STATE OF SOUTH CAROLINA
DEPARTMENT OF EDUCATION

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STATE SUPERINTENDENT OF EDUCATION

Biology 1 Performance Targets

for the

South Carolina College- and Career-Ready Science Standards 2021

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Contents

Purpose and Use

Science is a way of understanding the physical universe using observation and experimentation to explain natural phenomena. Science also refers to an organized body of knowledge that includes core ideas to the disciplines and common themes that bridge the disciplines. As science educators we must take a 3-dimensional approach in facilitating student learning. By addressing content, science and engineering practices and crosscutting concepts, students can have relevant and evidence-based instruction that can help solve current and future problems.

This document is intended as a guide for discerning and describing features of students and their work who have met the stated Performance Expectation (PE). This document is not intended to be read from cover to cover, but to be used, when needed, to support teacher professional learning and curriculum decisions. This is not intended for student use, and thus is not written in student-friendly language. This is not a curriculum or a means to limit instruction in the classroom. Although each PE states a dedicated Science and Engineering Practice (SEP) and Crosscutting Concept (CCC), students will need to use the whole range of SEPs and CCCs to achieve success by the end of instruction.

Three-dimensional science learning requires discipline specific communication skills. This means that effective science learning occurs when students are expected to speak, listen, read, and write in ways that are appropriate to science. With each Performance Target, there are question/sentence stems and terminology to support student discourse about phenomena to help teachers facilitate the acquisition of science discourse. Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding. The terms and stems in this section are intended to provide a baseline for teachers, neither list is exhaustive nor complete.

In addition to the doing (SEP), thinking (CCC), and learning of science knowledge (Disciplinary Core Ideas) outlined here, students will also require a working knowledge of grade-level appropriate tools and techniques of science. Students should know and recognize how scientists and engineers use these tools and techniques, not just identify them. Students should be able to use these tools to gather data, describe how these tools gather data, and/or interpret data sampled from them.

Acknowledgement:

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LS1 – From Molecules to Organisms: Structures and Processes

B-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.

State Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including [models, peer review, simulations, theories, students' own investigations]) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS1.A: Structure and Function** Systems of specialized cells within organisms help them perform the essential functions of life. All cells contain genetic information, in the form of DNA. Genes are specific regions within the extremely large DNA molecules that form the chromosomes. Genes contain the instructions that code for the formation of molecules called proteins, which carry out most of the work of cells to perform the essential functions of life. Proteins provide structural components, serve as signaling devices, regulate cell activities, and determine the performance of cells through their enzymatic actions. **LS3.A: Inheritance of Traits** The sequence of nucleotides spells out the information in a gene. DNA controls the expression of proteins by being transcribed into a "messenger" RNA, which is translated in turn by the cellular machinery into a protein.	**Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function.

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Observable features of student performance by the end of the course:

1. **Articulating the explanations of phenomena**
    a. Students articulate a statement describing/explaining relationships between the structure of DNA and the structure and function of resulting proteins, including:
        i. regions of DNA (limited to genes) determine the structure of proteins, and
        ii. proteins carry out the essential functions of life.
2. **Evidence**
    a. Students identify and describe the evidence to construct the explanation, including:
        i. all cells contain DNA,
        ii. DNA contains regions called genes,
        iii. the sequence of genes contains instructions that code for proteins,
        iv. a single gene codes for a protein,
        v. through the process of transcription, a DNA sequence is transcribed into a mRNA sequence,
        vi. through the process of translation, a mRNA sequence is translated into an amino acid sequence (limited to a protein) at the ribosome,
        vii. proteins carry out the essential functions of life, and
        viii. in complex organisms, groups of specialized cells (limited to tissues) use proteins to carry out functions that are essential to the organism.
    b. Students use multiple valid and reliable sources of evidence, including student experiments.
3. **Reasoning**
    a. Students use the following chain of reasoning to connect the evidence and support, refute, or revise an explanation, including:
        i. because all cells contain DNA, all cells contain genes that can code for the formation of proteins,
        ii. gene sequence affects protein function,
        iii. proper functioning of many proteins is necessary for the proper functioning of cells,
        iv. as a result of differentiation, different genes are activated in different cells that share the same genetic code in complex organisms, and
        v. systems of specialized cells (limited to tissues) share similar structures and functions, these are carried out by proteins.

B-LS1-1 Academic Language

Question/Sentence Stems

- The _______ structures help _______to function because _______.
- The _______ structures are present in _______ and are related to the function _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- adenine
- amino acid
- anticodon
- base
- cell
- chromosome
- codon
- cytoplasm
- cytosine
- deoxyribose
- differentiation
- DNA
- double helix
- double helix
- endoplasmic reticulum
(smooth and rough)
- enzyme
- gene
- Golgi apparatus
- guanine
- hydrogen bond
- mRNA
- mutation
- nuclear membrane
- nucleic acid
- nucleotide
- nucleus
- peptide bond
- phosphate
- polypeptide
- protein synthesis
- ribose
- ribosome
- RNA
- rRNA
- start codon
- stop codon
- thymine
- transcription
- translation
- tRNA
- uracil
- vesicle

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

> ***Clarification Statement:*** Emphasis is on normal cell division as well as instances in which cell division is uncontrolled (e.g., cancer).
> ***State Assessment Boundary:*** Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	**LS1.B: Growth and Development of Organisms** In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow (and repair). The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.	**Systems and System Models** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

*Mitosis is division of the nucleus; cytokinesis is division of the cytoplasm.

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Observable features of student performance by the end of the course:

1. **Components of the model**
    a. Students develop/use a model (conceptual, graphical, physical, etc.) and identify the relevant components to illustrate the role of mitosis and differentiation in producing and maintaining complex organisms, including:
        i. genetic material containing two variants of each chromosome pair (one for each parent),
        ii. parent and daughter cells,
        iii. a multicellular organism as a collection of differentiated cells, and/or
        iv. phases of the cell cycle, including:
            1. Gap 1 (G1 phase),
            2. Synthesis (S phase),
            3. Gap 2 (G2 phase),
            4. Mitosis (M phase),
            5. cytokinesis, and
            6. checkpoints.
2. **Relationships**
    a. Students develop/use a model to describe the relationships between components, including:
        i. daughter cells receive identical genetic information from a parent cell (including a fertilized egg),
        ii. the cell cycle is the process through which cells replicate, producing two genetically identical daughter cells,
        iii. mitotic division produces two genetically identical daughter cells from one parent cell (for example: describe the sequence of events during mitosis, etc.),
        iv. when cells bypass the checkpoints of the cell cycle, uncontrolled cell division (limited to cancer) may occur, and
        v. differences between cell types within a multicellular organism are due to gene expression and not genetic differences between the cells.
3. **Connections**
    a. Students develop/use a model to demonstrate that mitotic division results in more cells that:
        i. allow growth of the organism,
        ii. differentiation, and/or
        iii. replace damaged/dead cells to maintain a complex organism.
    b. Students develop/use a model to predict what will happen during the cell cycle/mitosis under different conditions (for example: did not complete DNA replication, cell bypasses a checkpoint, etc.).
    c. Students identify limits of the model (for example: accuracy of the model and the actual process of cellular division, etc.).

B-LS1-4 Academic Language

Question/Sentence Stems

- The key components of the system are_______.
- In the system, ____________ and ____________ are shown in the model.
- In the system, __________ and _________ work together to________.
- In the system, ____________ and ______________ interact in ________________ way.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- anaphase
- cancer
- carcinogen
- cell cycle
- cell plate
- centromere
- centrosome
- checkpoint
- chromosome
- cleavage furrow
- cytokinesis
- cytoplasm
- daughter cell
- differential gene expression
- differentiation
- diploid
- DNA (deoxyribonucleic acid)
- egg cell
- embryo
- fertilize
- gap 1 (G_1)
- gap 2 (G_2)
- gene
- genome
- growth
- haploid
- interphase
- maintenance
- metaphase
- mitosis
- mitotic phase (M)
- multicellular
- nucleus
- parent cell
- prophase
- protein
- replication
- sister chromatid
- somatic cell
- sperm cell
- spindle fibers
- stem cell
- synthesis phase (S)
- telophase
- tumor (benign and malignant)
- unicellular
- zygote

B-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

Clarification Statement: Emphasis is on explaining 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.
State Assessment Boundary: Assessment does not include specific biochemical steps.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.C: Organization for Matter and Energy Flow in Organisms** The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.	**Energy and Matter** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

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Observable features of student performance by the end of the course:

1. **Components of the model**
    a. Students develop/use a model (conceptual, graphical, physical, etc.) and identify the relevant components to illustrate the function of photosynthesis including:
        i. chloroplast,
        ii. solar energy,
        iii. chemical energy transfer between subsystems (light-dependent and light-independent reactions):
            1. ATP/ADP and
            2. NADPH/NADP+, and
        iv. matter:
            1. CO_2,
            2. H_2O,
            3. $C_6H_{12}O_6$, and
            4. O_2.
2. **Relationships**
    a. Students develop/use a model to describe relationships between the components, including:
        i. inputs,
        ii. outputs, and
        iii. energy transfer between subsystems.
3. **Connections**
    a. Students develop/use a model to demonstrate:
        i. The transfer of matter and flow of energy between an organism and its environment during photosynthesis.
        ii. The transfer of matter and flow of energy within the cell of a photosynthetic organism.
        iii. Photosynthesis results in the storage of energy in the difference between the energies of the chemical bonds of the inputs and the outputs.

B-LS1-5 Academic Language

Question/Sentence Stems

- _______ happens to matter as it moves within the system.
- In this system, energy is entering by _______, doing _______ in the system, and leaving the system by _______.
- The energy for _______ is from _______.
- The flow of energy causes _______ to occur in the system.
- The energy is entering the system by _______.
- In the system, the cycling of matter _______.
- The matter in the system enters from _______.
- When the matter leaves the system, it goes _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- ADP (adenosine diphosphate)
- ATP (adenosine triphosphate)
- Calvin cycle
- carbon dioxide
- carbon fixation
- cellular respiration
- chemical reaction
- chlorophyll
- chloroplasts
- energy flow
- glucose
- input
- light-dependent
- light-independent
- matter cycle
- mitochondrion
- NADP+
- NADPH
- output
- oxygen
- photosynthesis
- product
- reactant
- simple sugar
- solar energy
- stroma
- thylakoid
- water

B-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 other large carbon-based molecules necessary for essential life processes.

Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations of how the products of photosynthesis can be used to form the molecules of life.
State Assessment Boundary: Assessment does not include the details of the specific chemical reactions or molecular identification of macromolecules.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including [models, peer review, simulations, theories, students' own investigations]) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS1.C: Organization for Matter and Energy Flow in Organisms** The sugar molecules thus formed contain carbon, hydrogen, and oxygen: the 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 essential life functions. As matter and energy flow through organizational levels of living systems, chemical elements are recombined to form different products.	**Energy and Matter** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

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Observable features of student performance by the end of the course:

1. **Articulating the explanation of phenomena**
    a. Students articulate a statement describing/explaining the relationship between the products of photosynthesis and other biomolecules necessary for organism function, including:
        i. The relationship between the carbon, hydrogen, and oxygen atoms from sugar molecules formed in or ingested by an organism and those same atoms found in amino acids and other macromolecules.
        ii. That biomolecules and amino acids can be a result of chemical reactions between photosynthesis products (or component atoms) and other atoms.
        iii. That the energy for building these macromolecules comes from ATP produced during the process of cellular respiration.
2. **Evidence**
    a. Students identify and describe the evidence to construct the explanation, including:
        i. All organisms take in matter and rearrange the atoms through chemical reactions.
        ii. Sugar molecules (for example: glucose, etc.) are the energy storage molecules produced by photosynthetic organisms.
        iii. Sugar molecules (for example: glucose, etc.) are composed of carbon, oxygen, and hydrogen atoms.
        iv. Amino acids and other biomolecules (for example: carbohydrates, lipids, nucleic acids) are mostly composed of carbon, hydrogen, and oxygen atoms.
        v. Chemical reactions can create products that are more complex than the reactants.
        vi. Chemical reactions involve changes in the energies of the molecules involved in the reaction.
    b. Students use multiple valid and reliable sources of evidence, including student experiments.
3. **Reasoning**
    a. Students use the following chain of reasoning to connect the evidence and support, refute, or revise an explanation, including:
        i. The atoms in sugar molecules can provide most of the atoms that comprise amino acids and other biomolecules.
        ii. The energy released in cellular respiration can be used to drive chemical reactions between sugars and other substances to produce amino acids and other biomolecules.
        iii. The matter flows in cellular processes are the result of the rearrangements of primarily atoms in sugar molecules produced through photosynthesis because those are the molecules whose reactions release the energy needed for cell processes.

B-LS1-6 Academic Language

Question/Sentence Stems

- The matter in the system enters from _______.
- When the matter leaves the system, it goes _______.
- The flow of energy causes _______ to occur in the system.
- In the system, the cycling of matter _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- amino acid
- ATP (adenosine triphosphate)
- bond
- carbohydrate
- carbon (C)
- carbon dioxide (CO_2)
- cellular respiration
- cellulose
- chemical reaction
- energy
- enzyme
- fatty acid
- glucose
- hydrocarbon
- hydrogen (H)
- lipid
- macromolecule
- matter
- molecule
- nitrogen (N)
- nucleic acid
- nucleotide
- organic
- organic molecules
- oxygen (O_2)
- phosphorus (P)
- photosynthesis
- product
- protein
- reactant
- rearrangement
- starch
- sugar
- sulfur (S)

B-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.

Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the processes of aerobic and anaerobic cellular respiration.
State Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration nor specific types of fermentation. Assessment should be limited to comparing efficiency of aerobic and anaerobic cellular respiration.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.C: Organization for Matter and Energy Flow in Organisms** As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken, and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. Anaerobic cellular respiration follows a different and less efficient chemical pathway to provide energy in cells.	**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.

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Observable features of student performance by the end of the course:

1. **Components of the model**
    a. Students develop/use a model (conceptual, graphical, physical, etc.) to identify the relevant components to illustrate cellular respiration, including:
        i. mitochondrion,
        ii. cytoplasm,
        iii. matter:
            1. glucose ($C_6H_{12}O_6$),
            2. CO_2,
            3. H_2O, and
            4. O_2,
        iv. transfer of matter and energy between the following molecular systems:
            1. glycolysis,
            2. Kreb's cycle,
            3. Electron Transport Chain, and
            4. fermentation, and
        v. energy transfer and release:
            1. ATP/ADP and
            2. NADH/NAD+.
2. **Relationships**
    a. Students develop/use a model to describe the relationships between the components, including:
        i. inputs,
        ii. outputs,
        iii. energy transfer and conservation of matter between subsystems, and
        iv. efficiency.
3. **Connections**
    a. Students develop/use a model to demonstrate:
        i. The process of cellular respiration releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are formed, but matter and energy are neither created nor destroyed.
        ii. The process of cellular respiration transfers energy to the cell to sustain life's processes.
        iii. When oxygen is not available, cells will use the process of fermentation to maintain ATP production to continue cell work (fermentation/anaerobic respiration), with a marked decrease in ATP production efficiency as compared to aerobic respiration.

B-LS1-7 Academic Language

Question/Sentence Stems

- _______ happens to matter as it moves within the system.
- In this system, energy is entering by _______, doing _______ in the system, and leaving the system by _______.
- The energy for _______ is from _______.
- The flow of energy causes _______ to occur in the system.
- The energy is entering the system by _______.
- In the system, the cycling of matter _______.
- The matter in the system enters from _______.
- When the matter leaves the system, it goes _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- ADP (adenosine diphosphate)
- aerobic cellular respiration
- alcohol (ethanol)
- alcohol fermentation
- anaerobic cellular respiration
- ATP (adenosine triphosphate)
- bacteria
- carbon dioxide (CO_2)
- cellular respiration
- chemical reaction
- cytosol
- electron transport chain
- fermentation
- glucose
- glycolysis
- heterotroph
- input
- Krebs cycle
- lactic acid
- lactic acid fermentation
- matter cycle
- mitochondria
- muscle cell
- NAD+
- NADH
- organic molecules
- output
- phosphorous (P)
- products
- pyruvate (pyruvic acid)
- reactants
- water
- yeast

LS2 – Ecosystems: Interactions, Energy, and Dynamics

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

Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and challenges. Examples of mathematical comparisons could include graphs, charts, histograms, or population changes gathered from simulations and historical data sets. Examples of scales could be a pond versus an ocean.
State Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical and/or computational representations of phenomena or design solutions to support explanations.	**LS2.A: Interdependent Relationships in Ecosystems** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.	**Scale, Proportion, and Quantity** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

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Observable features of student performance by the end of the course:

1. **Representation**
    a. Students develop/use mathematical and/or computational models (for example: trends, averages, histograms, graphs, spreadsheets, etc.) to identify and describe the components that are relevant to support or refute an explanation of factors that affect carrying capacities of ecosystems at different scales, including:
        i. population changes gathered from historical data and/or simulations, and
        ii. data on:
            1. numbers and types of organisms,
            2. boundaries,
            3. resources, and
            4. climate.
    b. Students support or refute explanations about the factors (for example: boundaries resources, climate, competition, etc.) that affect the carrying capacity of an ecosystem and:
        i. some factors have larger effects than others,
        ii. factors are interrelated, and/or
        iii. factor significance depends on the scale at which it occurs.
2. **Mathematical and/or computational modeling**
    a. Students develop/use mathematical and/or computational models (for example: trends, averages, histograms, graphs, spreadsheets, etc.) of ecosystem factors to identify changes over time in the numbers and types of organisms in ecosystems of different scales.
3. **Analysis**
    a. Students develop/use and analyze a mathematical and/or computational model:
        i. To identify the interdependence of factors (both abiotic and biotic) and the resulting effect on carrying capacity.
        ii. To predict the resulting effect on carrying capacity of a change in abiotic and/or biotic factors.
        iii. As evidence to support or refute an explanation and identify the factors that have the largest effect on the carrying capacity of an ecosystem for an identified population.

B-LS2-1 Academic Language

Question/Sentence Stems

- The quantity of _______ and _______ can be compared.
- The proportion of _______ is _______because _______.
- The scale of the model of _______ is _______ compared to the actual population.
- To understand the phenomenon of _______, I/we can use a scale of _______ in my/our model.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic factor(s)
- abundance
- biodiversity
- biome
- biotic factor(s)
- carrying capacity
- climate change
- commensalism
- community
- competition
- deforestation
- density
- density-dependent
- density-independent
- disease
- disturbance
- ecosystem
- environment
- equilibrium
- exponential growth
- extinction
- fluctuation
- generation
- limiting factor
- limiting resource
- logistic growth
- mutualism
- niche
- parasitism
- pollution
- population
- population growth model
- predation
- species
- stability
- sustainable
- symbiosis
- trend

B-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.

Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show how relationships among variables between systems and their components in the natural and designed worlds. Develop a model based on evidence to illustrate the relationships between systems or components of a system.	**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 and Everyday Life** 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, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

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Observable features of student performance by the end of the course:

1. **Components of the model**
    a. Students develop/use a model (conceptual, graphical, physical, etc.) and identify the relevant components, including:
        i. inputs and outputs of photosynthesis,
        ii. inputs and outputs of cellular respiration, and
        iii. the biosphere, atmosphere, hydrosphere, and geosphere.
2. **Relationships**
    a. Students develop/use a model to identify and describe the relationships between components, including:
        i. the exchange of carbon between organisms and the environment and
        ii. the role of storing carbon in organisms as part of the carbon cycle.
3. **Connections**
    a. Students develop/use a model to describe the contributions of photosynthesis and cellular respiration to the exchange of carbon within and among the biosphere, atmosphere, hydrosphere, and geosphere.
        i. All organisms take in matter and rearrange the atoms in chemical reactions.
        ii. Photosynthesis captures light energy to create chemical products (limited to glucose) that can be used in cellular respiration.
        iii. Cellular respiration is the process by which glucose reacts chemically with other compounds (limited to glycolysis, Kreb's cycle, electron transport chain, fermentation), rearranging the matter to release stored chemical energy that is used for essential life processes.
    b. Students identify the limitations of a model.

B-LS2-5 Academic Language

Question/Sentence Stems

- The key components of the system are_______.
- In the system, ____________ and ____________ are shown in the model.
- In the system, __________ and _________ work together to________.
- In the system, ____________ and ______________ interact in ________________ way.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- acidification
- atmosphere
- autotroph
- biomass
- biosphere
- carbon cycle
- carbon dioxide (CO_2)
- carbon fixation
- carbon reservoir
- carbon sink
- chloroplast
- climate change
- combustion
- consumers
- decomposition
- deforestation
- Earth materials
- energy
- fossil fuel
- fossil fuels
- geosphere
- glucose/sugar
- greenhouse gas
- heterotroph
- hydrocarbons
- hydrosphere
- methane
- microbes
- mitochondrion
- molecule
- ocean uptake
- organic matter
- photosynthesis
- phytoplankton
- producers
- reaction
- respiration
- sedimentation
- transpiration

B-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. 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.	**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*) Humans depend on the living world for the resources and other benefits provided by biodiversity. Human activity is having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. These problems have the potential to cause biological extinctions which result in decreased biodiversity and the effects may be harmful to humans and other living things. 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. (*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*)	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable.

(Continued on next page.)

Observable features of student performance by the end of the course:

1. **Using scientific knowledge to generate design solutions**
    a. Students design a solution to reduce the negative effects of human activities on the environment and biodiversity, relying on factors affecting changes and stability in biodiversity. Examples of factors include but are not limited to:
        i. overpopulation,
        ii. overexploitation,
        iii. habitat destruction,
        iv. pollution,
        v. invasive species, and/or
        vi. climate change.
    b. Students describe/explain how the proposed solution decreases the negative effects of human activities on the environment and biodiversity.
2. **Describing criteria and constraints, including quantifications when appropriate**
    a. Students describe and quantify criteria, including:
        i. amount of reduction of impacts and/or
        ii. human activities to be mitigated
    b. Students describe the design constraints and tradeoffs, which may include:
        i. availability and cost of materials,
        ii. environmental impact,
        iii. human needs,
        iv. safety, and/or
        v. time (for example: construction, function, etc.).
3. **Evaluating potential solutions**
    a. Students evaluate the proposed solution for
        i. cost,
        ii. its impact on overall environmental stability and changes,
        iii. reliability,
        iv. safety, and/or
        v. social, cultural, and environmental impacts.
4. **Refining/optimizing the design solution**
    a. Students refine the proposed solution by prioritizing the criteria and making tradeoffs to further reduce environmental impact and loss of biodiversity while addressing human needs.

B-LS2-7 Academic Language

Question/Sentence Stems

- The things that stay the same are _______.
- The things that change are _______.
- The things that are changing slowly in this system are _______.
- The _______(event) changed this system by _______.
- _______ was affected by the change of _______.
- _______ are causing this system to be unstable.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic
- anthropogenic
- biodiversity
- biotic
- captive breeding
- carrying capacity
- climate
- climate change
- conservation
- conservation
- constraints
- criteria
- deforestation
- ecological restoration
- ecosystem
- ecosystem
- ecosystem diversity
- ecotourism
- endangered species
- environment
- extinction
- genetic diversity
- habitat
- habitat destruction
- habitat fragmentation
- habitat restoration
- human impact
- human population growth
- invasive species
- iterative
- optimize
- overharvesting
- pollution
- solution
- species diversity
- sustainable development

LS3 – Heredity: Inheritance and Variation of Traits

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

Clarification Statement: Emphasis is on using data to support arguments for the way genetic variation occurs.
State Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.	**LS3.B: Variation of Traits** In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

*References to "viable errors occurring during replication" are defined as errors that bypass DNA proofreading (the cell cycle successfully moves past G_2).

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Observable features of student performance by the end of the course:

1. **Developing a claim**
    a. Students make a claim that inheritable genetic variations may result from:
        i. new genetic combinations through meiosis,
        ii. viable errors occurring during replication, and/or
        iii. mutation caused by environmental factors (mutagen).
2. **Identifying scientific evidence**
    a. Students identify and describe the evidence that supports the claim, including:
        i. Variation in genetic material naturally results during meiosis from
            1. crossing over and
            2. independent assortment.
        ii. Genetic mutations can occur due to
            1. replication errors and
            2. environmental factors (mutagen).
        iii. Genetic material is inheritable.
    b. Students use multiple valid and reliable sources of evidence, including student generated data.
3. **Evaluating and critiquing evidence**
    a. Students identify strengths and weaknesses of the evidence used to support the claim, including:
        i. types of sources,
        ii. sufficiency, including validity and reliability, of the evidence to make and defend the claim, and/or
        iii. any alternative interpretations of the evidence and why the evidence supports or does not support the student's claim, as opposed to any other claims.
4. **Reasoning and synthesis**
    a. Students use the following chain of reasoning to connect the evidence:
        i. Genetic mutations produce genetic variation between cells or organisms.
        ii. Genetic variations produced by mutation and meiosis can be inherited.
    b. Students use reasoning and evidence to explain that new combinations of DNA can arise from several sources, including:
        i. meiosis,
        ii. replication error, and/or
        iii. mutations caused by mutagens.
    c. Students defend a claim against counterclaims by evaluating counterclaims and by describing the connections between the relevant and appropriate evidence to the strongest claim.

B-LS3-2 Academic Language

Question/Sentence Stems

- By looking at patterns in the data, I/we determined that _______ caused _______.
- _______ caused the patterns I am observing. I know this because _______.
- If _______ happens, I/we predict that _______ will occur.
- Even though I/we cannot see _______, it explains why _______ is happening.
- When I/we change _______ in the system, _______ is affected.
- The probability that _______ caused _______ is _______. I/We know this because _______.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- To conclude that _______ caused _______, the following evidence is needed _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- allele
- cellular division
- centromere
- chromatid
- chromosome
- codon (chart)
- crossing over
- daughter cell
- deletion
- gene mutation
- genetic code
- genetic variation
- genome
- haploid
- homologous chromosome
- independent assortment
- inherited
- insertion
- meiosis
- meiosis I
- meiosis II
- monosomy
- multicellular
- diploid
- DNA
- egg cell
- epigenetic
- fertilization
- frameshift
- gamete
- gene
- gene expression
- mutagen
- mutation
- nondisjunction
- offspring
- parent
- parent cell
- point mutation
- replication
- sexual reproduction
- somatic cell
- sperm cell
- substitution
- trait
- trisomy

B-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.
State Assessment Boundary: Assessment does not include Hardy-Weinberg or Chi-square analysis.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. 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).

(Continued on next page.)

Observable features of student performance by the end of the course:

1. **Organizing data**
    a. Students organize data for expressed traits in the population by:
        i. distribution,
        ii. frequency, and/or
        iii. variation.
2. **Identifying relationships**
    a. Students analyze data (for example: probability measures) to determine the relationship between a trait's occurrence within a population and environmental factors.
3. **Interpreting data**
    a. Students analyze and interpret data to explain the distribution of expressed traits, including:
        i. Recognition and use of patterns in statistical analysis to predict changes in trait distribution within a population if environmental variables change.
        ii. Description of the expression of a chosen trait and its relationship to some environmental factors based on reliable evidence.

B-LS3-3 Academic Language

Question/Sentence Stems

- The quantity of _______ and _______ can be compared.
- The proportion of _______ is _______because _______.
- The scale of the model of _______ is _______ compared to the actual population.
- To understand the phenomenon of _______, I/we can use a scale of _______ in my/our model.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- allele
- autosomal
- codominance
- complete dominance
- dihybrid cross
- distribution
- dominant
- environmental
- F_1 (first filial)
- F_2 (second filial)
- gamete
- gene expression
- genetic variability
- genotype
- genotypic ratio
- heredity
- heterozygous
- homozygous
- incomplete dominance
- karyotype
- monohybrid cross
- P (parental)
- pedigree
- phenotype
- phenotypic ratio
- polygenic inheritance
- population
- probability
- Punnett square
- ratio
- recessive
- sex linked
- trait
- variation

LS4 – Biological Evolution: Unity and Diversity

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

Clarification Statement: Emphasis is on students' 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.
State Assessment Boundary: Assessment is limited to conceptual explanations of the evidence for biological evolution and is not extended to the lines of evidence for specific species. Assessment does not include classification of organisms.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9-12 builds on K-8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	**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, notably, 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. **ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World** The understanding of evolutionary relationships has recently been greatly accelerated by using new molecular tools to study biology.	**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.

(Continued on next page.)

Observable features of student performance by the end of the course:

1. **Communication**
    a. Students use and cite at least two different formats (for example: oral, graphical, textual, mathematical, etc.) to communicate scientific information about how common ancestry and biological evolution are supported by multiple lines of empirical evidence.
2. **Connections**
    a. Students identify and communicate evidence for common ancestry and biological evolution, including:
        i. Information derived from DNA sequences, which vary among species but have many similarities between species.
        ii. Similarities of the patterns or amino acid sequences, even when DNA sequences are slightly different, including that multiple patterns of DNA sequences can code for the same amino acids.
        iii. The triplet codon pattern (for example: codon chart) that is used to decode sequences of mRNA for protein construction is universal amongst known species.
        iv. Patterns in the fossil record (for example: presence, location, and possible inferences in lines of evolutionary descent for multiple specimen, etc.).
        v. Patterns of anatomical and embryological similarities.
    b. Students identify and communicate connections between the lines of evidence and the claim of common ancestry and biological evolution.
    c. Students communicate that together, the patterns observed at multiple spatial and temporal scales (for example: DNA sequences, embryological development, fossil record, etc.) provide evidence for relationships relating biological evolution and common ancestry.

B-LS4-1 Academic Language

Question/Sentence Stems

- I/We can observe (notice) the pattern of _______ presented in the data collected.
- I/We can observe (notice) the pattern of _______in the data presented.
- The pattern seen in the collected data allows me/us to conclude (know) that _______.
- The observed pattern supports the conclusion that _______ is caused by _______, because _______.
- The pattern of _______ is changing over time.
- The following predictions can be made about _______ when using the pattern of _______ found in the data.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- amino acid sequencing
- analogous structure
- anatomy
- biochemical evidence
- biogeography
- cladogram
- common ancestry
- comparative anatomy
- decent with modification
- DNA sequencing
- electrophoresis
- embryo
- embryology
- evolution
- evolutionary tree
- fossil record
- heritable trait
- homologous structure
- homology
- natural selection
- paleontology
- phenotypic similarity
- phylogenic tree
- phylogeny
- sedimentary layers
- species
- vestigial structure

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

Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on 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.
State Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including [models, peer review, simulations, theories, students' own investigations]) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS4.B: Natural Selection** Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. **LS4.C: Adaptation** Evolution is driven by the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

(Continued on next page.)

Observable features of student performance by the end of the course:

1. **Articulating the explanation of phenomena**
    a. Students articulate a statement that evolution is caused primarily by one or more of the four factors:
        i. potential of species to increase in number,
        ii. heritable genetic variation of individuals in a species is due to mutation and sexual reproduction,
        iii. competition for limited resources, and/or
        iv. fitness.
2. **Evidence**
    a. Students identify and describe evidence necessary to construct an explanation, including:
        i. As a species grows in number, competition for limited resources can arise.
        ii. Individuals in a species have genetic variation that is passed on to their offspring.
        iii. Individuals can have specific traits that increase fitness relative to other individuals in the species.
    b. Students use multiple reliable and valid sources, including student generated data.
3. **Reasoning**
    a. Students use the following chain of reasoning to connect the evidence for the explanation:
        i. Genetic variation can lead to variation of expressed traits in individuals in a population.
        ii. Individuals with traits that give competitive advantages have increased fitness.
        iii. Individuals with increased fitness will provide their specific genetic variations to a greater proportion of the next generation.
        iv. Over many generations, groups of individuals with particular traits that increase fitness in distinct environments using distinct resources can speciate.
    b. Students use the evidence to describe the following in their explanation:
        i. The difference between natural selection and biological evolution.
        ii. The cause-and-effect relationship between genetic variation, the selection of traits that increase fitness, and the evolution of populations that express the trait.

B-LS4-2 Academic Language

Question/Sentence Stems

- By looking at patterns in the data, I/we determined that _______ caused _______.
- _______ caused the patterns I am observing. I know this because _______.
- If _______ happens, I/we predict that _______ will occur.
- Even though I/we cannot see _______, it explains why _______ is happening.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- To conclude that _______ caused _______, the following evidence is needed _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- adaptation
- behavior
- beneficial
- competition
- detrimental
- evolution
- fitness
- gene pool
- genetic variation
- geographic isolation
- heritable
- limited resources
- morphology
- mutation
- natural selection
- phenotypic expression
- physiology
- population
- proliferation
- reproductive isolation
- selective pressure
- sexual reproduction
- sexual selection
- speciation
- species
- trait

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

> ***Clarification Statement:*** Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.
> ***State Assessment Boundary:*** Assessment does not include allele frequency calculations.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including [models, peer review, simulations, theories, students' own investigations]) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**LS4.C: Adaptation** Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

(Continued on next page.)

Observable features of student performance by the end of the course:

1. **Articulating the explanation of phenomena**
    a. Students articulate a statement that describes/explains the cause-and-effect relationship between natural selection and adaptation.
2. **Evidence**
    a. Students identify and describe the evidence necessary to construct an explanation, including:
        i. Changes in a population when some feature of the environment changes.
        ii. Relative survival rates of organisms with different traits in a specific environment.
        iii. Individuals in a species have genetic variation that is passed on to their offspring.
        iv. Specific traits can increase an individual's fitness relative to other individuals in the species.
    b. Students use multiple reliable and valid sources, including student generated data.
3. **Reasoning**
    a. Students use the following chain of reasoning to synthesize the valid and reliable evidence about how natural selection provides a mechanism for species to adapt to changes in their environment:
        i. Abiotic and biotic differences in ecosystems contribute to changes in gene frequency over time through natural selection.
        ii. Increasing gene frequency in a population results in an increasing fraction of the population in each successive generation that carries a particular gene and expresses a particular trait.
        iii. Over time, this process leads to a population that is adapted to a particular environment by the widespread expression of a trait that confers a competitive advantage in that environment.
        iv. If abiotic or biotic factors of that environment change, then there is the potential for a change in gene frequency again.

B-LS4-4 Academic Language

Question/Sentence Stems

- By looking at patterns in the data, I/we determined that _______ caused _______.
- _______ caused the patterns I am observing. I know this because _______.
- If _______ happens, I/we predict that _______ will occur.
- Even though I/we cannot see _______, it explains why _______ is happening.
- The probability that _______ caused _______ is _______. I/We know this because _______.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- To conclude that _______ caused _______, the following evidence is needed _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic
- adaptation
- advantageous trait
- beneficial
- biotic
- coevolution
- convergent evolution
- detrimental
- distribution
- distribution
- diverge
- ecosystem
- fitness
- gene
- gene frequency
- gene pool
- genetic variation
- geographic isolation
- mutation
- natural selection
- phenotypic variation
- population
- survival rate
- trait
- variation

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

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science. Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**LS4.C: Adaptation** Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

(Continued on next page.)

Observable features of student performance by the end of the course:

1. **Identifying the explanation and supporting evidence**
    a. Students identify an explanation about the impacts of changes in environmental conditions on species and the relevant evidence including:
        i. increases in the number of individuals of some species,
        ii. emergence of a new species over time, and/or
        iii. extinction of a species.
2. **Identifying additional evidence relevant to the evaluation**
    a. Students identify and describe additional evidence (for example: data, information, etc.) that was not provided but is relevant to the explanation and its evaluation including:
        i. Data indicating the change over time in:
            1. the number of individuals in each species,
            2. the number of species in an environment, and/or
            3. the environmental conditions.
        ii. Environmental factors that can determine an individual's fitness.
3. **Evaluating and critiquing**
    a. Students use additional evidence to assess the validity, reliability, strengths, and weaknesses of the evidence and evaluate its ability to support logical and reasonable arguments about:
        i. environmental changes,
        ii. changes in numbers of individuals in each species,
        iii. the number of species in an environment, and/or
        iv. the emergence or extinction of species.
    b. Students evaluate the evidence for the degree to which it supports relationships between:
        i. environmental changes,
        ii. changes in numbers of individuals in each species,
        iii. the number of species in an environment, and/or
        iv. the emergence or extinction of species.
    c. Students evaluate the degree to which the empirical evidence can be used to construct logical arguments that identify relationships between environmental changes and changes in the numbers of individuals or species based on environmental factors that can determine the fitness of individuals in a species.

B-LS4-5 Academic Language

Question/Sentence Stems

- By looking at patterns in the data, I/we determined that _______ caused _______.
- ______________ caused the patterns I am observing. I know this because___________.
- If _______ happens, I/we predict that _______ will occur.
- Even though I/we cannot see _______, it explains why _______ is happening.
- The probability that _______ caused _______ is _______. I/We know this because _______.
- The evidence _______ presented in the scenario supports the claim that _______ causes _______.
- To conclude that _______ caused _______, the following evidence is needed _______.

Terminology to Support Student Discourse about Phenomena

*Teaching words or concepts in isolation or prior to experiences that give context (frontloading) deprives students of sense-making opportunities that lead to a greater depth of conceptual understanding.

- abiotic
- abiotic factor
- adaptation
- advantageous
- biotic
- biotic factor
- detrimental
- distribution
- disturbance
- diverge
- ecosystem
- environment
- evolution
- extinction
- fitness
- fossil
- founder effect
- gene
- gene flow
- gene frequency
- gene pool
- genetic drift
- genetic variation
- geographic isolation
- geologic record
- gradualism
- natural selection
- phenotypic variation
- population
- selective pressure
- speciation
- species
- stability
- survival rate
- trait
- variation

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