INDIANA DEPARTMENT of EDUCATION

ILEARN Biology End-of-Course Assessment Item and Item Cluster Specifications

Beginning School Year 2023-2024

Introduction

This document presents *cluster specifications* for use with the Next Generation Science Standards (NGSS). These standards are based on the Framework for K-12 Science Education. The present document is not intended to replace the standards, but rather to present guidelines for the development of items and item clusters used to measure those standards.

The remainder of this section provides a very brief introduction to the standards and the framework, an overview of the design and intent of the item clusters, and a description of the cluster specifications that follow. The bulk of the document is composed of cluster specifications, organized by grade and standard.

Background on the framework and standards

The Framework for K-12 Science Education are organized around three core dimensions of scientific understanding. The standards are derived from these same dimensions:

- Disciplinary Core Ideas: The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.
- Science and Engineering Practices: The practices are what students DO to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems.
- Cross-Cutting Concepts: These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.
- There is substantial overlap between and among the three dimensions. For example, the cross-cutting concepts are echoed in many of the disciplinary core ideas. The core ideas are often closely intertwined with the practices. This overlap reflects the nature of science itself. For example, we often come to understand and communicate causal relationships by employing models to make sense of observations. Even within a dimension, overlap exists. Quantifying characteristics of phenomena is important in developing an understanding of them, so employing computational and mathematical thinking in the construction and use of models is a very common scientific practice, and one of the cross-cutting concepts suggests that scientists often infer causality by observing patterns. In short, the dimensions are not orthogonal.

The framework envisions effective science education as occurring at the intersection of these interwoven dimensions: students learn science by doing science—applying the practices through the lens of the cross-cutting concepts to investigate phenomena that relate to the content of the disciplinary core ideas.

Item clusters

Each item cluster is designed to engage the examinee in a grade-appropriate, meaningful scientific activity aligned to a specific standard.

Each cluster begins with a phenomenon, an observable fact or design problem that engages student interest and can be explained, modeled, investigated, or designed using the knowledge and skill described by the standard in question.

What it means to be observable varies across practices. For example, a phenomenon for a performance expectation exercising the a*nalyze data* practice may be observable through regularities in a data set, while standards related to the *development and use of models* might be something that can be watched, seen, felt, smelled, or heard.

What it means to be observable also varies across grade levels. For example, elementary-level phenomena are very concrete and directly observable. At the high school level, an observation of the natural world may be more abstract--for example, “observing” changes in the chemical composition of cells through the observation of macroscopic results of those changes on organism physiology, or through the measurement of system- or organ-level indications.

Content limits refine the intent of the performance expectations and provide limits on what may be asked of items in the cluster to structure the student activity. The content limits also reflect the disciplinary core ideas learning progressions that are present in the K-12 Framework for Science Education.

The task or goal should be explicitly stated in the stimulus or the first item in the cluster: statements such as “In the questions that follow, you will develop a model that will allow you to identify moons of Jupiter,” or “In the questions below, you will complete a model to describe the processes that lead to the steam coming out of the teapot.”

Whereas item clusters have been described elsewhere as “scaffolded,” they are better described as providing structure to the task. For example, some clusters begin with students summarizing data to discover patterns that may have explanatory value. Depending on the grade level and nature of the standard, items may provide complete table shells or labeled graphs to be drawn, or may require the student to choose what to tabulate or graph. Subsequent items may ask the student to note patterns in the tabulated or graphed data and draw on domain content knowledge to posit explanations for the patterns.

These guidelines for clusters do not appear separately in the specifications. Rather, they apply to all clusters.

Structure of the cluster specifications

The item cluster specifications are designed to guide the work of item writers and the review of item clusters by stakeholders.

Each item cluster has the following elements:

- The text of the performance expectations, including the practice, core idea, and cross-cutting concept.
- Content limits, which refine the intent of the performance expectations and provide limits of what may be asked of examinees. For example, they may identify the specific formulae that students are expected to know or not know.
- Vocabulary, which identifies the relevant technical words that students are expected to know, and related words that they are explicitly not expected to know. Of course, the latter category should not be considered exhaustive, since the boundaries of relevance are ambiguous, and the list is limited by the imagination of the writers.
- Sample phenomena, which provide some examples of the sort of phenomena that would support effective item clusters related to the standard in question. In general, these should be guideposts, and item writers should seek comparable phenomena, rather than drawing on those within the documents. Novelty is valued when applying scientific practices.
- Task demands comprise the heart of the specifications. These statements identify the types of items and activities that item writers should use, and each item written should be clearly linked to one or more of the demands. The verbs in the demands (e.g., *select, identify, illustrate, describe*) provide guidance on the types of interactions that item writers might employ to elicit the student response. We avoid explicitly identifying interaction types or item formats to accommodate future innovations and to avoid discouraging imaginative work by the item writers.
- For each cluster we present, the printed documentation includes the cluster, the task demands represented by each item, and its linkage to the practice and cross-cutting concept identified in the performance expectation.

Item cluster specifications follow, organized by domain and standard.

<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>Science Vocabulary Students are Expected to Know</td><td colspan="3">Nucleus, chromosome, DNA, nucleated cell, transcription, double helix, adenine, guanine, cytosine, thymine, deoxyribose, phosphate, hydrogen bond, nucleotide base, mRNA, amino acid, translation</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">primary, secondary, tertiary protein structure, tRNA, ribosome.</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>
</table>

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.
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.
4.	Use evidence to construct an explanation of how protein structure and subsequent function depend on a DNA sequence.
5.	Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.

<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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Circulatory, respiratory, digestive, excretory, nervous, immune, integumentary, skeletal, muscle, reproductive, external stimuli, cell, tissue, organ,</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Synaptic transmission, neuron, neurotransmitter, biofeedback, hormonal signaling.</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.*</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.*</td></tr>
</table>

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.
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.
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Equilibrium, steady state, stable state, balanced state, stimulus, receptor, biotic factor, abiotic factor, external environment, internal environment, muscle, nerve, hormone, enzyme, chemical regulator, gland, system, metabolism, disturbance, fluctuation, maintenance, concentration, hibernation, convection, conduction, radiation, evaporation.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Effector, osmoregulation, conformer, set point, sensor, circadian rhythm, acclimatization, thermoregulation, endothermic, ectothermic, integumentary system, countercurrent exchange, bioenergetics, basal metabolic rate, standard metabolic rate, torpor, poikilotherm, homeotherm, countercurrent heat exchange.</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):
  ○ 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):
  ○ The liver both stores and produces sugar in response to blood glucose concentration.
  ○ The pancreas releases either glucagon or insulin in response to blood glucose concentration.
• Sunning lizards (negative feedback loop):
  ○ 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):
  ○ The counter-current system minimizes the loss of heat incurred when blood travels to the different parts of dolphins’ bodies.</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.	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.*
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.*
5.	Evaluate the sufficiency and limitations of data collected to explain the cause and effect mechanism(s) maintaining homeostasis.

*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-LS1-4
Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.</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.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.</td><td>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.</td></tr>
<tr><td>Clarifications and Content Limits</td><td colspan="3">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 names of the stages of mitosis – Interphase, G1 phase, S phase, G2 phase, prophase, metaphase, anaphase, telophase, cytokinesis.</td></tr>
<tr><td>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Nucleus, chromosome, sister chromatids, sperm cell, egg cell, fertilize, genome, gene, differential gene expression, cellular differentiation, cellular division, cytoplasm, daughter cell, parent cell, somatic cell, cell cycle, homologous, haploid, diploid, DNA.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Spindle, metaphase plate, cleavage furrow, chromatin modification, transcription regulation initiation, enhancers, transcription factors, post-transcriptional regulation; noncoding RNAs, cytoplasmic determinants, inductive signals, chiasmata, kinetochore, microtubule.</td></tr>
<tr><td colspan="4" align="center">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">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.</td></tr>
<tr><td colspan="4" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="4" align="center">Task Demands</td></tr>
<tr><td colspan="4">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.*</td></tr>
</table>

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.*
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

Performance Expectation	**HS-LS1-5** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.		
Dimensions	**Developing and Using Models** • Use a model based on evidence to illustrate the relationship between systems or between components of a system.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.	**Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
Clarifications and Content Limits	**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.		
Science Vocabulary Students are Expected to Know	Organic, hydrocarbon, net transfer, chloroplast, chlorophyll, cytoplasm, mitochondria, vacuole, nucleus, protein, ATP, amino acid, autotroph(s), heterotroph(s), algae		
Science Vocabulary Students are Not Expected to Know	Thylakoid, NADP(H/$^{+}$), Calvin cycle, carbon fixation, redox reactions, electron transport chain, oxidative phosphorylation, photoautotroph(s), mesophyll, stomata, stroma, thylakoids, thylakoid membrane, light reactions, carotenoids, cytochrome complex, C_3 pants, C_4 plants		
Phenomena			
Context/ Phenomena	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.		
This Performance Expectation and associated Evidence Statements support the following Task Demands.			
Task Demands			
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.			
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.*			
3. Use a model to show the transfer of matter and flow of energy between an organism and its environment during photosynthesis.*			

4.	Make predictions about how additions/substitutions/removals of model components affect the transformation of light energy into stored chemical energy.*
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.
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.*
7.	Identify missing components, relationships, or other limitations of a model intended to show how photosynthesis transforms light energy into stored chemical energy.
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Hydrocarbon, carbohydrate, amino acid, nucleic acid, DNA, ATP, lipid, fatty acid, ingestion, rearrangement, stable, open system.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Endothermic reaction, exothermic reaction, aerobic respiration, oxidation, reduction, oxidation-reduction reaction, glycolysis, citric acid cycle, electron transport chain.</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>
</table>

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.
2.	Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.
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.*
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.*
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">ATP, chemical bonds, energy transfer, glycolysis, enzymes, mitochondria, cytosol, cytoplasm, nitrogen, adenine, phosphate, amino acid.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Biochemical, fatty acids, oxidizing agent, electron acceptor, biosynthesis, locomotion, phosphorylation, electron transport chain, chemiosmosis, pyruvate, pentose.</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.
• A person feels tired and weak before eating lunch. After eating some fruit, the person feel more energetic and awake.</td></tr>
</table>

	• 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.

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 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.*
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.*
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Predation, interdependent, disturbance, equilibrium of ecosystems, fluctuation, stable, biotic, abiotic, sustain, anthropogenic, overexploitation, urbanization, population, emigrants, immigrants, exponential, generation, rebounding, limiting resources, logistic, competition, negative feedback, population control.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Dispersion, demography, survivorship curve (J or S), reproductive table, semelparity, iteroparity, metapopulation, demographic transition, resource partitioning, Shannon diversity, biomanipulation, density dependent selection (K-selection), density independent selection (r selection), intrinsic factors.</td></tr>
<tr><td colspan="4" align="center">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" align="center">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
</table>

Task Demands
1. Make calculations using given data to calculate or estimate factors affecting the carrying capacity of an ecosystem.*
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.*
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.
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

Performance Expectation	**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.		
Dimensions	**Using Mathematical and Computational Thinking** • Use mathematical representations of phenomena or design solutions to support and revise explanations.	**LS2.A: Interdependent Relationships in Ecosystems** • Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits 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.	**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.
Clarifications and Content Limits	**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)		
Science Vocabulary Students Are Expected to Know	Carrying capacity, anthropogenic changes, overexploitation, extinction, demographic, population pyramid, deforestation, habitat fragmentation, sustainable, abiotic factor, biotic factor, species richness, symbiosis, niche, fragile ecosystem, biodiversity index, zero population growth, density, dispersion, immigration, emigration, limiting factor		
Science Vocabulary Students Are Not Expected to Know	Water regime, direct driver, eutrophication, species evenness, range of tolerance, realized niche, niche generalist, niche specialist, edge habitat, endemic species, logistic growth model, exponential population growth, mark-recapture method, territoriality, demography, cohort, survivorship curve, reproductive table, life history, semelparity, iteroparity, K-selection, r-selection, dieback.		

Phenomena	
Context/ Phenomena	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.

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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Organic compound synthesis, net transfer, biomass, carbon cycle, solar energy</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Lactic acid fermentation, alcoholic fermentation, glycolysis, Kreb’s cycle, electron transport chain.</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>
</table>

2.	Identify and justify additional pieces of evidence that would help distinguish between competing hypotheses.
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.*
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.*
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.

<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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Interdependent, nutrient, hydrocarbon, transfer system, equilibrium of ecosystems, decomposer, producer, ATP, solar energy, predator-prey relationship, trophic level</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Detritivore, denitrification, thermodynamics, nitrogen fixation, biogeochemical cycle, anaerobic process.</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.</td></tr>
</table>

	• 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.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Calculate or estimate changes or differences in matter and energy between trophic levels of an ecosystem. **
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.*
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.*
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.

Performance Expectation	**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.
Dimensions	**Developing and Using Models** • Develop a model based on evidence to illustrate the relationships between systems or components of a system. **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** • Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. **PS3.D: Energy in Chemical Processes** • The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. *(secondary)* **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.
Clarifications and Content Limits	**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.
Science Vocabulary Students Are Expected to Know	Recycle, consumer, transform, organism, convert, decomposer, producer, hydrocarbon, microbes, ATP
Science Vocabulary Students Are Not Expected to Know	Endothermic reaction, exothermic reaction, free energy, hydrolysis, oxidation.
Phenomena	
Context/ Phenomena	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.
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 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.	

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).
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).
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).
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Biosphere, biodiversity, carbon cycle, water cycle, nitrogen cycle, fluctuation, consistent, stable, equilibrium, species, emergence, extinction, niche, native, non-native, invasive, overgrazing, human impact, succession, primary succession, secondary succession.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Genetic drift, founder effect, Hardy-Weinberg, intermediate disturbance hypothesis, species-area curve.</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>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
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.
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.
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.*
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.*
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.*

*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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Carrying capacity, competition, urbanization, conversation biology, endangered species, threatened species, introduced species, overharvesting, extinction, greenhouse effect, carbon footprint</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Laws of thermodynamics, Hardy-Weinberg equilibrium, Lotka-Volterra equations, allelopathy, density-dependent population regulation, extinction vortex, minimum viable population (MVP), effective population size, movement corridor, biodiversity hot spot, zoned reserve, critical load, biological magnification, assisted migration, sustainable development.</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.</td></tr>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
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.
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.
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Behavioral ecology, cooperative behavior, altruism, environmental stimuli, circadian clock, communication, foraging, optimal foraging model, energy costs and benefits, competition, predator, mutual protection, packs</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Fixed action pattern, pheromones, innate behavior, learning, imprinting, spatial learning, social learning, associative learning, problem solving, cognition, game theory, agonistic behavior, mating behavior, mating systems, parental care, mate choice, male competition for mates, reciprocal altruism, shoaling</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 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>
</table>

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.
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.*
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.
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.**

*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:
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Genome, zygote, fertilization, dominant, recessive, codominance, incomplete dominance, sex-linked, allele, sequencing, pedigree, parent generation, F1, F2, haploid, diploid, replication.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Epigenetics, interphase, prophase, metaphase, anaphase, telophase, cytokinesis, epistasis.</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.
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>
</table>

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
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.*
2. Assemble or complete, from a collection of potential model components, an illustration, or pedigree that is capable of representing the role of genetic material in coding the instructions for inheritance.*
3. Construct a question that arises from examining a model or theory to clarify the connections between DNA/chromosomes and inheritance of traits.*
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.
5. Assemble or complete a flow chart describing the cause and effect relationships between genetic material and the characteristic traits passed from parents to offspring.

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

Performance Expectation	**HS-LS3-2** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
Dimensions	**Engaging in Argument from Evidence** • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated knowledge. **LS3.B: Variation of Traits** • In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. • Environmental factors also affect expression of traits, and, hence, they affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors. **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation, and to make claims about specific causes and effects.

Clarifications and Content Limits	**Clarification Statements**
	• Emphasis is on using data to support arguments for the way variation occurs.
	• Inheritable traits should be traits that can be passed down through more than one generation.
	• Inheritable traits for this PE do not include dominant/recessive traits.
	• Examples of evidence for new genetic combinations and viable errors can include:
	    ○ karyotype comparison between parents and children;
	    ○ DNA sequence comparison.
	
	Content Limits
	• Assessment does not include assessing meiosis or the biochemical mechanism of specific steps in the process.
	• <u>Students do not need to know</u>: bioinformatics, specific genetic disorders.

Science Vocabulary Students Are Expected to Know	Amino acid, DNA, enzyme, protein synthesis, chromosome, egg, egg cell, sperm, sperm cell, dominant trait, recessive trait, recombination, sex cell, sex chromosome, sex-linked trait, meiosis, mutation, advantageous, expression, base pairs, genome, UV radiation, triplet codon, insertion, deletion, frameshift, substitution, somatic, epigenetic.
Science Vocabulary Students Are Not Expected to Know	Polyploidy, single nucleotide polymorphisms (SNPs), conjugation, DNA polymerase, mutagenic, chromosomal translocation, missense, nonsense, nongenic region, tautomerism, depurination, deamination, slipped-strand mispairing, Sheik disorder, prion, epidemiology.
Phenomena	
Context/ Phenomena	Some example phenomena for HS-LS3-2: • Due to pesticide residue, frogs have extra, non-functioning, limbs. • Most chickens have feathers that lay flat against their bodies. In one family of chickens, 50% of offspring have feathers that curl away from their bodies. • A single gene mutation accounts for the blue color of irises in over 99.5% of people with blue eyes.

	• One sunflower growing in a field has a wide, flat stem and an unusual number of leaves. The next year, several sunflowers in the field share these traits.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
Task Demands
1. Based on the provided data, make or construct a claim regarding inheritable genetic variations that may result from: 1) new genetic combinations through meiosis, 2) viable errors occurring during replication, and/or 3) mutations caused by environmental factors. This *does not* include selecting a claim from a list.
2. Sort inferences about inheritable genetic variation into those that are supported by the data, contradicted by the data, outliers in the data, or none of these—or some similar classification.
3. Identify patterns of information/evidence in the data that support correlative/causative inferences about inheritable genetic variation.
4. Construct an argument using scientific reasoning that draws on credible evidence to explain how inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. (Hand scored CR)
5. Identify additional evidence that would help clarify, support, or contradict a claim or causal argument.
6. Identify, describe, and/or construct alternate explanations or claims, and cite the data needed to distinguish among them.
7. Predict outcomes of genetic variations, given the cause-and-effect relationships of inheritance.

Performance Expectation	**HS-LS3-3** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.		
Dimensions	**Analyzing and Interpreting Data** • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.	**LS3.B Variation of Traits** • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Scale, Proportion and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).
Clarifications and Content Limits	**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.		
Science Vocabulary Students are Expected to Know	Gene, allele, dominant, recessive, homozygous, heterozygous, phenotype, genotype, P generation, F_1 generation, F_2 generation, complete dominance, incomplete dominance, codominance, pedigree, carrier, fertilization, sex linked traits, gamete, Mendelian genetics, zygote, haploid, diploid, epistasis.		
Science Vocabulary Students are Not Expected to Know	Test-cross, monohybrid, dihybrid, law of independent assortment, law of segregation, pleiotropy, norm of reaction, multifactorial, Barr Body, genetic recombination, latent allele.		
Phenomena			
Context/ Phenomena	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. • 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.		

This Performance Expectation and associated Evidence Statements support the following Task Demands.

Task Demands

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.*
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.*

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.
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.*
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>Science Vocabulary Students are Expected to Know</td><td colspan="3">Amino acids, cladogram, comparative anatomy, DNA sequencing, electrophoresis, embryology, evolution, fossil record, gene flow, genetic drift, mutation, natural selection, nucleotides, sedimentary layers, species, descent with modification, homologous structures, evolutionary tree, analogous structures.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Phylogenetic, phylogeny, phylogenetic tree, taxonomy, cladistics, vestigial structures, convergent evolution, analogous, endemic, phylocode, sister taxa, basal taxon, polytomy, homoplasy, molecular systematics, monophyletic, parphyletic, polyphyletic, maximum parsimony, orthologous genes, paralogous genes, horizontal gene transfer.</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>
</table>

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.*
2.	Evaluate the validity/relevance/reliability of scientific evidence about biological evolution.
3.	Identify relationships or patterns in scientific evidence at macroscopic and/or microscopic scales.*
4.	Describe the specific evidence needed to support an explanation about how organisms share a common ancestor.
5.	Synthesize an explanation that incorporates the scientific evidence from multiple sources.

*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-LS4-2
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Beneficial change, detrimental change, distribution, emergence, gene frequency, biotic, abiotic, advantageous, diverge, proliferation, bottleneck effect, island effect, geographic isolation, founder effect, recombination.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Hardy-Weinberg equilibrium, biotechnology, relative fitness, directional selection, disruptive selection, stabilizing selection, heterozygote advantage, frequency-dependent selection, prezygotic barriers, postzygotic barriers.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">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.</td></tr>
</table>

	• 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.

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.

*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-LS4-3
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>Science Vocabulary Students are Expected to Know</td><td colspan="3">Fitness, gene, allele, directional selection, diversifying (disruptional selection), stabilizing selection, standard deviation, vestigial structure.</td></tr>
<tr><td>Science Vocabulary Students are Not Expected to Know</td><td colspan="3">Hemizygous, aneuploidy, intragenomic conflict, sexual dimorphism, balanced polymorphism, apostatic 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.</td></tr>
</table>

	• 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.

This Performance Expectation and associated Evidence Statements support the following Task Demands.
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).*
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).*
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.
6. Use statistical analysis to calculate changes in traits in a population over time to provide evidence for an explanation of the relationship between a trait's occurrence and its prevalence in the population at different points in time.
7. Identify explanations for a change in a traits frequency and/or distribution in a population over time that can be supported by patterns or relationships in data.

*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-LS4-4
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Beneficial change, detrimental change, distribution, emergence, gene frequency, gene, biotic, abiotic, advantageous, diverge, proliferation, sexual reproduction, bottleneck effect, island effect, geographic isolation, gene flow, genetic drift, founder effect.</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Hardy Weinberg Equilibrium, biotechnology, relative fitness, directional selection, disruptive selection, stabilizing selection, heterozygote advantage, frequency-dependent selection, prezygotic barriers, postzygotic barriers.</td></tr>
<tr><td colspan="4">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td colspan="3">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.</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.	Organize or summarize the given data or evidence of population characteristics, environmental characteristics, and/or the relationships between them.
2.	Generate or construct graphs or tables of data to highlight patterns within the given data.
3.	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.
4.	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.
5.	Given an appropriate explanation for a phenomenon, predict the effects of subsequent changes in environmental conditions on the population.
6.	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.*
7.	Identify and justify additional pieces of evidence that would help distinguish among competing hypotheses.

*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-LS4-5
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>Science Vocabulary Students Are Expected to Know</td><td colspan="3">Beneficial change, detrimental change, distribution, emergence, gene frequency, biotic, abiotic, advantageous, diverge, mutation, proliferation, bottleneck effect, island effect, geographic isolation, founder effect, recombination, microevolution, gene flow, speciation, hybrid</td></tr>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td colspan="3">Biotechnology, relative fitness, directional selection, disruptive selection, stabilizing selection, heterozygote advantage, frequency dependent selection, prezygotic barriers, postzygotic barriers, average heterozygosity, cline, sexual selection, sexual dimorphism, intrasexual selection, intersexual selection, neutral variation, balancing selection</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).</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>
</table>

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.*
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.*
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.*

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

Performance Expectation	**HS-LS4-6** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.		
Dimensions	**Using Mathematics and Computational Thinking** • Create or revise a simulation of a phenomenon, designed device, process, or system.	**LS4.C: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. **LS4.D: Biodiversity and Humans** • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts *(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).*	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
Clarifications and Content Limits	**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)		
Science Vocabulary Students Are Expected to Know	Anthropogenic, efficient, overexploitation, urbanization, acidification, deforestation, concentration, radiation, greenhouse gas, surface runoff, civilization, consumption, mass wasting, urban development, per-capita, degradation, pollutant, best practice, cost-benefit, extract, regulation		

<table>
<tr><td>Science Vocabulary Students Are Not Expected to Know</td><td>Oligotrophic and eutrophic lakes/eutrophication, littoral zone, exponential population growth, logistic population growth, ecological footprint, ecosystem services, extinction vortex, minimum viable population, effective population size, critical load.</td></tr>
<tr><td colspan="2">Phenomena</td></tr>
<tr><td>Context/ Phenomena</td><td>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.</td></tr>
<tr><td colspan="2">This Performance Expectation and associated Evidence Statements support the following Task Demands.</td></tr>
<tr><td colspan="2">Task Demands</td></tr>
<tr><td colspan="2">1. Use data to calculate or estimate the effect of a solution on mitigating the adverse impacts of human activity on biodiversity.</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td colspan="2">3. Estimate or infer the properties or relationships that lead to mitigation of the adverse impacts of human activity on biodiversity, based on data.</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td colspan="2">5. Using given information, select or identify the criteria against which the solution should be judged.</td></tr>
<tr><td colspan="2">6. Using a simulator, test a proposed solution and evaluate the outcomes; may include proposing modifications to the solution.*</td></tr>
</table>

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