in a distinct pattern.
• A lioness charges toward a large herd of galloping zebra, but then stops and runs away in the opposite direction.
• A tiger shark exhibits a “yo-yo” swimming pattern through a school of fish off the shores of Hawaiʻi.
• A certain species of short-horned grasshoppers changes color, band together, and fly over several square kilometers over a period of a few weeks.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Based on the provided data, identify, describe, or construct a claim regarding how specific group behavior(s) can increase an individual’s or species’ chances of surviving and reproducing.</td></tr>
<tr><td colspan="4">2. Sort inferences about the effect of specific group behaviors on an individual’s and species’ chances to survive and reproduce into those that are supported by the data, contradicted by the data, outliers in the data, or neither, or some similar classification.</td></tr>
<tr><td colspan="4">3. Identify patterns of information/evidence in the data that support correlative/causative inferences about the effect of specific group behaviors on an individual’s and species’ chances to survive and reproduce. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">4. Construct an argument using scientific reasoning, drawing on credible evidence to explain the effect of specific group behaviors on an individual’s and species’ chances to survive and reproduce.</td></tr>
</table>

5.	Identify additional evidence that would help clarify, support, or contradict a claim or causal argument regarding the effect of specific group behaviors on an individual's and species' chances to survive and reproduce.
6.	Identify, summarize, or organize given data or other information to support or refute a claim regarding the effect of specific group behaviors on an individual's and species' chances to survive and reproduce. ****(SEP/DCI/CCC)**

*denotes those task demands which are deemed appropriate for use in stand-alone item development

**TD6 – summarize is the emphasis here. Avoid identify and organize.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Asking Questions and Defining Problems
• Ask questions that arise from examining models or a theory to clarify relationships.</td><td>LS1.A: Structure and Function
• All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary)

LS3.A: Inheritance of Traits
• Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements:
• All cells in an organism have identical DNA but certain genes are expressed in specific cells, causing cell differentiation.
• At this level, the study of inheritance is restricted to Mendelian genetics, including dominance, codominance, incomplete dominance, and sex-linked traits.
• Focus is on expression of traits on the organism level and should not be restricted to protein production.

Content Limits:
• Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.
• Assessment does not include mutations or species-level genetic variation including Hardy-Weinberg equilibrium.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS3-1:
• DNA sequencing shows that all people have the gene for lactase production, but only about 30% of adults can digest milk.
• Polydactyl tabby cat Jake holds the world record for most toes, with seven toes on each paw.
• Albinism exists in all mammals.
• E. coli bacteria are healthful in mammalian intestines, but makes mammals sick when ingested.
• E. coli bacteria are used to produce human insulin.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Identify or construct an empirically testable question based on the phenomenon that could lead to design of an experiment or model to define the relationships between the role of DNA and/or chromosomes in the inheritance of traits.*(SEP/DCI/CCC)</td></tr>
</table>

2.	Based on an empirically testable question, assemble or complete, from a collection of potential model components, an illustration, flow chart, or pedigree that is capable of representing the role of DNA and/or chromosomes in coding the instructions for inheritance. ***(SEP/DCI/CCC)**
3.	Construct a question that arises from examining a model or theory to clarify the connections between DNA/chromosomes and inheritance of traits.***(SEP/DCI)**
4.	Make predictions about the pattern of inheritance based on a model derived from the empirically testable question. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

**1 AND 2; 3

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS3-3
Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.</td><td>LS3.B Variation of Traits
• Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.</td><td>Scale, Proportion and Quantity
• Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.
• Sensitivity and precaution should be used around the use of both lethal recessive and dominant human traits (i.e., Huntington's, achondroplasia, Tay-Sachs, cystic fibrosis).

Content Limits
• Assessment is limited to basic statistical and graphical analysis.
• Assessment does not include Hardy-Weinberg calculations ($p^2 + 2pq + q^2 = 1$ or $p + q = 1$).
• <u>Students do not need to know:</u> pleiotropy, meiosis, specific names of genetic disorders.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS3-3:
• O Positive is the most common blood type. Not all ethnic groups have the same mix of these blood types. Hispanic people, for example, have a relatively high number of O's, while Asian people have a relatively high number of B's.
• Hydrangea flowers of the same genetic variety range in color from blue-violet to pink, with the shade and intensity of color depending on the acidity and aluminum content of the soil.
• When two purple heterozygous dominant flower plants are crossed, both purple and white flowers are produced. When two orange-colored tigers are bred, both orange and white tigers are produced.
• Most humans were born with five fingers on each hand, yet the polydactyl trait (having more than five fingers on each hand) is the dominant trait.
• When a red rose is crossed with a white rose, all pink roses are produced.
• If a red homozygous camellia flower is crossed with a white homozygous camellia flower, offspring with both red and white spots will occur.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe data or patterns/relationships in given data that support (or refute) an explanation for the change in trait frequency or magnitude in a population, due to both genetic and environmental factors. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">2. Make predictions about the trait frequency or distribution in a population due to the presence/absence or addition/removal of both genetic and environmental factors. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">3. Organize and/or arrange (e.g., using illustrations and/or labels) data, or summarize data to provide evidence for an explanation of the relationship between a trait's occurrence in a population and genetic and environmental factors.</td></tr>
</table>

4.	Analyze, evaluate, estimate, calculate, and/or construct an equation for the statistical mean and/or the standard deviation, to describe the change in the distribution of a trait in a population over time, due to genetic and environmental factors. ***(SEP/DCI/CCC)**
5.	Identify statistical anomalies or outliers for a trait or a population that are outside the expected range (norm reaction), which may or may not be quickly removed due to genetic and environmental factors.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-1
Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Communicate scientific information (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td><td>LS4.A: Evidence of Common Ancestry and Diversity
• 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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• <u>Students do not need to know</u>: specific genetic mutations, specific genetic disorders, specific proteins, Occam’s razor (maximum parsimony), formation of orthologous and paralogous genes, molecular clock, Neutral theory.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS4-1:
• Red pandas look a bit like bears and a bit like raccoons. Task Statement: Provide evidence about whether red pandas are better classified as raccoons or bears. Stimulus material might include pictures, DNA information, embryological information, and homologous structures.
• Hermit crabs live in shells, like oysters, but look like crabs. Provide evidence classifying hermit crabs either as mollusks (like oysters) or arachnids (like crabs).
• Crawfish look just like lobster, but smaller. Which came first, the lobster or the crawfish?
• Fossil records of an extinct hooved animal show a thickened knob of bone in its middle ear. This structure is also found in modern whales and helps them hear underwater.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Analyze and interpret scientific evidence from multiple scientific/technical sources including text, diagrams, charts, symbols, mathematical representations that support common ancestry among organisms and/or biological evolution.</td></tr>
<tr><td colspan="4">2. Evaluate the validity/relevance/reliability of scientific evidence about biological evolution.</td></tr>
<tr><td colspan="4">3. Identify relationships or patterns in scientific evidence at macroscopic and/or microscopic scales. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">4. Describe the specific evidence needed to support an explanation about how organisms share a common ancestor.</td></tr>
</table>

5. Synthesize an explanation that incorporates the scientific evidence from multiple sources.

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<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, and peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS4.B: Natural Selection
▪ Natural selection occurs only if there is both 1) variation in the genetic information between organisms in a population and 2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.

LS4.C: Adaptation
• Evolution is a consequence of the interaction of four factors: 1) the potential for a species to increase in number, 2) the genetic variation of individuals in a species due to mutation and sexual reproduction, 3) competition for an environment’s limited supply of the resources that individuals need in order to survive and reproduce, and 4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on using evidence to explain the influence each of the four factors has on the 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.
Content Limits
• Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.
• Students do not need to know: Hardy-Weinberg equation.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Phenomena will probably need to be augmented by actual data or multiple sources.

Some example phenomena for HS-LS4-2:
• Cane toads introduced to Australia in the 1930s have evolved to be bigger, more active, and have longer legs.
• In the late 1990s, a resurgence of bedbug outbreaks began. Bedbugs are now much harder to kill with thick, waxy exoskeletons, faster metabolism, and mutations to block certain insecticides.
• Skinks living in cooler regions give live birth, while those living in warm coastal areas lay eggs.
• A butterfly parasite found on the Samoan Islands destroyed the male embryos of blue moon butterflies, decreasing the male population to only 1%. After a year, males had rebounded to 40% of the population.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Describe the cause-and-effect relationship between: (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, and change in species over time. This may include indicating directions of causality in a model or completing cause-and-effect chains.
2. Describe, identify, or select evidence supporting or contradicting a claim about the role of (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 in causing the phenomenon. The evidence may be evidence generated by the students in the simulation or selected from provided data.
3. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the population.
4. Use evidence to construct an explanation of the changes in species over time as a result of (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.***(SEP/DCI/CCC)**
5. Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses for the changes in species over time.

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<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.</td><td>LS4.B: Natural Selection
• Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation —that leads to differences in performance among individuals.
• The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

LS4.C: Adaptation
• Natural selection leads to adaptation that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. The differential survival and reproduction of organisms in a population that have an advantageous heritable trait lead to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
• Adaptation also means that the distribution of traits in a population can change when conditions change.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.

Content Limits
• Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.
• <u>Students do not need to know</u>: sexual selection, kin selection, artificial selection, frequency-dependent selection.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Example phenomena for HS-LS4-3:
• Green Treefrogs (Hyla versicolor) are abundant in the wetlands of Florida where no Gray Treefrogs (Hyla cinerea) are observed. In the wooded areas of New York, only Gray Treefrogs are observed.
• In the Amazon rainforest, a kapok trees (Ceiba pentandra) measures 200 feet in height, approximately 30 feet above the rest of the canopy.
• A school of mummichog fish (Fundulus heteroclitus) is found in the 6°C waters of the Chesapeake Bay. These fish are normally found in warmer climates, like the 21°C waters of Kings Bay, Georgia.
• A population of the fish Poecilia mexicana lives in the murky hydrogen-sulfide (H2S)-rich waters in southern Mexico that would kill the same species of fish living in clear freshwaters only 10 km away.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Describe or identify patterns or relationships in given data that support (or refute) an explanation for the change in trait frequency or magnitude in a population due to natural selection/selection pressure(s). ***(SEP/DCI/CCC)**
2. Make predictions about the trait frequency or distribution in a population due to the presence/absence or addition/removal of selection pressure(s) in the environment (including Hardy-Weinberg-based predictions about changes in allele/trait frequency/magnitude NOT based on calculations). ***(SEP/DCI/CCC)**
3. Organize and/or arrange (e.g., using illustrations and/or labels) data, or summarize data to provide evidence for an explanation of the effect of selection on a population.
4. Analyze, evaluate, estimate, calculate, and/or construct an equation to describe the change in the distribution of a trait in a population over time due to selection pressure(s).
5. Identify statistical anomalies or outliers for a trait or a population that are outside the expected range (for example, Joe DiMaggio’s hitting streak, tossing 10 consecutive heads on a fair coin, etc.) which may or may not be quickly removed due to selection pressure.

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<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-4
Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>LS4.C: Adaptation
• Natural selection leads to adaptation; that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. The differential survival and reproduction of organisms in a population that has 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.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">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.

Content Limits
• Assessment does not include the Hardy-Weinberg equation.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Phenomena will probably need to be augmented by actual data or multiple sources.

Some example phenomena for HS-LS4-4:
• Following a four-year drought in California, field mustard plants are found to flower earlier in the season.
• A new antibiotic is discovered. Within ten years, many bacterial diseases that were previously treated by the antibiotic no longer respond to treatment (e.g., MRSA).
• A small population of Italian wall lizards that feed mainly on insects is introduced to a neighboring island. After several decades, the lizards are found to have thrived and heavily populated the island, and their diet is now mostly vegetation.
• Following climatic changes, the European Great Tit bird begins laying eggs earlier in the spring.
• The orchid mantis resembles the orchid flower and attracts pollinators.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Describe the cause and effect relationship between natural selection and adaptation using evidence. This may include assembling descriptions from illustrations or lists of options and distractors, or indicating directions of causality in a model or completing cause and effect chains.</td></tr>
<tr><td colspan="4">2. Describe, identify, or select evidence supporting or contradicting a claim about the role of adaptation in causing the phenomenon. The evidence may be generated by the students in a simulation.</td></tr>
<tr><td colspan="4">3. Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the population.</td></tr>
</table>

4.	Use evidence to construct an explanation of the adaptation of a species through natural selection. Evidence can be described, identified, or selected/assembled from lists with distractors. Explanations can be written, assembled by manipulating the components of a flow chart or model, or assembled from lists of options that include distractors. Options and distractors should not be single words or short phrases; rather, they should be complete thoughts that, when correctly emplaced within a sentence or paragraph, work to provide evidence of a coherent train of thought. ***(SEP/DCI/CCC)**
5.	Identify and justify additional pieces of evidence that would help distinguish among competing hypotheses.

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<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.</td><td>LS4.C: Adaptation
• Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes extinction—of some species.
• Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species’ evolution is lost.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• <u>Students do not need to know</u>: Hardy Weinberg Equation.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-LS4-5:
• PCB pollution in the Hudson River wiped out many fish species, but the Atlantic tomcod thrives there (results 1 and 3).
• The population of Greater Prairie Chickens in Illinois decreased from millions of birds in the 1800s to fewer than 50 birds in 1993 (result 3).
• In 1681 the dodo bird went extinct due to hunting and introduction of invasive species (result 3).
• In 1988, the Orange-Spotted Filefish went extinct in response to warmer ocean temperatures (result 3).
• Climate Change has led to a decrease in the health and quantity of coral reefs world-wide, which also affect species that depend on the reef habitat (result 3).</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Based on the provided data, identify, describe, or construct a claim regarding the effect of changes to the environment on the (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.</td></tr>
<tr><td colspan="4">2. Sort inferences about the effect of changes to the environment on (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 into those that are supported by the data, contradicted by the data, outliers in the data, or neither, or some similar classification. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">3. Identify patterns of information/evidence in the data that support correlative/causative inferences about the effect of changes to the environment on the (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. *(SEP/DCI/CCC)</td></tr>
</table>

4.	Construct an argument and/or explanation using scientific reasoning drawing on credible evidence to explain the effect of changes to the environment on the (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.
5.	Identify additional evidence that would help clarify, support, or contradict a claim or causal argument regarding the effect of changes to the environment on the (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.
6.	Identify, summarize, or organize given data or other information to support or refute a claim regarding the effect of changes to the environment on (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. ***(SEP/DCI/CCC)**

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<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-LS4-6
Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Create or revise a simulation of a phenomenon, designed device, process, or system.</td><td>LS4.C: Adaptation
• Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species.
LS4.D: Biodiversity and Humans
• Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

ETS1.B: Developing Possible Solutions
• When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts (secondary).
• 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 (secondary).</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.
The simulation should model the effect of human activity and provide quantitative information about the effect of solutions on threatened or endangered species or to genetic variation within a species.
Content Limits
<u>Students do not need to know</u>: Calculus/advanced mathematics (e.g., exponential growth and decay)</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
</table>

Context/ Phenomena	Some example phenomena for HS-LS4-6: • The habitat of the Florida Panther is only 5% of its former range, causing the species to become endangered. • The café marron plant is critically endangered due to massive habitat destruction on the Island of Rodrigues in the Indian Ocean, as a result of deforestation for agricultural use. • The population of Atlantic Bluefin Tuna has declined by more than 80% since 1970 due to overfishing. • In the past 120 years, about eighty percent of suitable orangutan habitat in Indonesia has been lost from expansion of oil palm plantations. At the same time, the estimated number of orangutans on Borneo, an island in Indonesia, has declined from about 230,000 to about 54,000.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Use data to calculate or estimate the effect of a solution on mitigating the adverse impacts of human activity on biodiversity.
2. Illustrate, graph, or identify features or data that can be used to determine how effective a solution is for mitigating the adverse impacts of human activity on biodiversity.
3. Estimate or infer the properties or relationships that lead to mitigation of the adverse impacts of human activity on biodiversity, based on data.
4. Compile the data needed for an inference about the impacts of human activity on biodiversity. This can include sorting out the relevant data from the given information.
5. Using given information, select or identify the criteria against which the solution should be judged.
6. Using a simulator, test a proposed solution and evaluate the outcomes; may include proposing modifications to the solution.*

*In order to satisfy this PE, the student must use a simulator. Therefore, this task demand must always be used.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-1
Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation.</td></tr>
<tr><td>Dimensions</td><td>Developing and using models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>ESS1.A: The Universe and Its Stars
• The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

PS3.D: Energy in Chemical Processes and Everyday Life
• Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (secondary)</td><td>Scale, Proportion, and Quantity
• The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun’s core to reach Earth.
• Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun’s radiation varies due to sudden solar flares (“space weather”), the 11-year sunspot cycle, and non-cyclic variations over centuries.

Content Limits
• Assessment does not include details of the atomic and sub-atomic processes involved with the sun’s nuclear fusion.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS1-1:
• The habitable zone in our solar system currently contains both Earth and Mars. In the future it will contain a different set of planets.
• The sun's current surface temperature is about 5,800 K. In 5 billion years, the sun's surface temperature will cool to 3,500 K.
• The sun is 40% brighter, 6% larger than 5% hotter than it was 5 billion years ago.
• The Earth’s atmosphere will contain more water vapor and the oceans will contain less water in a few billion years.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), summarize or make inferences about data to highlight trends, patterns, or correlations.</td></tr>
<tr><td colspan="4">2. Identify patterns or evidence in the data that supports inferences about the lifespan of the sun or the transfer of energy from the sun to the earth.</td></tr>
<tr><td colspan="4">3. Select or identify from a collection of potential model components, including distractors, the components needed for a model that illustrates the lifespan of the sun or the transfer of energy from the sun to the earth.</td></tr>
<tr><td colspan="4">4. Construct or complete a model capable of illustrating the lifespan of the sun or the transfer of energy from the sun to the earth.</td></tr>
<tr><td colspan="4">5. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that relevant to the lifespan of the sun or the transfer of energy from the sun to the earth.</td></tr>
<tr><td colspan="4">6. Identify missing components, relationships, or other limitations of the model.</td></tr>
</table>

7. Make predictions about the effects of changes in the sun or in the transfer of energy from the sun to the earth. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, 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.</td><td>ESS1.A: The Universe and Its Stars
• The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
• The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
• Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

PS4.B: Electromagnetic Radiation
• Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. (secondary)</td><td>Energy and Matter
• Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the astronomical evidence of the redshift 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).</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example Phenomena for HS-ESS1-2:
• The farthest known galaxy has a greater recessional velocity than the farthest known quasar.
• The spectrum of NGC450 shows a greater abundance of elements heavier than helium than does the spectrum of NGC60
• Two galaxy clusters observed in opposite parts of the sky both contain galaxies with about the same chemical composition: 75% hydrogen and 25% helium.
• A galaxy in the constellation Cetus is moving away from us at a different speed than another galaxy in the adjacent constellation Pisces.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail organizing, interpreting and analyzing data, making calculations, and sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Identify evidence that supports and/or does not support the Big Bang Theory.</td></tr>
</table>

3. Describe, select, or identify components of the Big Bang Theory supported by given evidence.
4. Use an explanation of the Big Bang Theory to predict how the universe will continue to change over time.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS1-3
Communicate scientific ideas about the way stars, over their life cycle, produce elements.</td></tr>
<tr><td>Dimensions</td><td>Obtaining, Evaluating, and Communicating Information
• Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td><td>ESS1.A: The Universe and Its Stars
• The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
• Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.</td><td>Energy and Matter
• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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.

Content Limits
• Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.
• Include basic/simplified nucleosynthesis reactions:
o Hydrogen fuses into helium
o Helium fuses into carbon
o Carbon fuses into oxygen
o Oxygen fuses into silicon
o Silicon fuses into iron
• Exclude complex nucleosynthesis reactions and details:
o CNO cycle
o Neutron-capture (r-process and s-process)
o Proton-capture: Rp-process
o Photo-disintegration: P-process
o Other details about radiation or particles – focus on conservation of nucleons</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomenon for HS-ESS1-3:
• Two larger stars, Spica and Pollux are eight times larger than the sun. However, Spica is 420 times brighter and 6 times more massive than Pollux.
• Procyon is a 1.5 solar mass star and is 8 times brighter than the sun. Aldebaran is a star of similar mass but Aldebaran is 425 times brighter than the sun.
• The stars in a globular cluster (old low mass stars) are red and show few absorption lines in their spectra while the stars in an open cluster (young high mass stars) are blue and show many absorption lines in their spectra.
• In the core of some stars, carbon can fuse into neon, sodium or magnesium.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Illustrate, model or make calculations involving the nucleosynthesis process in stars of different mass, different luminosity, different age or different evolutionary stage using graphs, diagrams, text and mathematical models.</td></tr>
</table>

2.	Compare and contrast the nucleosynthesis processes of stars of different mass, different luminosity, different age or different evolutionary stage using graphs, diagrams, text and mathematical models.
3.	Make predictions about nucleosynthesis processes given changes or differences in other stellar characteristics.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td>ESS2.A. Earth Materials and Systems
• Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.B. Plate Tectonics and Large-Scale System Interactions
• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geologic history.
• Plate movements are responsible for most of continental and ocean-floor features and for the distribution of most rocks and minerals within Earth’s crust.</td><td>Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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).

Content Limits
• <u>Students do not need to know:</u> the details of the formation of specific geographic features of Earth’s surface.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some sample phenomena for HS-ESS2-1:
• A limestone cliff that contains Cambrian-aged fossils extends several hundred feet above the surface of the ocean. A large section of the cliff has collapsed.
• An oceanic trench 10,000 is meters below sea level. Inland, 200km away, a chain of active volcanoes is present.
• 1.8 billion year old rocks in the Black Hills of South Dakota are capped by 10,000 year old gravel terraces.
• A photograph from March shows large Precambrian-aged pink granite boulder at the top of a 100 m tall hill. A photograph in April shows the same boulder sitting in a pile of soil and sediment in the valley below the hill.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Select or identify from a collection of potential model components, including distractors, the components that are relevant for explaining the phenomenon. Components might include different rock types, rates of uplift and erosion, surface environments on Earth where these processes occur and where different rock types exist, and layers within Earth where these processes occur. Sources of energy (radiation, convection) that drive the cycling (but not the creation of) matter should also be included as components. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">2. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon of Earth’s internal and surface processes.</td></tr>
<tr><td colspan="4">3. Make predictions about the effects of changes in the magnitude and/or rate of Earth’s internal and surface properties. Predictions can be made by manipulating model components, completing illustrations, or selecting from lists with distractors.</td></tr>
</table>

4.	Given models or diagrams of land features, internal and surface processes, identify factors that affect constructive and destructive forces, feedback effects and how they vary in different scenarios OR identify the constructive and destructive mechanisms that operate at different spatial and temporal time scales and how this causes changes in the appearance of continental and ocean-floor features.
5.	Identify missing components, relationships, or other limitations of the model of how Earth's internal and surface processes form continental and ocean-floor features.
6.	Describe, identify, or select the relationships among components of a model that describe the formation of continental and ocean-floor features with respect to spatial and temporal variability in internal and external surface processes or explains how changes in these processes affect the formation of continental and ocean-floor features. ***(SEP/DCI/CCC)**
7.	Express or complete a causal chain explaining how changes in the flow of energy (interval vs. surface processes) affect the formation of continental and ocean-floor features. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-2
Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to Earth’s systems.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze data using tools, technologies and/or models (e.g. computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design.</td><td>ESS2.A: Earth Materials and Systems
• Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

ESS2.D: Weather and Climate
• The foundation for the 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.</td><td>Stability and Change
• Feedback (negative or positive) can stabilize or destabilize a system.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples should include climate feedbacks, such as:
o 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.
o Loss of ground vegetation causes an increase in water runoff and soil erosion
o Damned rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion
o Loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.

Content Limits
• <u>Students do not need to know:</u>
o Specifically which gases are greenhouse gases.
o Composition of the atmosphere</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-2:
• Farming causes the loss of forest in the Amazon. This leads to an increase in erosion and water runoff, which leads to more forest loss.
• Loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.
• As the Permafrost in the Artic melts, methane is released into the atmosphere. Methane, a greenhouse gas, traps heat causing the Earth to heat up, leading to more Permafrost melting.
• Increased CO2 in the atmosphere warms the oceans. Warmer oceans take up less CO2 than cooler oceans, further increasing atmospheric temperature.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in how changes to Earth’s surface can create feedbacks that affect Earth’s systems.</td></tr>
<tr><td colspan="4">2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in how changes to Earth’s surface can create feedbacks that affect Earth’s systems. This may include sorting out distractors.</td></tr>
<tr><td colspan="4">3. Use relationships identified in the data to predict how changing the Earth’s surfaces affects the feedback loop.</td></tr>
</table>

4. Identify patterns or evidence in the data that supports inferences about how the altering of Earth's surface will affect the Earth in the long term.

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Developing and Using Models
• Use a model to provide mechanistic accounts of phenomena.</td><td>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 Earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary)

ESS2.A: Earth Materials and Systems
• The geologic record shows that changes to global and regional climate can be caused by interactions among changes in the sun’s energy output of Earth’s orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of timescales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

ESS2.D: Weather and Climate
• The foundation for Earth’s global climate system is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy’s re-radiation into space.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of the causes of climate change differ by time scale, 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.

Content Limits
• 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.
• <u>Students do not need to know:</u> chemical mechanisms of fossil fuel combustion or ozone depletion</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-4:
• Temperatures were warmer in 1990 than in the 5 previous years. In 1992 and 1993, the global temperatures were 1°F cooler than in 1991. (volcanic eruption of Mount Pinatubo)
• 11,000 years ago large portions of the northern United States contained glaciers. Today, very little of this area contains glaciers. (changes to Earth’s orbit)
• Earth experiences 4 distinct seasons. Venus does not experience distinct seasons. (tilt of planet’s axis)
• 25,000 years ago, the level of carbon dioxide in the atmosphere was around 180 parts per million (ppm). Today, carbon dioxide levels exceed 400 ppm. (atmospheric composition)</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Select or identify from a collection of potential model components, including distractors, the components that are relevant for explaining the phenomenon. Components might include factors that affect the input, storage, redistribution, and output of energy in Earth's systems.
2. Manipulate the components of a model to demonstrate the changes, properties, processes, and/or events that act to result in the phenomenon of the flow of energy in Earth's systems.
3. Make predictions about the effects of changes in energy flow on Earth's climate.
4. Given models or diagrams of energy flow in Earth's systems, identify factors that affect energy input, output, storage, and redistribution and how they change in different scenarios OR identify the changes in energy flow that cause changes in Earth's climate.
5. Identify missing components, relationships, or other limitations of the model of energy flow in Earth's systems.
6. Describe, identify, or select the relationships among components of a model that describe changes in the flow of energy in Earth's systems or explains how changes in energy flow affect climate.
7. Express or complete a causal chain explaining how changes in the flow of energy in Earth's systems affects climate. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS2-7
Construct an argument based on evidence about the simultaneous coevolution of Earth’s systems and life on Earth.</td></tr>
<tr><td>Dimensions</td><td>Engaging in Argument from Evidence
• Construct an oral and written argument or counter-arguments based on data and evidence.</td><td>ESS2.D: Weather and Climate
• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.

ESS2.E: Biogeology
• The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth’s surface and the life that exists on it.</td><td>Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and the Earth’s 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 plats; or how the evolution of corals created reefs that altered patterns or erosion and deposition along coastlines and provided habitats for the evolution of new life forms.

Content Limits
• Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth’s other systems.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS2-7:
• Eospermatopteris fossils (first trees) begin to appear in rocks dated 390 million years. Fossils of Tiktaalik (four legged fish), one of the earliest land animals, are found in the rock layers above Esopermatopteris.
• The appearance of cyanobacteria is recorded in fossils that formed roughly 3.5 billion years ago. Superior Type banded iron formed roughly 1.8 to 2.7 billion years ago. It is characterized by alternating red and gray layers of iron rich minerals and silica rich minerals.
• The Rhynie Chert beds in Aberdeenshire Scotland contain detailed fossils of early plants. Bryophyte fossils from about 500 million years ago, show small simple structured plants. Cooksonia pertoni fossils from about 430 million years ago show plants that were larger, spore bearing, and contained tissues that move water through the plant (vascular).
• In 2016 two-thirds of the Northern portion of the Great Barrier Reef experienced severe bleaching. The Great Barrier Reef prior to this event, was made up of corals with a variety of bright colors that attracted a variety of marine life. In 2016, the coral turned completely white and few fish inhabit the area where bleaching has occurred.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Express or complete a causal chain explaining how Earth’s systems coevolved simultaneously with life on Earth. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains.</td></tr>
</table>

3. Identify and/or describe additional relevant evidence not provided that would support or clarify the explanation of the simultaneous coevolution of Earth's systems and life on Earth. This may entail sorting relevant from irrelevant information or features.
4. Construct or identify from a collection, including distractors, an explanation based on evidence that explains how Earth's systems coevolved simultaneously with life on Earth. ***(SEP/DCI/CCC)**
5. Describe, identify, and/or select information and/or evidence needed to support an explanation. This may entail sorting relevant from irrelevant information or features.

*denotes those task demands which are deemed appropriate for use in stand-alone item development

<table>
<tr><td>Performance Expectation</td><td colspan="3">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.</td></tr>
<tr><td>Dimensions</td><td>Constructing Explanations and Designing Solutions
• Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td><td>ESS3.A: Natural Resources
• Resource availability has guided the development of human society.

ESS3.B: Natural Hazards
• Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.</td><td>Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels.
• Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts).
• Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Content Limits
• <u>Students do not need to know:</u> distribution of specific resources</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-1:
• In 2001, 85% of Australians lived within 50 km of the ocean.
• There are large solar power plants in the southern California desert. California solar power had a capacity of 18,296 MW in 2016. In the same year, New York State had a capacity of 927 MW.
• As many as 1.5 million inhabitants of Dhaka, Bangladesh, have moved there from villages near the Bay of Bengal.
• After the eruption of Mt. Vesuvius in 79 AD, the city of Pompeii was completely buried in volcanic ash. The city was never reoccupied and was lost for more than 1,500 years.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features.</td></tr>
<tr><td colspan="4">2. Express or complete a causal chain explaining how resource availability/natural hazards/climate change drive changes in human society/population/migration. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains. *(SEP/DCI/CCC)</td></tr>
<tr><td colspan="4">3. Identify evidence supporting the inference of causation that is expressed in a causal chain.</td></tr>
</table>

4. Use an explanation to predict the change in human /activity given a change in resource availability/natural hazards/climate.
5. Describe, identify, and/or select information and/or evidence needed to support an explanation.
6. Construct an explanation based on evidence that explains that the availability of natural resources/occurrence of natural hazards/changes in climate have influenced human activity. ***(SEP/DCI/CCC)**

*denotes those task demands which are deemed appropriate for use in stand-alone item development.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS3-3
Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.</td></tr>
<tr><td>Dimensions</td><td>Using Mathematics and Computational Thinking
• Create a computational model or simulation of a phenomenon, designed device, process, or system.</td><td>ESS3.C: Human Impacts of Earth Systems
• The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources.</td><td>Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• Examples of factors that affect the management of natural resources include the costs of resource extraction and waste management, per-capita consumption, and development of new technologies.
• Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.

Content Limits
• Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-3:
• The number of birds and other wildlife in an area decreases by 30% after a shopping mall is built in northern California.
• Two 1,330 square-foot homes are side by side in northern California. One has six solar panels on the roof, and the other does not. During one month in June, the one with solar panels produces less carbon dioxide than the other house by 384 pounds.
• Beetles are present throughout a forest. Chemicals are sprayed at intervals needed to control the beetles on one acre. Fifty years later, this acre is the only part of the forest that has oak trees.
• Three species of fish, the Colorado squawfish, the roundtail chub, and the bonytail chub became extinct in the years immediately following construction of the Glen Canyon Dam in Colorado.</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Use data to calculate or estimate the effect of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity.</td></tr>
<tr><td colspan="4">2. Illustrate, graph, or identify features or data that can be used to determine the effects of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity.</td></tr>
<tr><td colspan="4">3. Estimate or infer the effects of an action or solution that affects natural resources, the sustainability of human populations, and/or biodiversity. *(in combination with TD4 only)</td></tr>
<tr><td colspan="4">4. Compile the data needed for an inference about the impacts of an action or solution on natural resources, the sustainability of human populations, and/or biodiversity. This can include sorting out the relevant data from the given information (or choosing relevant inputs for a simulation). *(SEP/DCI – in combination with 3 to hit CCC)</td></tr>
<tr><td colspan="4">5. Using given information, select or identify the criteria against which the solution should be judged.</td></tr>
</table>

6.	Using a simulator, test a proposed action or solution and evaluate the outcomes; may include proposing modifications to the action or solution. ***(SEP/DCI/CCC)**
7.	Evaluate and/or critique models, simulations, or predictions in terms of identifiable limitations and whether or not they yield realistic results. ***(SEP/DCI/CCC)**

*denotes those task demands which are deemed appropriate for use in stand-alone item development. NOTE: If TD 3 or TD4 are used, they must be paired with another approved TD.

<table>
<tr><td>Performance Expectation</td><td colspan="3">HS-ESS-3-5
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 on Earth's systems.</td></tr>
<tr><td>Dimensions</td><td>Analyzing and Interpreting Data
• Analyze data using computational models in order to make valid and reliable scientific claims.</td><td>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.</td><td>Stability and Change
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">Clarification Statements
• 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 sea level, glacial ice volumes, or atmosphere and ocean composition).

Content Limits
• Assessment is limited to one example of a climate change and its associated impacts.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">Some example phenomena for HS-ESS3-5:
• The model predictions for the Great Lakes region of the United States consist of increased precipitation of 5-30% during the spring and decreased precipitation of 5-10% in the summer.
• Concentrations of CO_2 under the higher emissions scenario for 2100 could reach as high as 850 parts per million (ppm).
• Global warming of 2°C is predicted by the year 2050
• The model mean global temperature change for a high emissions scenario is 4-6°</td></tr>
<tr><td colspan="4">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4">Task Demands</td></tr>
<tr><td colspan="4">1. Organize and/or arrange (e.g., using illustrations and/or labels), or summarize data to highlight trends, patterns, or correlations in global or regional climate models and their associated future impacts on Earth's systems.</td></tr>
<tr><td colspan="4">2. Generate/construct graphs, tables, or assemblages of illustrations and/or labels of data that document patterns, trends, or correlations in global or regional climate models to forecast regional climate change and the associated future impacts on Earth's systems. This may include sorting out distractors.</td></tr>
<tr><td colspan="4">3. Use relationships identified in the data to forecast the current rate of global or regional climate change and how it will affect Earth's systems.</td></tr>
<tr><td colspan="4">4. Identify patterns or evidence in the data that supports inferences about how the changing of global or regional climates will affect Earth's systems in the long term.</td></tr>
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