Science Standard-Specific Supports

Biology

Revised October 2022

Contents

Science Standard-Specific Supports

Overview

The West Virginia College- and Career-Readiness Standards for Science[1] identify what students should know and be able to do at the end of science instruction. Each standard represents the integration of three "dimensions" of science education: practices of scientists and engineers, core science content, and science connecting concepts. As such, both student learning and assessment around the standards should be "three dimensional." The Science Standard-Specific Supports in this document are intended to show what it looks like for students to fully satisfy the intent of the standard.

The Science Standard-Specific Supports are adapted from the Evidence Statements of the Next Generation Science Standards (NGSS)[2], created when West Virginia was a lead state during the NGSS writing process, and the Framework for K-12 Science Instruction[3], created prior to the development of the NGSS. For more information on the Evidence Statements, please refer to them in their original form.

Purpose

The Science Standard-Specific Supports were designed to articulate how students can use the practices of scientists and engineers to demonstrate their understanding of the core science content through the lens of the science connecting concepts, and thus, demonstrate proficiency on each standard. The Science Standard-Specific Supports do this by clarifying:

- how the three dimensions could be assessed together, rather than in independent units;
- the underlying knowledge required for each core science content;
- the detailed approaches to the practices of scientists and engineers; and
- how science connecting concepts might be used to deepen content- and practice-driven learning.

The Science Standard-Specific Supports are not intended to be used as curriculum or limit or dictate instruction.

Structure

The practices of scientists and engineers are used as the organizing structure for the Science Standard-Specific Supports. However, this does not mean that the practices are more important than the other dimensions. The practices of scientists and engineers form the activities through which students demonstrate understanding of the science content. The proper integration of the practices makes students' thinking visible.

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[1] *West Virginia College- and Career-Readiness Standards for Science* (Policy 2520.3C) https://apps.sos.wv.gov/adlaw/csr/readfile.aspx?DocId=54673&Format=PDF

[2] NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press.

[3] National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press.

How to Use the Science Standard-Specific Supports

- For instruction:
    - The Science Standard-Specific Supports can be used to aid instructional design, but it is crucial to recognize there are numerous pathways educators may use throughout the sequence of lessons and units to allow students to ultimately be prepared to demonstrate mastery of the standards.
- For assessment:
    - The Science Standard-Specific Supports can be used to inform the development of formative and summative assessments by the classroom educator.

Although supports are listed individually for each standard, this does not indicate that they should be measured individually, or that standards should be taught or assessed individually. Best practices in classroom instruction should be focused on helping students build towards several standards at one time because many concepts and practices are interrelated.

Limitations of the Science Standard-Specific Supports

The science standard supports cannot do the following:

- Provide or prescribe the contexts through which the standards may be taught or assessed.
- Be the rubrics on which levels of student success would be measured.
- Identify the sequence of instruction or assessment.
- Put limits on student learning or student coursework.
- Replace lesson plans or assessment items.
- Serve as complete scoring rubrics.

*Only the standards for which specific Science Standard-Specific Supports exist are included in this document. Please refer to the complete standards policy (*West Virginia College- and Career-Readiness Standards for Science* (Policy 2520.3C)) when planning instruction.

Biology Introduction

The Biology content provides more in-depth studies of the living world and enables students to make sense of emerging research findings and apply those understandings to solving problems. Students focus on five life science topics: Structure and Function, Inheritance and Variation of Traits, Matter and Energy in Organisms and Ecosystems, Interdependent Relationships in Ecosystems, and Natural Selection and Evolution. Engineering, Technology, and the Application of Science are integrated throughout instruction as students define problems and design solutions related to the course topics. There is a focus on multiple indicators including developing and using models, planning and conducting investigations, analyzing and interpreting data, using mathematical and computational thinking, constructing explanations and designing solutions. Students will engage in active inquiries, investigations, and hands-on activities at least 50% of the instructional time as they develop and demonstrate conceptual understandings along with research and laboratory skills described in the standards and indicators for science. Safety instruction is integrated into all activities, and students will implement safe procedures and practices when manipulating equipment, materials, organisms, and models. Standards followed by an asterisk (*) denote the integration of traditional science content with an engineering practice.

College- and Career-Readiness Indicators for Science Grades 9-12

Nature of Science	
• Scientific knowledge is simultaneously reliable and subject to change based on empirical evidence and interpretation. • Scientific knowledge is obtained through a combination of observations of the natural world and inferences based on those observations. • Science is a creative human endeavor which is influenced by social and cultural biases. • A primary goal of science is the formation of theories and laws. Theories are inferred explanations of some aspect of the natural world based on successfully tested information from evidence and evaluated phenomena. Laws describe relationships among what has been observed in the natural world. • Scientific investigations use a variety of methods to address questions about the natural and material world.	
Practices of Scientists and Engineers	**Science Connecting Concepts**
• Asking questions and defining problems • Developing and using models • Planning and carrying out investigations • Analyzing and interpreting data • Using mathematical and computational thinking • Constructing explanations and designing solutions • Engaging in argument from evidence • Obtaining, evaluating, and communicating information	• Observing patterns • Investigating and explaining cause and effect • Recognizing scale, proportion, and quantity • Defining systems and system models • Tracking energy and matter flows, into, out of, and within systems to understand system behavior • Determining the relationships between structure and function • Studying stability and change
Science Literacy	**Science Lab Safety**
• Producing clear and coherent technical writing in which the development, organization and style are appropriate for the science topic • Correctly utilizing and explaining visually expressed information (e.g., flowchart, diagram, model, graph, table, or digital mapping technology) in a science narrative. • Appropriately using technical terminology or scientific concepts and processes to create visually expressed information • Reading with understanding articles about science in the popular press and engaging in social conversation about the validity of the conclusions • Identifying scientific issues underlying national and local decisions and expressing positions that are scientifically and technologically informed • Evaluating the quality and validity of scientific information on the basis of its source and the methods used to generate it.	• Requiring student lab safety training and demonstrating appropriate proficiency before participating in lab activities • Archiving signed student safety contracts documenting lab safety training and medical contraindications (e.g., allergies, contact lenses, medical conditions) • Wearing proper protective gear as needed (e.g., goggles, apron, and gloves) • Requiring grade appropriate lab equipment operation and safety training • Using and following SDS protocols • Storing and disposing of chemical/biological materials properly • Following ethical classroom uses of living materials/organisms • Displaying proper safety signage and laboratory rules in the classroom and lab

Life Science

Topic: Structure and Function

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

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>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. Students will 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 rowspan="3">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></tr>
<tr><td>Science Connecting Concepts</td></tr>
<tr><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 connections of components to reveal its function and/or solve a problem.</td></tr>
</table>

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

1) Articulating the explanation of phenomena
   a) Students construct an explanation that includes the idea that regions of DNA called genes determine the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
2) Evidence
   a) Students identify and describe the evidence to construct their explanation, including that:
      i) All cells contain DNA;
      ii) DNA contains regions that are called genes;
      iii) The sequence of genes contains instructions that code for proteins; and
      iv) Groups of specialized cells (tissues) use proteins to carry out functions that are essential to the organism.
   b) Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, peer review, students’ own investigations).
3) Reasoning
   a) Students use reasoning to connect evidence, along with 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, to construct the explanation. Students describe the following chain of reasoning in their explanation:
      i. Because all cells contain DNA, all cells contain genes that can code for the formation of proteins.

ii. Body tissues are systems of specialized cells with similar structures and functions, each of whose functions are mainly carried out by the proteins they produce in the explanation.
iii. Proper function of many proteins is necessary for the proper functioning of the cells.
iv. Gene sequence affects protein function, which in turn affects the function of body tissues.

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

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>Planning and Carrying Out Investigations
Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. Students will plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Scientific Investigations Use a Variety of Methods
Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open- mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings.</td><td rowspan="3">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></tr>
<tr><td>Science Connecting Concepts</td></tr>
<tr><td>Stability and Change
Feedback (negative or positive) can stabilize or destabilize a system.</td></tr>
</table>

Observable features of the student performance by the end of the course:
1) Components of the model
   a) Students develop a model in which they identify and describe the relevant parts (e.g., organ system, organs, and their component tissues) and processes (e.g., transport of fluids, motion) of body systems in multicellular organisms.
2) Relationships
   a) In the model, students describe the relationships between components, including:
      i) The functions of at least two major body systems in terms of contributions to overall function of an organism;
      ii) Ways the functions of two different systems affect one another; and
      iii) A system's function and how that relates both to the system's parts and to the overall function of the organism.
3) Connections
   a) Students use the model to illustrate how the interaction between systems provides specific functions in multicellular organisms.
   b) Students make a distinction between the accuracy of the model and actual body systems and functions it represents.

S.B.4. Develop and use a model to provide evidence that feedback mechanisms maintain homeostasis. [Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>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. Students will develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td rowspan="3">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></tr>
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Observable features of the student performance by the end of the course:

1) Identifying the phenomenon to model
   a) Students describe the phenomenon under investigation, which includes the following idea: that feedback mechanisms maintain homeostasis.
2) Identifying the mechanisms to model
   a) Students develop a model, including:
      i) Changes within a chosen range in the external environment of a living system; and
      ii) Responses of a living system that would stabilize and maintain the system's internal conditions (homeostasis), even though external conditions change, thus establishing the positive or negative feedback mechanism.
   b) Students describe why the data will provide information relevant to the purpose of the investigation.
3) Developing the model
   a) Students use the given model to illustrate:
      i) How the change in the external environment is to be measured or identified;
      ii) How the response of the living system will be measured or identified;
      iii) How the stabilization or destabilization of the system's internal conditions are modeled;
4) Refining the design
   a) Students evaluate their model, including:
      i) Assessment of the accuracy and precision of the model, as well as limitations and make suggestions for refinement
      ii) Assessment of the ability of the data to provide the evidence required

Topic: Matter and Energy in Organisms and Ecosystems

S.B.5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [*Assessment Boundary: Assessment does not include specific biochemical steps.*]*laws of orbital motions should not deal with more than two bodies, nor involve calculus.*]

Practices of Scientists and Engineers	Core Science Content
Science and Engineering Practices 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. Students will use a model based on evidence to illustrate the relationships between systems or between components of a system.	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.
Science Connecting Concepts	
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.	

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

1) Components of the model
    a) From the given model, students identify and describe the components of the model relevant for illustrating that photosynthesis transforms light energy into stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen, including:
        i) Energy in the form of light;
        ii) Breaking of chemical bonds to absorb energy;
        iii) Formation of chemical bonds to release energy; and
        iv) Matter in the form of carbon dioxide, water, sugar, and oxygen.
2) Relationships
    a) Students identify the following relationship between components of the given model: Sugar and oxygen are produced by carbon dioxide and water by the process of photosynthesis.
3) Connections
    a) Students use the given model to illustrate:
        i) The transfer of matter and flow of energy between the organism and its environment during photosynthesis; and
        ii) Photosynthesis as resulting in the storage of energy in the difference between the energies of the chemical bonds of the inputs (carbon dioxide and water) and outputs (sugar and oxygen).

S.B.6. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [*Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.*]

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<tr><td>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. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td><td rowspan="3">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></tr>
<tr><td>Science Connecting Concepts</td></tr>
<tr><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>
</table>

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

1) Components of the model
   a) From a given model, students identify and describe the components of the model relevant for their illustration of cellular respiration, including:
   b) Matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO_2);
      i) The breaking and formation of chemical bonds; and
      ii) Energy from the chemical reactions.
2) Relationships
   a) From the given model, students describe the relationships between components, including:
      i) Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration; and
      ii) The process of cellular respiration releases energy because the energy released when the bonds that are formed in CO_2 and water is greater than the energy required to break the bonds of sugar and oxygen.
3) Connections
   a) Students use the given model to illustrate that:
      i) The chemical reaction of oxygen and food molecules 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) Food molecules and oxygen transfer energy to the cell to sustain life’s processes, including the maintenance of body temperature despite ongoing energy transfer to the surrounding environment.

S.B.7. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.] [Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]

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<tr><td>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. Students will 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.

Scientific Knowledge is Open to Revision in Light of New Evidence
Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.</td><td rowspan="3">Cycles of Matter and Energy Transfer in Ecosystems
Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.</td></tr>
<tr><th>Science Connecting Concepts</th></tr>
<tr><td>Energy and Matter
Energy drives the cycling of matter within and between systems.</td></tr>
</table>

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

1) Articulating the explanation of phenomena
   a) Students construct an explanation that includes that:
      i) Energy from photosynthesis and respiration drives the cycling of matter and flow of energy under aerobic or anaerobic conditions within an ecosystem.
      ii) Anaerobic respiration occurs primarily in conditions where oxygen is not available.
2) Evidence
   a) Students identify and describe the evidence to construct the explanation, including:
      i) All organisms take in matter and rearrange the atoms in chemical reactions.
      ii) Photosynthesis captures energy in sunlight to create chemical products that can be used as food in cellular respiration.
      iii) Cellular respiration is the process by which the matter in food (sugars, fats) reacts chemically with other compounds, rearranging the matter to release energy that is used by the cell for essential life processes.
   b) Students use a variety of valid and reliable sources for the evidence, which may include theories, simulations, peer review, and students' own investigations.

3) Reasoning
   a) Students use reasoning to connect evidence, along with 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, to construct their explanation. Students describe the following chain of reasoning used to construct their explanation:
      i) Energy inputs to cells occur either by photosynthesis or by taking in food.
      ii) Since all cells engage in cellular respiration, they must all produce products of respiration.

iii) The flow of matter into and out of cells must therefore be driven by the energy captured by photosynthesis or obtained by taking in food and released by respiration.
iv) The flow of matter and energy must occur whether respiration is aerobic or anaerobic.

4) Revising the explanation
   a) Given new data or information, students revise their explanation and justify the revision (e.g., recent discoveries of life surrounding deep sea ocean vents have shown that photosynthesis is not the only driver for cycling matter and energy in ecosystems).

S.B.8. Use mathematical representations to support claims for the cycling of matter and flow of energy between trophic levels in an ecosystem.

- transfer of calories
- energy loss (entropy)
- 10% Rule
- bioaccumulation.

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

Practices of Scientists and Engineers	Core Science Content
Using Mathematical 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. Students will use mathematical representations of phenomena or design solutions to support claims.	Cycles of Matter and Energy Transfer in Ecosystems Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
Science Connecting Concepts	
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.	

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

1) Representation
   a) Students identify and describe the components in the mathematical representations that are relevant to supporting the claims. The components could include relative quantities related to organisms, matter, energy, and the food web in an ecosystem.
   b) Students identify the claims about the cycling of matter and energy flow among organisms in an ecosystem.
2) Mathematical modeling

a) Students describe how the claims can be expressed as a mathematical relationship in the mathematical representations of the components of an ecosystem
b) Students use the mathematical representation(s) of the food web to:
    i) Describe the transfer of matter (as atoms and molecules) and flow of energy upward between organisms and their environment;
    ii) Identify the transfer of energy and matter between tropic levels; and
    iii) Identify the relative proportion of organisms at each trophic level by correctly identifying producers as the lowest trophic level having the greatest biomass and energy and consumers decreasing in numbers at higher trophic levels.

3) Analysis
    a) Students use the mathematical representation(s) to support the claims that include the idea that matter flows between organisms and their environment.
    b) Students use the mathematical representation(s) to support the claims that include the idea that energy flows from one trophic level to another as well as through the environment.
    c) Students analyze and use the mathematical representation(s) to account for the energy not transferred to higher trophic levels, but which is instead used for growth, maintenance, or repair, and/or transferred to the environment, and the inefficiencies in transfer of matter and energy.

S.B.9. **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** [Clarification Statement: Examples of models could include simulations and mathematical models.] [*Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.*]

Practices of Scientists and Engineers	Core Science Content
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 world(s). Students will develop a model based on evidence to illustrate the relationships between systems or components of a system.	**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.
Science Connecting Concepts	**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, computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales.	

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

1) Components of the model
    a) Students use evidence to develop a model in which they identify and describe the relevant components, including:
        i) The inputs and outputs of photosynthesis;
        ii) The inputs and outputs of cellular respiration; and
        iii) The biosphere, atmosphere, hydrosphere, and geosphere.

2) Relationships
   a) Students describe relationships between components of their model, including:
      i) The exchange of carbon (through carbon-containing compounds) between organisms and the environment; and
      ii) The role of storing carbon in organisms (in the form of carbon-containing compounds) as part of the carbon cycle.
3) Connections
   a) Students describe the contribution of photosynthesis and cellular respiration to the exchange of carbon within and among the biosphere, atmosphere, hydrosphere, and geosphere in their model.
   b) Students make a distinction between the model's simulation and the actual cycling of carbon via photosynthesis and cellular respiration.

Topic: Interdependent Relationships in Ecosystems

SB.10. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. [Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [*Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.*]

Practices of Scientists and Engineers	Core Science Content
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. Students will use mathematical and/or computational representations of phenomena or design solutions to support explanations.	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.
Science Connecting Concepts	
Scale, Proportion, and Quantity The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	

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

1) Representation
   a) Students identify and describe the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that are relevant to supporting given explanations of factors that affect carrying capacities of ecosystems at different scales. The components include:
      i) The population changes gathered from historical data or simulations of ecosystems at different scales; and
      ii) Data on numbers and types of organisms as well as boundaries, resources, and climate.
   b) Students identify the given explanation(s) to be supported, which include the following ideas: Factors (including boundaries, resources, climate, and competition) affect carrying capacity of an ecosystem, and:
      i) Some factors have larger effects than do other factors.
      ii) Factors are interrelated.
      iii) The significance of a factor is dependent on the scale (e.g., a pond vs. an ocean) at which it occurs
2) Mathematical and/or computational modeling
   a) Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) of ecosystem factors to identify changes over time in the numbers and types of organisms in ecosystems of different scales.
3) Analysis
   a) Students analyze and use the given mathematical and/or computational representations
      i) To identify the interdependence of factors (both living and nonliving) and resulting effect on carrying capacity; and

ii) As evidence to support the explanation and identify the factors that have the largest effect on the carrying capacity of an ecosystem for a given population.

S.B.11. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [*Assessment Boundary: Assessment is limited to provided data.*]

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<tr><td>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. Students will use mathematical representations of phenomena or design solutions to support and revise explanations.

Scientific Knowledge is Open to Revision in Light of New Evidence
Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.</td><td rowspan="3">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.

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></tr>
<tr><td>Science Connecting Concepts</td></tr>
<tr><td>Scale, Proportion, and Quantity
Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.</td></tr>
</table>

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

1) Representation
   a) Students identify and describe the components in the given mathematical representations (which include trends, averages, and graphs of the number of organisms per unit of area in a stable system) that are relevant to supporting and revising the given explanations about factors affecting biodiversity and ecosystems, including:
      i) Data on numbers and types of organisms are represented.
      ii) Interactions between ecosystems at different scales are represented.
   b) Students identify the given explanation(s) to be supported of factors affecting biodiversity and population levels, which include the following ideas:

        i) The populations and number of organisms in ecosystems vary as a function of the physical and biological dynamics of the ecosystem.
        ii) The response of an ecosystem to a small change might not significantly affect populations, whereas the response to a large change can have a large effect on populations that then feeds back to the ecosystem at a range of scales.
        iii) Ecosystems can exist in the same location on a variety of scales (e.g., plants and animals vs. microbes), and these populations can interact in ways that significantly change these ecosystems (e.g., interactions among microbes, plants, and animals can be an important factor in the resources available to both a microscopic and macroscopic ecosystem).
2) Mathematical Modeling
    a) Students use the given mathematical representations (including trends, averages, and graphs) of factors affecting biodiversity and ecosystems to identify changes over time in the numbers and types of organisms in ecosystems of different scales.
3) Analysis
    a) Students use the analysis of the given mathematical representations of factors affecting biodiversity and ecosystems
        i) To identify the most important factors that determine biodiversity and population numbers of an ecosystem.
        ii) As evidence to support explanation(s) for the effects of both living and nonliving factors on biodiversity and population size, as well as the interactions of ecosystems on different scales.
        iii) To describe how, in the model, factors affecting ecosystems at one scale can cause observable changes in ecosystems at a different scale.
    b) Students describe the given mathematical representations in terms of their ability to support explanation(s) for the effects of modest to extreme disturbances on an ecosystems' capacity to return to original status or become a different ecosystem.
4) Revision
    a) Students revise the explanation(s) based on new evidence about any factors that affect biodiversity and populations (e.g., data illustrating the effect of a disturbance within the ecosystem).

S.B.12. 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 possibly leading to speciation. [Clarification Statement: 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.]

Practices of Scientists and Engineers	Core Science Content
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. Students will evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. **Scientific Knowledge is Open to Revision in Light of New Evidence**	**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

Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.	conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
Science Connecting Concepts	
Stability and Change Much of science deals with constructing explanations of how things change and how they remain stable.	

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

1) Identifying the given explanation and the supporting claims, evidence, and reasoning.
   a) Students identify the given explanation that is supported by the claims, evidence, and reasoning to be evaluated, and which includes the following idea: 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.
   b) From the given materials, students identify:
      i) The given claims to be evaluated;
      ii) The given evidence to be evaluated; and
      iii) The given reasoning to be evaluated.
2) Identifying any potential additional evidence that is relevant to the evaluation
   a) Students identify and describe additional evidence (in the form of data, information, or other appropriate forms) that was not provided but is relevant to the explanation and to evaluating the given claims, evidence, and reasoning:
      i) The factors that affect biodiversity;
      ii) The relationships between species and the physical environment in an ecosystem; and
      iii) Changes in the numbers of species and organisms in an ecosystem that has been subject to a modest or extreme change in ecosystem conditions.
3) Evaluating and critiquing
   a) Students describe the strengths and weaknesses of the given claim in accurately explaining a particular response of biodiversity to a changing condition, based on an understanding of the factors that affect biodiversity and the relationships between species and the physical environment in an ecosystem.
   b) Students use their additional evidence to assess the validity and reliability of the given evidence and its ability to support the argument that resiliency of an ecosystem is subject to the degree of change in the biological and physical environment of an ecosystem.
   c) Students assess the logic of the reasoning, including the relationship between degree of change and stability in ecosystems, and the utility of the reasoning in supporting the explanation of how:
      i) Modest biological or physical disturbances in an ecosystem result in maintenance of relatively consistent numbers and types of organisms.
      ii) Extreme fluctuations in conditions or the size of any population can challenge the functioning of ecosystems in terms of resources and habitat availability and can even result in a new ecosystem.

S.B.13. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>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. Students will design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student- generated sources of evidence, prioritized criteria, and tradeoff considerations.</td><td rowspan="3">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.

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. 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. (secondary)

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.</td></tr>
<tr><th>Science Connecting Concepts</th></tr>
<tr><td>Stability and Change
Much of science deals with constructing explanations of how things change and how they remain stable.</td></tr>
</table>

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

1) Using scientific knowledge to generate the design solution
    a) Students design a solution that involves reducing the negative effects of human activities on the environment and biodiversity, and that relies on scientific knowledge of the 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) Introduction of invasive species; and
        vi) Changes in climate.
    b) Students describe the ways the proposed solution decreases the negative effects of human activity on the environment and biodiversity.
2) Describing criteria and constraints, including quantification when appropriate
    a) Students describe and quantify (when appropriate) the criteria (amount of reduction of impacts and human activities to be mitigated) and constraints (for example, cost, human needs, and environmental impacts) for the solution to the problem, along with the tradeoffs in the solution.
3) Evaluating potential solutions
    a) Students evaluate the proposed solution for its impact on overall environmental stability and changes.
    b) Students evaluate the cost, safety, and reliability, as well as social, cultural, and environmental impacts, of the proposed solution for a select human activity that is harmful to an ecosystem.

4) Refining and/or optimizing the design solution
    a) Students refine the proposed solution by prioritizing the criteria and making tradeoffs as necessary to further reduce environmental impact and loss of biodiversity while addressing human needs.

S.B.14. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>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. Students will create or revise a simulation of a phenomenon, designed device, process, or system.</td><td rowspan="3">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.

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.

Developing Possible Solutions
When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (secondary)</td></tr>
<tr><td>Science Connecting Concepts</td></tr>
<tr><td>Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
</table>

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

1) Representation
    a) Students create or revise a simulation that:
        i) Models effects of human activity (e.g., overpopulation, overexploitation, adverse habitat alterations, pollution, invasive species, changes in climate) on a threatened or endangered species or to the genetic variation within a species; and
        ii) Provides quantitative information about the effect of the solutions on threatened or endangered species.

   b) Students describe the components that are modeled by the computational simulation, including human activity (e.g., overpopulation, overexploitation, adverse habitat alterations, pollution, invasive species, changes in climate) and the factors that affect biodiversity.
   c) Students describe the variables that can be changed by the user to evaluate the proposed solutions, tradeoffs, or other decisions.
2) Computational modeling
   a) Students use logical and realistic inputs for the simulation that show an understanding of the reliance of ecosystem function and productivity on biodiversity, and that take into account the constraints of cost, safety, and reliability as well as cultural, and environmental impacts.
   b) Students use the simulation to identify possible negative consequences of solutions that would outweigh their benefits.
3) Analysis
   a) Students compare the simulation results to expected results.
   b) Students analyze the simulation results to determine whether the simulation provides sufficient information to evaluate the solution.
   c) Students identify the simulation’s limitations.
   d) Students interpret the simulation results and predict the effects of the specific design solutions on biodiversity based on the interpretation.
4) Revision
   a) Students revise the simulation as needed to provide sufficient information to evaluate the solution.

Topic: Inheritance and Variation of Traits

S.B.15. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. [Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]

Practices of Scientists and Engineers	Core Science Content
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. Students will use a model based on evidence to illustrate the relationships between systems or between components of a system.	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.
Science Connecting Concepts	
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.	

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

1) Components of the model
   a) From the given model, students identify and describe the components of the model relevant for illustrating the role of mitosis and differentiation in producing and maintaining complex organisms, including:
      i) Genetic material containing two variants of each chromosome pair, one from each parent;
      ii) Parent and daughter cells (i.e., inputs and outputs of mitosis); and
      iii) A multi-cellular organism as a collection of differentiated cells.
2) Relationships
   a) Students identify and describe the relationships between components of the given model, including:
      i) Daughter cells receive identical genetic information from a parent cell or a fertilized egg.
      ii) Mitotic cell division produces two genetically identical daughter cells from one parent cell.
      iii) Differences between different cell types within a multicellular organism are due to gene expression — not different genetic material within that organism.
3) Connections
   a) Students use the given model to illustrate that mitotic cell division results in more cells that:
      i) Allow growth of the organism;
      ii) Can then differentiate to create different cell types; and
      iii) Can replace dead cells to maintain a complex organism.
   b) Students make a distinction between the accuracy of the model and the actual process of cellular division.

S.B.16. Develop and use a model to demonstrate the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. *Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>Asking Questions and Defining Problems
Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining and evaluating empirically testable questions and design problems using models and simulations. Students will ask questions that arise from examining models or a theory to clarify relationships.</td><td rowspan="3">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)

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></tr>
<tr><th>Science Connecting Concepts</th></tr>
<tr><td>Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
</table>

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

1) Addressing phenomena or scientific theories
   a) Students use models of DNA to formulate questions, the answers to which would clarify:
      i) The cause and effect relationships (including distinguishing between causal and correlational relationships) between DNA, the proteins it codes for, and the resulting traits observed in an organism;
      ii) That the DNA and chromosomes that are used by the cell can be regulated in multiple ways; and
      iii) The relationship between the non-protein coding sections of DNA and their functions (e.g., regulatory functions) in an organism.
2) Evaluating empirical testability
   a) Students' questions are empirically testable by scientists.

S.B.17. Make and defend a claim based on evidence that inheritable genetic variations may result from:

- new genetic combinations through meiosis
- viable errors occurring during replication
- mutations caused by environmental factors.

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

Practices of Scientists and Engineers	Core Science Content
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. Students will make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated evidence.	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.
Science Connecting Concepts	
Cause and Effect Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	

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

1) Developing a claim
   a) Students make a claim that includes the idea that inheritable genetic variations may result from:
      i) New genetic combinations through meiosis;
      ii) Viable errors occurring during replication; and
      iii) Mutations caused by environmental factors.
2) Identifying scientific evidence
   a) Students identify and describe evidence that supports the claim, including:
      i) Variations in genetic material naturally result during meiosis when corresponding sections of chromosome pairs exchange places.
      ii) Genetic mutations can occur due to:
         (1) errors during replication; and/or
         (2) environmental factors.
      iii) Genetic material is inheritable.
   b) Students use scientific knowledge, literature, student-generated data, simulations and/or other sources for evidence.

3) Evaluating and critiquing evidence
   a) Students identify the following strengths and weaknesses of the evidence used to support the claim:
      i) Types and numbers of sources;
      ii) Sufficiency to make and defend the claim, and to distinguish between causal and correlational relationships; and
      iii) Validity and reliability of the evidence.

4) Reasoning and synthesis
   a) Students use reasoning to describe links between the evidence and claim, such as:
      i) Genetic mutations produce genetic variations between cells or organisms.
      ii) Genetic variations produced by mutation and meiosis can be inherited.
   b) Students use reasoning and valid evidence to describe that new combinations of DNA can arise from several sources, including meiosis, errors during replication, and mutations caused by environmental factors.
   c) Students defend a claim against counter-claims and critique by evaluating counter-claims and by describing the connections between the relevant and appropriate evidence and the strongest claim.

S.B.18. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]

Practices of Scientists and Engineers	Core Science Content
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. Students will 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.	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.
Science Connecting Concepts	
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). Science is a Human Endeavor Technological advances have influenced the progress of science and science has influenced advances in technology. Science and engineering are influenced by society and society is influenced by science and engineering.	

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

1) Organizing data
   a) Students organize the given data by the frequency, distribution, and variation of expressed traits in the population.
2) Identifying relationships
   a) Students perform and use appropriate statistical analyses of data, including 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 the statistical analysis to predict changes in trait distribution within a population if environmental variables change; and
      ii) Description of the expression of a chosen trait and its variations as causative or correlational to some environmental factor based on reliable evidence.

Topic: Natural Selection and Evolution

S.B.19. Engage in argumentation utilizing evidence to support common ancestry and biological evolution.

- phylogenetic trees
- cladograms.

[Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>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. Students 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).

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.</td><td rowspan="3">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></tr>
<tr><th>Science Connecting Concepts</th></tr>
<tr><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.

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.</td></tr>
</table>

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

1) Communication style and format
   a) Students use at least two different formats (e.g., oral, graphical, textual and mathematical), to communicate scientific information, including that common ancestry and biological evolution are supported by multiple lines of empirical evidence. Students cite the origin of the information as appropriate.
2) Connecting the DCIs and the CCCs

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 of amino acid sequences, even when DNA sequences are slightly different, including the fact that multiple patterns of DNA sequences can code for the same amino acid;
   iii) Patterns in the fossil record (e.g., presence, location, and inferences possible in lines of evolutionary descent for multiple specimens); and
   iv) The pattern of anatomical and embryological similarities.

b) Students identify and communicate connections between each line 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 (e.g., DNA sequences, embryological development, fossil records) provide evidence for causal relationships relating to biological evolution and common ancestry.

S.B.20. Construct an explanation based on evidence that the process of evolution primarily results from four factors:

- potential for a species to increase in number
- heritable genetic variation of individuals in a species due to mutation and sexual reproduction
- competition for limited resources
- 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.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>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. Students will 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 rowspan="2">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.

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</td></tr>
<tr><th>Science Connecting Concepts</th></tr>
</table>

Cause and Effect Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	those organisms that are better able to survive and reproduce in that environment.

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

1) Articulating the explanation of phenomena
   a) Students construct an explanation that includes a description that evolution is caused primarily by one or more of the 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.
2) Evidence
   a) Students identify and describe evidence to construct their explanation, including that:
      i) As a species grows in number, competition for limited resources can arise.
      ii) Individuals in a species have genetic variation (through mutations and sexual reproduction) that is passed on to their offspring.
      iii) Individuals can have specific traits that give them a competitive advantage relative to other individuals in the species.
   b) Students use a variety of valid and reliable sources for the evidence (e.g., data from investigations, theories, simulations, peer review).
3) Reasoning
   a) Students use reasoning to connect the evidence, along with 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, to construct the explanation. Students describe the following chain of reasoning for their explanation:
      i) Genetic variation can lead to variation of expressed traits in individuals in a population.
      ii) Individuals with traits that give competitive advantages can survive and reproduce at higher rates than individuals without the traits because of the competition for limited resources.
      iii) Individuals that survive and reproduce at a higher rate will provide their specific genetic variations to a greater proportion of individuals in the next generation.
      iv) Over many generations, groups of individuals with particular traits that enable them to survive and reproduce in distinct environments using distinct resources can evolve into a different species.
   b) Students use the evidence to describe the following in their explanation:
      i) The difference between natural selection and biological evolution (natural selection is a process, and biological evolution can result from that process); and
      ii) The cause and effect relationship between genetic variation, the selection of traits that provide comparative advantages, and the evolution of populations that all express the trait.

S.B.21. 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.]

Practices of Scientists and Engineers	Core Science Content

<table>
<tr><td>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. Students will 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 rowspan="3">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.</td></tr>
<tr><td>Science Connecting Concepts</td></tr>
<tr><td>Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.</td></tr>
</table>

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

1) Articulating the explanation of phenomena
   a) Students construct an explanation that identifies the cause and effect relationship between natural selection and adaptation.
2) Evidence
   a) Students identify and describe the evidence to construct their 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) The fact that individuals in a species have genetic variation (through mutations and sexual reproduction) that is passed on to their offspring; and
      iv) The fact that individuals can have specific traits that give them a competitive advantage relative to other individuals in the species.
   b) Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, peer review, students' own investigations)
3) Reasoning
   a) Students use reasoning to synthesize the valid and reliable evidence to distinguish between cause and correlation to construct the explanation about how natural selection provides a mechanism for species to adapt to changes in their environment, including the following elements:
      i) Biotic and abiotic 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.

S.B.22. Evaluate the evidence supporting claims that changes in environmental conditions drive natural selection.

{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.]

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>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. Students will evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.</td><td rowspan="3">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</td></tr>
<tr><td>Science Connecting Concepts</td></tr>
<tr><td>Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
</table>

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

1) Identifying the given claims and evidence to be evaluated
    a) Students identify the given claims, which include the idea that changes in environmental conditions may result in:
        i) Increases in the number of individuals of some species;
        ii) The emergence of new species over time; and
        iii) The extinction of other species.
    b) Students identify the given evidence to be evaluated.
2) Identifying any potential additional evidence that is relevant to the evaluation
    a) Students identify and describe additional evidence (in the form of data, information, models, or other appropriate forms) that was not provided but is relevant to the claims and to evaluating the given evidence, including:
        i) Data indicating the change over time in:
            (a) The number of individuals in each species;
            (b) The number of species in an environment; and
            (c) The environmental conditions.
        ii) Environmental factors that can determine the ability of individuals in a species to survive and reproduce.
3) Evaluating and critiquing
    a) Students use their additional evidence to assess the validity, reliability, strengths, and weaknesses of the given evidence, along with its ability to support logical and reasonable arguments about the outcomes of group behavior.
    b) Students assess the ability of the given evidence to be used to determine causal or correlational effects between environmental changes, the changes in the number of individuals in each species, the number of species in an environment, and/or the emergence or extinction of species.
4) Reasoning and synthesis

a) Students evaluate the degree to which the given empirical evidence can be used to construct logical arguments that identify causal links between environmental changes and changes in the number of individuals or species based on environmental factors that can determine the ability of individuals in a species to survive and reproduce.

Engineering, Technology, and Applications of Science

Topic: Engineering Design

S.B.23. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

<table>
<tr><th>Practices of Scientists and Engineers</th><th>Core Science Content</th></tr>
<tr><td>Asking Questions and Defining Problems
Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. Students will analyze complex real-world problems by specifying criteria and constraints for successful solutions.</td><td rowspan="3">Defining and Delimiting Engineering Problems
Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.</td></tr>
<tr><td>Science Connecting Concepts</td></tr>
<tr><td>Influence of Science, Engineering, and Technology on Society and the Natural World
New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.</td></tr>
</table>

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

1) Identifying the problem to be solved
   a) Students analyze a major global problem. In their analysis, students:
      i) Describe the challenge with a rationale for why it is a major global challenge;
      ii) Describe, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and
      iii) Document background research on the problem from two or more sources, including research journals.
2) Defining the process or system boundaries, and the components of the process or system
   a) In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem.
   b) In their analysis, students describe societal needs and wants that are relative to the problem (e.g., for controlling CO_2 emissions, societal needs include the need for cheap energy).
3) Defining the criteria and constraints
   a) Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.

S.B.24 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Practices of Scientists and Engineers	Core Science Content
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. Students will design a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.
Science Connecting Concepts	

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

1) Using scientific knowledge to generate the design solution
   a) Students restate the original complex problem into a finite set of two or more sub-problems (in writing or as a diagram or flow chart).
   b) For at least one of the sub-problems, students propose two or more solutions that are based on student-generated data and/or scientific information from other sources.
   c) Students describe how solutions to the sub-problems are interconnected to solve all or part of the larger problem.
2) Describing criteria and constraints, including quantification when appropriate
   a) Students describe criteria and constraints for the selected sub-problem.
   b) Students describe the rationale for the sequence of how sub-problems are to be solved, and which criteria should be given highest priority if tradeoffs must be made.

S.B.25 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

<table>
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<tr><td>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. Students will evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</td><td rowspan="3">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.</td></tr>
<tr><td>Science Connecting Concepts</td></tr>
<tr><td>Influence of Science, Engineering, and Technology on Society and the Natural World
New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.</td></tr>
</table>

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

1) Evaluating potential solutions
   a) In their evaluation of a complex real-world problem, students:
      i) Generate a list of three or more realistic criteria and two or more constraints, including such relevant factors as cost, safety, reliability, and aesthetics that specifies an acceptable solution to a complex real-world problem;
      ii) Assign priorities for each criterion and constraint that allows for a logical and systematic evaluation of alternative solution proposals;
      iii) Analyze (quantitatively where appropriate) and describe the strengths and weaknesses of the solution with respect to each criterion and constraint, as well as social and cultural acceptability and environmental impacts;
      iv) Describe possible barriers to implementing each solution, such as cultural, economic, or other sources of resistance to potential solutions; and
      v) Provide an evidence-based decision of which solution is optimum, based on prioritized criteria, analysis of the strengths and weaknesses (costs and benefits) of each solution, and barriers to be overcome.
2) Refining and/or optimizing the design solution
   a) In their evaluation, students describe which parts of the complex real-world problem may remain even if the proposed solution is implemented.

S.B.26. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Practices of Scientists and Engineers	Core Science Content
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. Students will use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.	**Developing Possible Solutions** 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.
Science Connecting Concepts	
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.	

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

1) Representation
   a) Students identify the following components from a given computer simulation:
      i) The complex real-world problem with numerous criteria and constraints;
      ii) The system that is being modeled by the computational simulation, including the boundaries of the systems;
      iii) What variables can be changed by the user to evaluate the proposed solutions, tradeoffs, or other decisions; and
      iv) The scientific principle(s) and/or relationship(s) being used by the model.
2) Computational Modeling
   a) Students use the given computer simulation to model the proposed solutions by:
      i) Selecting logical and realistic inputs; and
      ii) Using the model to simulate the effects of different solutions, tradeoffs, or other decisions.
3) Analysis
   a) Students compare the simulated results to the expected results.
   b) Students interpret the results of the simulation and predict the effects of the proposed solutions within and between systems relevant to the problem based on the interpretation.
   c) Students identify the possible negative consequences of solutions that outweigh their benefits.
   d) Students identify the simulation's limitations.

David L. Roach
West Virginia Superintendent of Schools