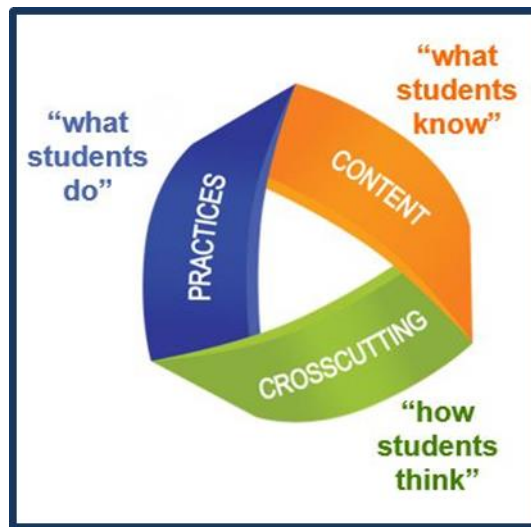


Ledyard Public Schools  
Ledyard High School  
NGSS Science Curriculum  
Biology

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1 credit course  
Required for graduation

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# District Philosophy

Ledyard's vision for K-12 inquiry based science is to engage students in scientific and engineering practices as they apply crosscutting concepts to deepen their understanding of the core ideas in these fields.

## A New Vision for Science Education

Implications of the Vision of the Framework for K-12 Science Education and the Next Generation Science Standards

SCIENCE EDUCATION WILL INVOLVE LESS:	SCIENCE EDUCATION WILL INVOLVE MORE:
Rote memorization of facts and terminology.	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning.
Learning of ideas disconnected from questions about phenomena.	Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned.
Teachers providing information to the whole class.	Students conducting investigations, solving problems, and engaging in discussions with teachers' guidance.
Teachers posing questions with only one right answer.	Students discussing open-ended questions that focus on the strength of the evidence used to generate claims.
Students reading textbooks and answering questions at the end of the chapter.	Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information.
Pre-planned outcome for "cookbook" laboratories or hands-on activities.	Multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas.
Worksheets.	Student writing of journals, reports, posters, and media presentations that explain and argue.
Oversimplification of activities for students who are perceived to be less able to do science and engineering	Provision of supports so that all students can engage in sophisticated science and engineering practices

Source: National Research Council. (2015). *Guide to Implementing the Next Generation Science Standards* (pp. 8-9). Washington, DC: National Academies Press.  
<http://www.nap.edu/catalog/18802/guide-to-implementing-the-next-generation-science-standards>

## Three Dimensions of the *Next Generation Science Standards*: Practices of Science and Engineering:

### Scientific and Engineering Practices Matrix - SEP (appendix F)

#### Asking Questions and Defining Problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.

Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify the ideas of others.

#### Planning and Carrying Out Investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.

#### Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.

Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

#### Developing and Using Models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

#### Constructing Explanations and Designing Solutions

*The products of science are explanations and the products of engineering are solutions.* The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

#### Engaging in Argument from Evidence

*Argumentation is the process by which explanations and solutions are reached.* In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to identify strengths and weaknesses of claims.

#### Using Mathematics and Computational Thinking

In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions. Statistical methods are frequently used to identify significant patterns and establish correlational relationships.

#### Obtaining, Evaluating, and Communicating Information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to acquire information that is used to evaluate the merit and validity of claims, methods, and designs.



[www.nsta.org/ngss](http://www.nsta.org/ngss)

## Three Dimensions of the *Next Generation Science Standards*: Disciplinary Core Ideas:

### Disciplinary Core Ideas Matrix - DCI (appendix E)

Physical Science	Life Science	Earth and Space Science	Engineering, Technology, and the Application of Science
<p><b><u>PS1: Matter and Its Interactions</u></b>            PS1.A: Structure and Properties of Matter            PS1.B: Chemical Reactions            PS1.C: Nuclear Processes</p> <p><b><u>PS2: Motion and Stability: Forces and Interactions</u></b>            PS2.A: Forces and Motion            PS2.B: Types of Interactions            PS2.C: Stability and Instability in Physical Systems</p> <p><b><u>PS3: Energy</u></b>            PS3.A: Definitions of Energy            PS3.B: Conservation of Energy and Energy Transfer            PS3.C: Relationship Between Energy and Forces            PS3.D: Energy in Chemical Processes and Everyday Life</p> <p><b><u>PS4: Waves and Their Applications in Technologies for Information Transfer</u></b>            PS4.A: Wave Properties            PS4.B: Electromagnetic Radiation            PS4.C: Information Technologies and Instrumentation</p>	<p><b><u>LS1: From Molecules to Organisms: Structures and Processes</u></b>            LS1.A: Structure and Function            LS1.B: Growth and Development of Organisms            LS1.C: Organization for Matter and Energy Flow in Organisms            LS1.D: Information Processing</p> <p><b><u>LS2: Ecosystems: Interactions, Energy, and Dynamics</u></b>            LS2.A: Interdependent Relationships in Ecosystems            LS2.B: Cycles of Matter and Energy Transfer in Ecosystems            LS2.C: Ecosystem Dynamics, Functioning, and Resilience            LS2.D: Social Interactions and Group Behavior</p> <p><b><u>LS3: Heredity: Inheritance and Variation of Traits</u></b>            LS3.A: Inheritance of Traits            LS3.B: Variation of Traits</p> <p><b><u>LS4: Biological Evolution: Unity and Diversity</u></b>            LS4.A: Evidence of Common Ancestry and Diversity            LS4.B: Natural Selection            LS4.C: Adaptation            LS4.D: Biodiversity and Humans</p>	<p><b><u>ESS1: Earth's Place in the Universe</u></b>            ESS1.A: The Universe and Its Stars            ESS1.B: Earth and the Solar System            ESS1.C: The History of Planet Earth</p> <p><b><u>ESS2: Earth's Systems</u></b>            ESS2.A: Earth Materials and Systems            ESS2.B: Plate Tectonics and Large-Scale System Interactions            ESS2.C: The Roles of Water in Earth's Surface Processes            ESS2.D: Weather and Climate            ESS2.E: Biogeology</p> <p><b><u>ESS3: Earth and Human Activity</u></b>            ESS3.A: Natural Resources            ESS3.B: Natural Hazards            ESS3.C: Human Impacts on Earth Systems            ESS3.D: Global Climate Change</p>	<p><b><u>ETS1: Engineering Design</u></b>            ETS1.A: Defining and Delimiting an Engineering Problem            ETS1.B: Developing Possible Solutions            ETS1.C: Optimizing the Design Solution</p> <p><b><u>ETS2: Links Among Engineering, Technology, Science, and Society</u></b>            ETS2.A: Interdependence of Science, Engineering, and Technology            ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World</p>

Developed by NSTA based on content from the *Framework for K-12 Science Education* and supporting documents for the *May 2012 Public Draft of the NGSS*

## Three Dimensions of the *Next Generation Science Standards*: Crosscutting Concepts:

### Crosscutting Concepts Matrix - CCC (appendix G)

<p><b><u>Patterns</u></b></p> <p>Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.</p> <p><b><u>Cause and Effect: Mechanism and Explanation</u></b> Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.</p>	<p><b><u>Scale, Proportion, and Quantity</u></b></p> <p>In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.</p> <p><b><u>Systems and System Models</u></b></p> <p>Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.</p>	<p><b><u>Energy and Matter: Flows, Cycles, and Conservation</u></b></p> <p>Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.</p> <p><b><u>Structure and Function</u></b></p> <p>The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.</p> <p><b><u>Stability and Change</u></b></p> <p>For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.</p>
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Developed by NSTA based on content from the *Framework for K-12 Science Education* and supporting documents for the *May 2012 Public Draft of the NGSS*

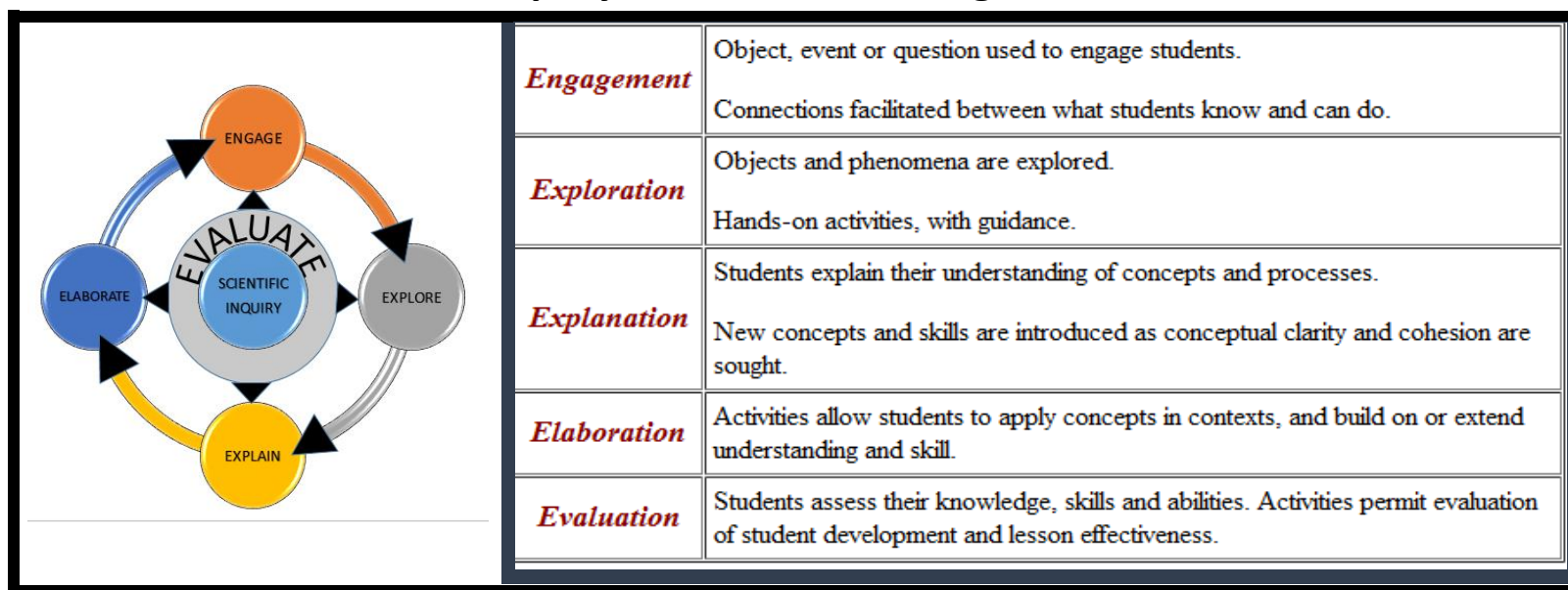
## Connections to the Nature of Science

<b>Nature of Science Practices</b>	<b>Nature of Science Crosscutting Concepts</b>
These understandings about the nature of science are closely associated with the science and engineering practices, and are found in that section of the foundation box on a standards page. More information about the Connections to Engineering, Technology and Applications of Science can be found in <a href="#">Appendix H</a> .	These understandings about the nature of science are closely associated with the crosscutting concepts, and are found in that section of the foundation box on a standards page. More information about the Connections to Engineering, Technology and Applications of Science can be found in <a href="#">Appendix H</a> .
<a href="#"><u>Scientific Investigations Use a Variety of Methods</u></a>	<a href="#"><u>Science is a Way of Knowing</u></a>
<a href="#"><u>Science Knowledge is Based on Empirical Evidence</u></a>	<a href="#"><u>Scientific Knowledge Assumes and Order and Consistency in Natural Systems</u></a>
<a href="#"><u>Scientific Knowledge is Open to Revision in Light of New Evidence</u></a>	<a href="#"><u>Science is a Human Endeavor</u></a>
<a href="#"><u>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena.</u></a>	<a href="#"><u>Science Addresses Questions About the Natural and Material World</u></a>

## How does Ledyard Define Inquiry?

Inquiry is defined as a way of seeking information, knowledge, or truth through questioning. Inquiry is a way for a learner to acquire new information and data and turn it into useful knowledge. Inquiry involves asking good questions and developing robust investigations from them. Inquiry also involves considering possible solutions and consequences. A third component of inquiry is separating evidence based claims from common opinion, and communicating claims with others, and acting upon these claims when appropriate. Questions lead to gathering information through research, study, experimentation, observation, or interviews. During this time, the original question may be revised, a line of research refined, or an entirely new path may be pursued. As more information is gathered, it becomes possible to make connections and allows individuals to construct their own understanding to form new knowledge. Sharing this knowledge with others develops the relevance of the learning for both the student and a greater community. Sharing is followed by reflection and potentially more questions, bringing the inquiry process full circle.

## Inquiry 5 Science Teaching Model



## Course Overview

### This course addresses four major themes:

- ❖ The first is **From Molecules to Organisms: Structures and Processes**, which addresses how individual organisms are configured and how these structures function to support life, growth, behavior, and reproduction.
- ❖ The second is **Ecosystems: Interactions, Energy, and Dynamics**, which explores organisms' interactions with each other and their physical environment. This includes how organisms obtain resources, how they change their environment, how changing environmental factors affect organisms and ecosystems, how social interactions and group behavior play out within and between species, and how these factors all combine to determine ecosystem functioning.
- ❖ The third is **Heredity: Inheritance and Variation of Traits across generations**, which focuses on the flow of genetic information between generations. This idea explains the mechanisms of genetic inheritance and describes the environmental and genetic causes of gene mutation and the alteration of gene expression.
- ❖ The fourth is **Biological Evolution: Unity and Diversity**, which explores “changes in the traits of populations of organisms over time” and the factors that account for species' unity and diversity alike. The section begins with a discussion of the converging evidence for shared ancestry that has emerged from a variety of sources (e.g., comparative anatomy and embryology, molecular biology and genetics). It describes how variation of genetically determined traits in a population may give some members a reproductive advantage in a given environment. This natural selection can lead to adaptation, that is, to a distribution of traits in the population that is matched to and can change with environmental conditions. Such adaptations can eventually lead to the development of separate species in separated populations. Finally, the idea describes the factors, including human activity, that affect biodiversity in an ecosystem, and the value of biodiversity in ecosystem resilience.
- ❖ This course builds on the knowledge and skills from K-8, supporting high school students in meeting NGSS performance expectations.
- ❖ This course addresses all of the 21<sup>st</sup> century academic expectations of Ledyard High School with an emphasis on academic expectations #2 and #3.

### LHS 21<sup>st</sup> Century Learning Expectations:

1. Read and write critically and effectively for a variety of purposes.
2. **Communicate information clearly and effectively in a variety of settings.**
3. **Demonstrate critical thinking and problem solving skills effectively.**
4. Employ effective research and study skills.
5. Use technology effectively and responsibly.

Core Idea : LS1: From Molecules to Organisms: Structures and Processes (20 class periods)

**Compelling Question: How do organisms live, grow, respond to their environment, and reproduce?**

All living organisms are made of cells. Life is the quality that distinguishes living things—composed of living cells—from nonliving objects or those that have died. While a simple definition of life can be difficult to capture, all living things—that is to say all organisms—can be



characterized by common aspects of their structure and functioning. Organisms are complex, organized, and built on a hierarchical structure, with each level providing the foundation for the next, from the chemical foundation of elements and atoms, to the cells and systems of individual organisms, to species and populations living and interacting in complex ecosystems. Organisms can be made of a single cell or millions of cells working together and include animals, plants, algae, fungi, bacteria, and all other microorganisms.

Organisms respond to stimuli from their environment and actively maintain their internal environment through homeostasis. They grow and reproduce, transferring their genetic information to their offspring. While individual organisms carry the same genetic information over their lifetime, mutation and the transfer from parent to offspring produce new combinations of genes. Over generations natural selection can lead to changes in a species overall; hence, species evolve over time. To maintain all of these processes and functions, organisms require materials and energy from their environment; nearly all energy that sustains life ultimately comes from the sun.

<u>Component Ideas</u>	<u>NGSS Performance Expectations</u>
<u><b>LS1.A: STRUCTURE AND FUNCTION</b></u> Supporting question: <i>How do the structures of organisms enable life's functions?</i>	<a href="#">HS-LS1-1</a> , <a href="#">HS-LS1-2</a> , <a href="#">HS-LS1-3</a> , <a href="#">HS-LS3-1</a>
<u><b>LS1.B: GROWTH AND DEVELOPMENT OF ORGANISMS</b></u> Supporting question: <i>How do organisms grow and develop?</i>	<a href="#">HS-LS1-4</a>
<u><b>LS1.C: ORGANIZATION FOR MATTER AND ENERGY FLOW IN ORGANISMS</b></u> Supporting question: <i>How do organisms obtain and use the matter and energy they need to live and grow?</i>	<a href="#">HS-LS1-5</a> , <a href="#">HS-LS1-6</a> , <a href="#">HS-LS1-7</a>
<b>LS1.D: INFORMATION PROCESSING</b> Supporting questions: <i>How do organisms detect, process, and use information about the environment?</i>	N/A (There is a description in the framework, but none in NGSS Performance Expectations)
<b>NGSS Performance Expectations</b> <i>Students who demonstrate understanding can:</i>	
<a href="#">HS-LS1-1</a> 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.

**Clarification Statement:** None

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

#### [HS-LS1-2](#)

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.

#### [HS-LS1-3](#)

Plan and conduct an investigation 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.

#### [HS-LS1-4](#)

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

**Clarification Statement:** None

**Assessment Boundary:** Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.

#### [HS-LS1-5](#)

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.

### [HS-LS1-6](#)

Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

**Clarification Statement:** Emphasis is on using evidence from models and simulations to support explanations.

**Assessment Boundary:** Assessment does not include the details of the specific chemical reactions or identification of macromolecules.

### [HS-LS1-7](#)

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

**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.

## [LS1.A: STRUCTURE AND FUNCTION](#)

([HS-LS1-1](#), [HS-LS1-2](#), [HS-LS1-3](#), [HS-LS3-1](#))

(For HS-LS3-1, see [LS3.A](#))

**Supporting Question:** *How do the structures of organisms enable life's functions?*

**Suggested Content –Vocabulary in bold**

- A central feature of **life** is that **organisms** grow, **reproduce**, and die. They have characteristic structures (**anatomy** and **morphology**), functions (molecular-scale processes to organism-level **physiology**), and behaviors (**neurobiology** and, for some animal species, **psychology**).
- Organisms and their parts are made of **cells**, which are the structural units of life and which themselves have **molecular substructures** that support their functioning.
  - Organisms range in composition from a single cell (**unicellular microorganisms**) to **multicellular organisms**, in which different groups of

large numbers of cells work together to form systems of **tissues** and **organs** (e.g., **circulatory, respiratory, nervous, musculoskeletal**), that are specialized for particular functions.

- Special structures within cells are also responsible for specific cellular functions. The essential functions of a cell involve **chemical reactions** between many types of **molecules**, including water, **proteins, carbohydrates, lipids**, and **nucleic acids**.
- All cells contain **genetic information**, in the form of **DNA**. **Genes** are specific regions within the extremely large DNA molecules that form the **chromosomes**. Genes contain the instructions that code for the formation of molecules called proteins, which carry out most of the work of cells to perform the essential functions of life. That is, proteins provide structural components, serve as **signaling devices**, regulate cell activities, and determine the performance of cells through their **enzymatic actions**.

<u>Disciplinary Core Ideas</u>	<u>Observable features of student performance</u> *Unless otherwise specified, “descriptions” referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.
<ul style="list-style-type: none"> <li>• Systems of specialized cells within organisms help them perform the essential functions of life. (<a href="#">HS-LS1-1</a>)</li> <li>• 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. (<a href="#">HS-LS1-1</a>) (Note: This Disciplinary Core Idea is also addressed by <a href="#">HS-LS3-1</a>.)</li> </ul>	<p><a href="#">HS-LS1-1</a></p> <ol style="list-style-type: none"> <li>1. Articulating the explanation of phenomena             <ol style="list-style-type: none"> <li>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.</li> </ol> </li> <li>2. Evidence             <ol style="list-style-type: none"> <li>a. Students identify and describe* the evidence to construct their explanation, including that:                     <ol style="list-style-type: none"> <li>i. All cells contain DNA;</li> <li>ii. DNA contains regions that are called genes;</li> <li>iii. The sequence of genes contains instructions that code for proteins; and</li> <li>iv. Groups of specialized cells (tissues) use proteins to carry out functions that are essential to the organism.</li> </ol> </li> <li>b. Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, peer review, students’ own investigations).</li> </ol> </li> <li>3. Reasoning             <ol style="list-style-type: none"> <li>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:                     <ol style="list-style-type: none"> <li>i. Because all cells contain DNA, all cells contain genes that can code for the formation of</li> </ol> </li> </ol> </li> </ol>

<ul style="list-style-type: none"> <li>• Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (<a href="#">HS-LS1-2</a>)</li> <li>• 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.</li> </ul>	<p>proteins.</p> <ul style="list-style-type: none"> <li>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.</li> <li>iii. Proper function of many proteins is necessary for the proper functioning of the cells.</li> <li>iv. Gene sequence affects protein function, which in turn affects the function of body tissues.</li> </ul> <p><a href="#">HS-LS1-2</a></p> <ol style="list-style-type: none"> <li>1. Components of the model       <ol style="list-style-type: none"> <li>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.</li> </ol> </li> <li>2. Relationships       <ol style="list-style-type: none"> <li>a. In the model, students describe* the relationships between components, including:           <ol style="list-style-type: none"> <li>i. The functions of at least two major body systems in terms of contributions to overall function of an organism;</li> <li>ii. Ways the functions of two different systems affect one another; and</li> <li>iii. A system's function and how that relates both to the system's parts and to the overall function of the organism.</li> </ol> </li> </ol> </li> <li>3. Connections       <ol style="list-style-type: none"> <li>a. Students use the model to illustrate how the interaction between systems provides specific functions in multicellular organisms.</li> <li>b. Students make a distinction between the accuracy of the model and actual body systems and functions it represents.</li> </ol> </li> </ol> <p><a href="#">HS-LS1-3</a></p> <ol style="list-style-type: none"> <li>1. Identifying the phenomenon under investigation       <ol style="list-style-type: none"> <li>a. Students describe* the phenomenon under investigation, which includes the following idea: that feedback mechanisms maintain homeostasis.</li> </ol> </li> <li>2. Identifying the evidence to answer this question       <ol style="list-style-type: none"> <li>a. Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including:</li> </ol> </li> </ol>
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Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. ([HS-LS1-3](#))

- 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. Planning for the investigation
  - a. In the investigation plan, students describe\*:
    - 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 will be measured or determined;
    - iv. The experimental procedure, the minimum number of different systems (and the factors that affect them) that would allow generalization of results, the evidence derived from the data, and identification of limitations on the precision of data to include types and amounts; and
    - v. Whether the investigation will be conducted individually or collaboratively.
4. Collecting the data
  - a. Students collect and record changes in the external environment and organism responses as a function of time.
5. Refining the design
  - a. Students evaluate their investigation, including:
    - i. Assessment of the accuracy and precision of the data, as well as limitations (e.g., cost, risk, time) of the investigation, and make suggestions for refinement; and
    - ii. Assessment of the ability of the data to provide the evidence required.
  - b. If necessary, students refine the investigation plan to produce more generalizable data.

### Crosscutting Concepts

#### 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. (HS-LS1-1)

#### Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS1-2)

### **Stability and Change**

- Feedback (negative or positive) can stabilize or destabilize a system. (HS-LS1-3)

## **Science and Engineering Practices**

### **Constructing Explanations and Designing Solutions**

- Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
  - Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1)

### **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. (HS-LS1-2)

### **Planning and Carrying Out Investigations**

- Planning and carrying out in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.
  - Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS1-3)

### **Connections to Nature of Science**

### **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. (HS-LS1-3)

**Grade Band Endpoint for LS1.A***By the end of grade 12:*

Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules, such as water, proteins, carbohydrates, lipids, and nucleic acids. 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.

Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. 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. Outside that range (e.g., at a too high or too low external temperature, with too little food or water available), the organism cannot survive. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

**K-12 Endpoint Progression****Activities**

Required activities: To be determined

Suggested activities:

- [DNA Family Relationship Analysis \(Genetics\)](#) - The lesson engages students in an argumentation cycle to determine if an individual could be the abducted son who disappeared 20 years prior by posing the question of whether or not the individual could be a member of this family using Short Tandem Repeats (STRs) of DNA segments as genetic markers.
- [How We Get Our Skin Color](#) -The interactive animation describes how and where melanin is produced and includes five stop points where students can learn more information. The resource can be used with units related to genetics, evolution and cell structure and function.
- [Human Homeostasis](#) - This interactive simulation provides students the opportunity to explore how our body maintains a stable internal environment in spite of the outside conditions, within certain limits. It allows students to investigate a phenomenon that may in real life, be dangerous to humans.
- [NGSS-HUB \(project ideas\)](#)- link to various activities



Modifications to Content/Differentiation	
Priority	Enrichment
<p>-To include suggestions regarding depth of coverage</p> <p>-Minimum depth of coverage</p> <p>- Systems of specialized cells within organisms help perform essential functions of life. Any one system in an organism is made up of numerous parts. Feedback mechanisms maintain an organism's internal conditions within certain limits and mediate behaviors. (<a href="#">Appendix E</a>)</p>	<p>-To include suggested extensions to investigations</p> <p>-Increased depth</p> <p>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 2.C.1-2</a>, <a href="#">3.A.1</a>, <a href="#">3.E.2</a>, <a href="#">4.A.1</a>, <a href="#">3-4</a>, <a href="#">4.B.2</a>)</p> <p>- Designing or modeling cells/systems are used show the connections of structures and functions and feedback mechanisms.</p>
Assessments	
<p>Require assessments: To be determined</p> <p>Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> <li>• A combination of traditional assessment with project, or</li> <li>• Other format of teacher's choice</li> </ul>	

### LS1.B: GROWTH AND DEVELOPMENT OF ORGANISMS

([HS-LS1-4](#))

Supporting Question: *How do organisms grow and develop?*

#### Suggested Content-Vocabulary in bold

- The characteristic structures, functions, and behaviors of **organisms** change in predictable ways as they progress from birth to old age.
  - For example, upon reaching **adulthood**, organisms can **reproduce** and transfer their **genetic information** to their **offspring**. Animals engage in behaviors that increase their chances for reproduction, and plants may develop specialized structures and/or depend on animal behavior to accomplish reproduction.
- Understanding how a single cell can give rise to a complex, **multicellular organism** builds on the concepts of **cell division** and **gene**

expression.

- In multi-cellular organisms, cell division is an essential component of **growth, development, and repair**. Cell division occurs via a process called **mitosis**: when a cell divides in two, it passes **identical genetic material** to two **daughter cells**. Successive divisions produce many cells.
- Although the genetic material in each of the cells is identical, small differences in the immediate environments activate or inactivate different genes, which can cause the cells to develop slightly differently. This process of **differentiation** allows the body to form specialized cells that perform diverse functions, even though they are all descended from a single cell, the **fertilized egg**. **Cell growth** and differentiation are the mechanisms by which a fertilized egg develops into a complex organism.
- In sexual reproduction, a specialized type of cell division called **meiosis** occurs and results in the production of **sex cells**, such as **gametes (sperm and eggs)** or **spores**, which contain only one member from each **chromosome pair** in the **parent cell**.

#### Disciplinary Core Ideas

#### Observable features of student performance

\*Unless otherwise specified, “descriptions” referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.

- 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,

#### HS-LS1-4

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:

composed of systems of tissues and organs that work together to meet the needs of the whole organism. ( <a href="#">HS-LS1-4</a> )	<ul style="list-style-type: none"> <li>i. Allow growth of the organism;</li> <li>ii. Can then differentiate to create different cell types; and</li> <li>iii. Can replace dead cells to maintain a complex organism.</li> </ul> <ul style="list-style-type: none"> <li>b. Students make a distinction between the accuracy of the model and the actual process of cellular division.</li> </ul>
Crosscutting Concepts	
<b>Systems and System Models</b> <ul style="list-style-type: none"> <li>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.</li> </ul>	
Science and Engineering Practices	
<b>Developing and Using Models</b> <ul style="list-style-type: none"> <li>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.             <ul style="list-style-type: none"> <li>Use a model based on evidence to illustrate the relationships between systems or between components of a system.</li> </ul> </li> </ul>	
Grade Band Endpoint for LS1.B	
<p><i><a href="#">By the end of grade 12:</a></i></p> <p>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. As successive subdivisions of an embryo's cells occur, programmed genetic instructions and small differences in their immediate environments activate or inactivate different genes, which cause the cells to develop differently—a process called differentiation. 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. In sexual reproduction, a specialized type of cell division called meiosis occurs that results in the production of sex cells, such as gametes in animals (sperm and eggs), which contain only one member from each chromosome pair in the parent cell.</p> <p><a href="#">K-12 Endpoint Progression</a></p>	

Activities	
<p>Required activities: To be determined</p> <p>Suggested activities:</p> <ul style="list-style-type: none"> <li>• <a href="#">Cell Cycle Flipbook</a> - Students learn about the cell division by creating a paper flipbook animation including interphase, mitosis and cytokinesis. This project can easily be converted into a meiosis flipbook. (Science and engineering practice: Developing and using models)</li> <li>• <a href="#">Seed Germination Lab</a> -The goal of this basic lab is to break the misconception that photosynthesis is how plants grow. Students should also learn that plants grow by cell division. (Science and engineering practice: Planning and carrying out investigations, Applying and interpreting data)</li> <li>• <a href="#">The Nerve of Stem Cells</a> – Students will describe the process of nerve specialization and nervous system development from the stage of embryonic stem cells to early infancy. (Science and engineering practice: Developing and using models)</li> <li>• <a href="#">NGSS-HUB (project ideas)</a>- link to various activities</li> </ul>	
Modifications to Content/Differentiation	
Priority	Enrichment
<ul style="list-style-type: none"> <li>- <i>To include suggestions regarding depth of coverage</i></li> <li>- <i>Minimum depth of coverage</i></li> <li>- Growth and division of cells in organisms occurs by mitosis and differentiation for specific cell types. (<a href="#">Appendix E</a>)</li> </ul>	<ul style="list-style-type: none"> <li>- <i>To include suggested extensions to investigations</i></li> <li>- <i>Increased depth</i></li> <li>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 2.E.1</a>, <a href="#">3.A.2</a>, <a href="#">3.B.1-2</a>, <a href="#">4.A.3</a>)</li> <li>- Building a model to demonstrate understanding of mitosis and growth</li> </ul>
Assessments	
<p>Required assessments: To be determined</p> <p>Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> <li>• A combination of traditional assessment with project, or</li> <li>• Other format of teacher's choice</li> </ul>	

**LS1.C: ORGANIZATION FOR MATTER AND ENERGY FLOW IN ORGANISMS**

(HS-LS1-5, HS-LS1-6, HS-LS1-7)

**Supporting Question:** *How do organisms obtain and use the matter and energy they need to live and grow?***Suggested Content-Vocabulary in bold**

- Sustaining life requires substantial **energy** and **matter** inputs. The complex structural organization of organisms accommodates the capture, transformation, transport, release, and elimination of the matter and energy needed to sustain them.
- As matter and energy flow through different organizational levels—cells, tissues, organs, organisms, populations, communities, and ecosystems—of living systems, chemical elements are recombined in different ways to form different products. The result of these chemical reactions is that energy is transferred from one system of interacting molecules to another.
- In most cases, the energy needed for life is ultimately derived from the sun through **photosynthesis** (although in some ecologically important cases, energy is derived from reactions involving inorganic chemicals in the absence of sunlight—e.g., **chemosynthesis**).
  - Plants, **algae** (including **phytoplankton**), and other **energy-fixing microorganisms** use sunlight, water, and carbon dioxide to facilitate photosynthesis, which stores energy, forms plant matter, releases oxygen, and maintains plants' activities.
  - Plants and algae—being the resource base for animals, the animals that feed on animals, and the **decomposers**—are energy-fixing organisms that sustain the rest of the food web.

Disciplinary Core IdeasObservable features of student performance

\*Unless otherwise specified, "descriptions" referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. ([HS-LS1-5](#))

HS-LS1-5

- Components of the model
  - 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:
    - Energy in the form of light;
    - Breaking of chemical bonds to absorb energy;
    - Formation of chemical bonds to release energy; and
    - Matter in the form of carbon dioxide, water, sugar, and oxygen.
- Relationships
  - Students identify the following relationship between components of the given model: Sugar and

<ul style="list-style-type: none"> <li>The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (<a href="#">HS-LS1-6</a>)</li> <li>As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (<a href="#">HS-LS1-6</a>), (<a href="#">HS-LS1-7</a>)</li> </ul>	<p>oxygen are produced by carbon dioxide and water by the process of photosynthesis.</p> <ol style="list-style-type: none"> <li>Connections       <ol style="list-style-type: none"> <li>Students use the given model to illustrate:           <ol style="list-style-type: none"> <li>The transfer of matter and flow of energy between the organism and its environment during photosynthesis; and</li> <li>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).</li> </ol> </li> </ol> </li> <li><a href="#">HS-LS1-6</a></li> <li>Articulating the explanation of phenomena       <ol style="list-style-type: none"> <li>Students construct an explanation that includes:           <ol style="list-style-type: none"> <li>The relationship between the carbon, hydrogen, and oxygen atoms from sugar_molecules formed in or ingested by an organism and those same atoms found in amino acids and other large carbon-based molecules; and</li> <li>That larger carbon-based molecules and amino acids can be a result of chemical_reactions between sugar molecules (or their component atoms) and other atoms.</li> </ol> </li> </ol> </li> <li>Evidence       <ol style="list-style-type: none"> <li>Students identify and describe* the evidence to construct the explanation, including:           <ol style="list-style-type: none"> <li>All organisms take in matter (allowing growth and maintenance) and rearrange the_atoms in chemical reactions.</li> <li>Cellular respiration involves chemical reactions between sugar molecules and other_molecules in which energy is released that can be used to drive other chemical_reactions.</li> <li>Sugar molecules are composed of carbon, oxygen, and hydrogen atoms.</li> <li>Amino acids and other complex carbon-based molecules are composed largely of_carbon, oxygen, and hydrogen atoms.</li> <li>Chemical reactions can create products that are more complex than the reactants.</li> <li>Chemical reactions involve changes in the energies of the molecules involved in the_reaction.</li> </ol> </li> <li>Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, students' own investigations).</li> </ol> </li> <li>Reasoning       <ol style="list-style-type: none"> <li>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</li> </ol> </li> </ol>
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<ul style="list-style-type: none"> <li>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</li> </ul>	<p>the future, to construct the explanation that atoms from sugar molecules may combine with other elements via chemical reactions to form other large carbon-based molecules. Students describe* the following chain of reasoning for their explanation:</p> <ol style="list-style-type: none"> <li>The atoms in sugar molecules can provide most of the atoms that comprise amino acids and other complex carbon-based molecules.</li> <li>The energy released in respiration can be used to drive chemical reactions between sugars and other substances, and the products of those reactions can include amino acids and other complex carbon-based molecules.</li> <li>The matter flows in cellular processes are the result of the rearrangement of primarily the atoms in sugar molecules because those are the molecules whose reactions release the energy needed for cell processes.</li> </ol> <ol style="list-style-type: none"> <li>Revising the explanation       <ol style="list-style-type: none"> <li>Given new evidence or context, students revise or expand their explanation about the relationships between atoms in sugar molecules and atoms in large carbon-based molecules, and justify their revision.</li> </ol> </li> </ol> <p><a href="#"><u>HS-LS1-7</u></a></p> <ol style="list-style-type: none"> <li>Components of the model       <ol style="list-style-type: none"> <li>From a given model, students identify and describe* the components of the model relevant for their illustration of cellular respiration, including:           <ol style="list-style-type: none"> <li>Matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO<sub>2</sub>);</li> <li>The breaking and formation of chemical bonds; and</li> <li>Energy from the chemical reactions.</li> </ol> </li> </ol> </li> <li>Relationships       <ol style="list-style-type: none"> <li>From the given model, students describe* the relationships between components, including:           <ol style="list-style-type: none"> <li>Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration; and</li> <li>The process of cellular respiration releases energy because the energy released when the bonds that are formed in CO<sub>2</sub> and water is greater than the energy required to break the bonds of sugar and oxygen.</li> </ol> </li> </ol> </li> <li>Connections</li> </ol>
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<p>ongoing energy transfer to the surrounding environment. (<a href="#">HS-LS1-7</a>)</p>	<p>a. Students use the given model to illustrate that:</p> <ul style="list-style-type: none"> <li>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.</li> <li>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.</li> </ul>
<p style="text-align: center;"><b>Crosscutting Concepts</b></p>	
<p><b>Energy and Matter</b></p> <ul style="list-style-type: none"> <li>• Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5), (HS-LS1-6)</li> <li>• Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS1-7)</li> </ul>	
<p style="text-align: center;"><b>Science and Engineering Practices</b></p>	
<p><b>Developing and Using Models</b></p> <ul style="list-style-type: none"> <li>• 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.             <ul style="list-style-type: none"> <li>○ Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-5) and (HS-LS1-7)</li> </ul> </li> </ul> <p><b>Constructing Explanations and Designing Solutions</b></p> <ul style="list-style-type: none"> <li>• 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.             <ul style="list-style-type: none"> <li>○ Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-6)</li> </ul> </li> </ul>	



## Grade Band Endpoint for LS1.C

[By the end of grade 12:](#)

The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. The sugar molecules thus formed contain carbon, hydrogen, and oxygen; their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. For example, aerobic (in the presence of oxygen) 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. Anaerobic (without oxygen) cellular respiration follows a different and less efficient chemical pathway to provide energy in cells. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy loss to the surrounding environment. Matter and energy are conserved in each change. This is true of all biological systems, from individual cells to ecosystems.

[K-12 Endpoint Progression](#)

## Activities

Required activities: To be determined

Suggested activities:

- [Lab 5: Photosynthesis: Why Do Temperature and Light Intensity Affect the Rate of Photosynthesis in Plants? From Argument-Driven Inquiry in Biology: Lab Investigations for Grades 9-12](#) – (needs to buy online) The lab asks students to design experiments, construct arguments, and develop conceptual models to answer the guiding question.
- [Wetlands Are Wonderlands](#): This resource consists of five activities for students to explore food webs and food pyramids within the context of a wetlands ecosystem. This is a 5<sup>th</sup>-grade activity, but can be modified to high school level.
- [Energy Transfer in Living Organisms](#): This activity shows students how is the law of conservation of energy applied to living organisms. (Science and engineering practice: Developing and using models and using mathematics and computational thinking)
- [NGSS-HUB \(project ideas\)](#)- link to various activities

## Modifications to Content/Differentiation

Priority	Enrichment
<ul style="list-style-type: none"> <li>- To include suggestions regarding depth of coverage</li> <li>- Minimum depth of coverage</li> <li>- The hydrocarbon backbones of sugars produced through</li> </ul>	<ul style="list-style-type: none"> <li>- To include suggested extensions to investigations</li> <li>- Increased depth</li> <li>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 2.A.1-3</a>, <a href="#">4.A.1</a>, <a href="#">3</a>)</li> </ul>

photosynthesis are used to make amino acids and other molecules that can be assembled into proteins or DNA. Through cellular respiration, matter and energy flow through different organizational levels of an organism as elements are recombined to form different products and transfer energy. ( <a href="#">Appendix E</a> )	- Creating a terrarium to make observations of the terrarium, then develop a model to explain how matter transfers and how energy flows within the ecosystem.
<b>Assessments</b>	
<p>Required assessments: To be determined</p> <p>Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> <li>• A combination of traditional assessment with project, or</li> <li>• Other format of teacher's choice</li> </ul>	

### Core Idea : LS 2: Ecosystems: Interactions, Energy, and Dynamics (26 class periods)

#### Compelling Question: How and why do organisms interact with their environment and what are the effects of these interactions?

Ecosystems are complex, interactive systems that include both biological communities (biotic) and physical (abiotic) components of the environment. As with individual organisms, a hierarchal structure exists; groups of the same organisms (species) form populations, different populations interact to form communities, communities live within an ecosystem, and all of the ecosystems on Earth make up the biosphere. Organisms grow, reproduce, and perpetuate their species by obtaining necessary resources through interdependent relationships with other organisms and the physical environment. These same interactions can facilitate or restrain growth and enhance or limit the size of populations, maintaining the balance between available resources and those who consume them. These interactions can also change both biotic and abiotic characteristics of the environment. Like individual organisms, ecosystems are sustained by the continuous flow of energy, originating primarily from the sun, and the recycling of matter and nutrients within the system. Ecosystems are dynamic, experiencing shifts in population composition and abundance and changes in the physical environment over time, which ultimately affects the stability and resilience of the entire system.

<u>Component Ideas</u>	<u>NGSS Performance Expectations</u>
<p><a href="#"><u>LS2.A: INTERDEPENDENT RELATIONSHIPS IN ECOSYSTEMS</u></a></p> <p>Supporting question: <i>How do organisms interact with the living and nonliving environments to obtain matter and energy?</i></p>	<p><a href="#"><u>HS-LS2-1</u></a>, <a href="#"><u>HS-LS2-2</u></a></p>
<p><a href="#"><u>LS2.B: CYCLES OF MATTER AND ENERGY TRANSFER IN ECOSYSTEMS</u></a></p> <p>Supporting question: <i>How do matter and energy move through an ecosystem?</i></p>	<p><a href="#"><u>HS-LS2-3</u></a>, <a href="#"><u>HS-LS2-4</u></a>, <a href="#"><u>HS-LS2-5</u></a></p>
<p><a href="#"><u>LS2.C: ECOSYSTEM DYNAMICS, FUNCTIONING, AND RESILIENCE</u></a></p> <p>Supporting question: <i>What happens to ecosystems when the environment changes?</i></p>	<p><a href="#"><u>HS-LS2-2</u></a>, <a href="#"><u>HS-LS2-6</u></a>, <a href="#"><u>HS-LS2-7</u></a></p>
<p><a href="#"><u>LS2.D: SOCIAL INTERACTIONS AND GROUP BEHAVIOR</u></a></p> <p>Supporting question: <i>How do organisms interact in groups so as to benefit individuals?</i></p>	<p><a href="#"><u>HS-LS2-8</u></a></p>
<p align="center"><b>NGSS Performance Expectations</b> <i>Students who demonstrate understanding can:</i></p>	
<p><a href="#"><u>HS-LS2-1</u></a></p> <p>Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.</p> <p><b>Clarification Statement:</b> 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.</p> <p><b>Assessment Boundary:</b> Assessment does not include deriving mathematical equations to make comparisons.</p>	
<p><a href="#"><u>HS-LS2-2</u></a></p> <p>Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in</p>	

ecosystems of different scales.

**Clarification Statement:** Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.

**Assessment Boundary:** Assessment is limited to provided data.

### [HS-LS2-3](#)

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.

### [HS-LS2-4](#)

Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

**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.

### [HS-LS2-5](#)

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

**Clarification Statement:** Examples of models could include simulations and mathematical models.

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

### [HS-LS2-6](#)

Evaluate 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.

**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.

Assessment Boundary: N/A

### [HS-LS2-7](#)

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.

Assessment Boundary: N/A

### [HS-LS2-8](#)

Evaluate evidence for the role of group behavior on individual and species' chances to survive and reproduce.

**Clarification Statement:** Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.

Assessment Boundary: N/A

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

## [LS2.A: INTERDEPENDENT RELATIONSHIPS IN ECOSYSTEMS](#)

([HS-LS2-1](#), [HS-LS2-2](#))

**Supporting Question: *How do organisms interact with the living and nonliving environments to obtain matter and energy?***

### **Suggested Content-Vocabulary in bold**

- **Ecosystems** are ever changing because of the interdependence of organisms of the same or different species and the **nonliving (physical) elements** of the environment.
- Seeking matter and energy resources to sustain life, organisms in an ecosystem interact with one another in complex **feeding hierarchies** of producers, consumers, and decomposers, which together represent a food web. Interactions between organisms may be predatory, competitive, or mutually beneficial.
- Ecosystems have **carrying capacities** that limit the number of organisms (within populations) they can support. Individual survival and

population sizes depend on such factors as predation, disease, availability of resources, and parameters of the physical environment. Organisms rely on physical factors, such as light, temperature, water, soil, and space for shelter and reproduction.

- Earth's varied combinations of these factors provide the physical environments in which its ecosystems (e.g., **deserts, grasslands, rain forests, and coral reefs**) develop and in which the diverse species of the planet live. Within any one ecosystem, the **biotic interactions** between organisms (e.g., competition, predation, and various types of facilitation, such as pollination) further influence their growth, survival, and reproduction, both individually and in terms of their populations.

<u>Disciplinary Core Ideas</u>	<u>Observable features of student performance</u> *Unless otherwise specified, "descriptions" referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.
<ul style="list-style-type: none"> <li>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. (<a href="#">HS-LS2-1</a>), (<a href="#">HS-LS2-2</a>). Note: <a href="#">HS-LS2-2</a> is also addressed by <a href="#">LS2.C</a>:</li> </ul>	<p><a href="#">HS-LS2-1</a></p> <ol style="list-style-type: none"> <li>Representation             <ol style="list-style-type: none"> <li>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:                     <ol style="list-style-type: none"> <li>The population changes gathered from historical data or simulations of ecosystems at different scales; and</li> <li>Data on numbers and types of organisms as well as boundaries, resources, and climate.</li> </ol> </li> <li>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:                     <ol style="list-style-type: none"> <li>Some factors have larger effects than do other factors.</li> <li>Factors are interrelated.</li> <li>The significance of a factor is dependent on the scale (e.g., a pond vs. an ocean) at which it occurs.</li> </ol> </li> </ol> </li> <li>Mathematical and/or computational modeling             <ol style="list-style-type: none"> <li>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.</li> </ol> </li> <li>Analysis             <ol style="list-style-type: none"> <li>Students analyze and use the given mathematical and/or computational representations</li> </ol> </li> </ol>

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.

- 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.

#### HS-LS2-2

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

	<p>an ecosystem.</p> <ul style="list-style-type: none"> <li>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.</li> <li>iii. To describe* how, in the model, factors affecting ecosystems at one scale can cause observable changes in ecosystems at a different scale.</li> </ul> <ul style="list-style-type: none"> <li>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.</li> </ul> <p>4. Revision</p> <ul style="list-style-type: none"> <li>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).</li> </ul>
Crosscutting Concepts	
<p><b>Scale, Proportion, and Quantity</b></p> <ul style="list-style-type: none"> <li>The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1)</li> <li>Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2)</li> </ul>	
Science and Engineering Practices	
<p><b>Using Mathematics and Computational Thinking</b></p> <ul style="list-style-type: none"> <li>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.             <ul style="list-style-type: none"> <li>Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HS-LS2-1)</li> <li>Use mathematical representations of phenomena or design solutions to support and revise explanations. (HS-LS2-2)</li> </ul> </li> </ul> <p style="text-align: center;"><u><b>Connections to Nature of Science</b></u></p> <p><b>Scientific Knowledge is Open to Revision in Light of New Evidence</b></p> <ul style="list-style-type: none"> <li>Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing</li> </ul>	



evidence. (HS-LS2-2)

### Grade Band Endpoint for LS2.A

#### By the end of grade 12:

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 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.

#### K-12 Endpoint Progression

### Activities

Required activities: To be determined

- Suggested activities:
- [African Lions: Modeling Population Growth](#) - This activity examines exponential and logistic growth and asks students to analyze the factors that influence population growth by interpreting data. (Science and engineering practice: Developing and using models)
- [Population Ecology Lab](#) - Students participate in an activity that models a population of rabbits, and learn how density-dependent factors affect a population size (Science and engineering practice: Developing and using models and using mathematics and computational thinking)
- [Limiting factors and models of population growth](#) - Students will be able to categorize factors that limit population growth as density-dependent or density-independent; define carrying capacity; and accurately predict how density-dependent factors will limit the growth of populations. (Science and engineering practice: Developing and using models and using mathematics and computational thinking)
- [NGSS-HUB \(project ideas\)](#)- link to various activities

### Modifications to Content/Differentiation

Priority	Enrichment
<ul style="list-style-type: none"> <li>- To include suggestions regarding depth of coverage</li> <li>- Minimum depth of coverage</li> <li>- Ecosystems have carrying capacities resulting from biotic and abiotic factors. The fundamental tension between resource availability and organism populations affects the abundance of species in any given</li> </ul>	<ul style="list-style-type: none"> <li>- To include suggested extensions to investigations</li> <li>- Increased depth</li> <li>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 2.D.1</a>, <a href="#">4.A.5-6</a>, <a href="#">4.B.3</a>, <a href="#">4.C.4</a>)</li> <li>- Predicting changes in ecosystem carrying capacities with climate changes, nonnative species invading, etc.</li> </ul>

ecosystem. ( <a href="#">Appendix E</a> )	
Assessments	
<p>Required assessments: To be determined</p> <p>Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> <li>• A combination of traditional assessment with project, or</li> <li>• Other format of teacher's choice</li> </ul>	

### [LS2.B: CYCLES OF MATTER AND ENERGY TRANSFER IN ECOSYSTEMS](#)

([HS-LS2-3](#), [HS-LS2-4](#), [HS-LS2-5](#))

Supporting Question: *How do matter and energy move through an ecosystem?*

#### Suggested Content-Vocabulary in bold

- The **cycling of matter** and **the flow of energy** within ecosystems occur through interactions among different organisms and between organisms and the physical environment. All living systems need matter and energy. Matter fuels the energy-releasing chemical reactions that provide energy for life functions and provides the material for growth and repair of tissue. Energy from light is needed for plants because the chemical reaction that produces plant matter from air and water requires an energy input to occur. Animals acquire matter from food, that is, from plants or other animals.
- The chemical elements that make up the **molecules of organisms** pass through food webs and the environment and are combined and recombined in different ways. At each level in a **food web**, some matter provides energy for life functions, some is stored in newly made structures, and much is discarded to the surrounding environment. Only a small fraction of the matter consumed at one level is captured by the next level up. As matter cycles and energy flows through living systems and between living systems and the physical environment, matter and energy are conserved in each change.
- The **carbon cycle** provides an example of matter cycling and energy flow in ecosystems. Photosynthesis, digestion of plant matter, respiration, and decomposition are important components of the carbon cycle, in which carbon is exchanged between the **biosphere**, **atmosphere**, **oceans**, and **geosphere** through chemical, physical, geological, and biological processes.

Disciplinary Core Ideas	Observable features of student performance *Unless otherwise specified, “descriptions” referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.
<ul style="list-style-type: none"> <li>Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (<a href="#">HS-LS2-3</a>)</li> <li>Plants or algae form the</li> </ul>	<p><a href="#">HS-LS2-3</a></p> <ol style="list-style-type: none"> <li>Articulating the explanation of phenomena             <ol style="list-style-type: none"> <li>Students construct an explanation that includes that:                 <ol style="list-style-type: none"> <li>Energy from photosynthesis and respiration drives the cycling of matter and flow of energy under aerobic or anaerobic conditions within an ecosystem.</li> <li>Anaerobic respiration occurs primarily in conditions where oxygen is not available.</li> </ol> </li> </ol> </li> <li>Evidence             <ol style="list-style-type: none"> <li>Students identify and describe* the evidence to construct the explanation, including:                 <ol style="list-style-type: none"> <li>All organisms take in matter and rearrange the atoms in chemical reactions.</li> <li>Photosynthesis captures energy in sunlight to create chemical products that can be used as food in cellular respiration.</li> <li>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.</li> </ol> </li> <li>Students use a variety of valid and reliable sources for the evidence, which may include theories, simulations, peer review, and students’ own investigations.</li> </ol> </li> <li>Reasoning             <ol style="list-style-type: none"> <li>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:                 <ol style="list-style-type: none"> <li>Energy inputs to cells occur either by photosynthesis or by taking in food.</li> <li>Since all cells engage in cellular respiration, they must all produce products of respiration.</li> <li>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.</li> <li>The flow of matter and energy must occur whether respiration is aerobic or anaerobic.</li> </ol> </li> </ol> </li> <li>Revising the explanation             <ol style="list-style-type: none"> <li>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</li> </ol> </li> </ol>

<p>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. (<a href="#">HS-LS2-4</a>)</p> <ul style="list-style-type: none"> <li>• Photosynthesis and cellular respiration are important components of the carbon</li> </ul>	<p>the only driver for cycling matter and energy in ecosystems).</p> <p><a href="#">HS-LS2-4</a></p> <ol style="list-style-type: none"> <li>1. Representation       <ol style="list-style-type: none"> <li>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.</li> <li>b. Students identify the claims about the cycling of matter and energy flow among organisms in an ecosystem.</li> </ol> </li> <li>2. Mathematical modeling       <ol style="list-style-type: none"> <li>a. Students describe* how the claims can be expressed as a mathematical relationship in the mathematical representations of the components of an ecosystem</li> <li>b. Students use the mathematical representation(s) of the food web to:           <ol style="list-style-type: none"> <li>i. Describe* the transfer of matter (as atoms and molecules) and flow of energy upward between organisms and their environment;</li> <li>ii. Identify the transfer of energy and matter between trophic levels; and</li> <li>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.</li> </ol> </li> </ol> </li> <li>3. Analysis       <ol style="list-style-type: none"> <li>a. Students use the mathematical representation(s) to support the claims that include the idea that matter flows between organisms and their environment.</li> <li>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.</li> <li>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.</li> </ol> </li> </ol> <p><a href="#">HS-LS2-5</a></p> <ol style="list-style-type: none"> <li>1. Components of the model       <ol style="list-style-type: none"> <li>a. Students use evidence to develop a model in which they identify and describe* the relevant components, including:</li> </ol> </li> </ol>
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<p>cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (<a href="#">HS-LS2-5</a>). Note: <a href="#">HS-LS2-5</a> is also addressed by <a href="#">PS3.D: Energy in Chemical Processes</a>: The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary)</p>	<ul style="list-style-type: none"> <li>i. The inputs and outputs of photosynthesis;</li> <li>ii. The inputs and outputs of cellular respiration; and</li> <li>iii. The biosphere, atmosphere, hydrosphere, and geosphere.</li> </ul> <p>2. Relationships</p> <ul style="list-style-type: none"> <li>a. Students describe* relationships between components of their model, including: <ul style="list-style-type: none"> <li>i. The exchange of carbon (through carbon-containing compounds) between organisms and the environment; and</li> <li>ii. The role of storing carbon in organisms (in the form of carbon-containing compounds) as part of the carbon cycle.</li> </ul> </li> </ul> <p>3. Connections</p> <ul style="list-style-type: none"> <li>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.</li> <li>b. Students make a distinction between the model's simulation and the actual cycling of carbon via photosynthesis and cellular respiration.</li> </ul>
Crosscutting Concepts	
<p><b>Energy and Matter</b></p> <ul style="list-style-type: none"> <li>Energy drives the cycling of matter within and between systems. (HS-LS2-3)</li> <li>Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS2-4)</li> </ul> <p><b>Systems and System Models</b></p> <ul style="list-style-type: none"> <li>Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales. (HS-LS2-5)</li> </ul>	
Science and Engineering Practices	
<p><b>Constructing Explanations and Designing Solutions</b></p> <ul style="list-style-type: none"> <li>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. <ul style="list-style-type: none"> <li>Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own</li> </ul> </li> </ul>	

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. (HS-LS2-3)

### 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.
  - Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4)

### 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).
  - Develop a model based on evidence to illustrate the relationships between systems or components of a system. (HS-LS2-5)

### Connections to Nature of Science

### Scientific Knowledge is Open to Revision in Light of New Evidence

- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS-LS2-3)

### Grade Band Endpoint for LS2.B

#### *By the end of grade 12:*

Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. 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, and there is a limit to the number of organisms that an ecosystem can sustain.

The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. Competition among species is ultimately competition for the matter and energy needed for life.

Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

[K-12 Endpoint Progression](#)

Activities	
<p>Required activities: To be determined</p> <ul style="list-style-type: none"> <li>Suggested activities:</li> <li><a href="#">Food Webs, Energy Flow, Carbon Cycle, and Trophic Pyramids</a> - Students construct a food web for Yellowstone National Park, including producers, primary consumers, secondary consumers, decomposers, and trophic omnivores; then analyze a trophic cascade that resulted when wolves were re-introduced to Yellowstone.</li> <li><a href="#">Plant Biomass (Photosynthesis)</a> - The lesson engages students in an argumentation cycle in which they evaluate three alternative claims regarding where most of the matter that makes up the stem and leaves of a plant comes from.</li> <li><a href="#">Carbon Lab</a> - This interactive simulation uses a robust model of the carbon cycle to give student an intuitive sense for how carbon circulates through the atmosphere, biosphere, oceans, and crust to help students understand the carbon cycle on the global scale.</li> <li><a href="#">NGSS-HUB (project ideas)</a>- link to various activities</li> </ul>	
Modifications to Content/Differentiation	
Priority	Enrichment
<ul style="list-style-type: none"> <li>- <i>To include suggestions regarding depth of coverage</i></li> <li>- <i>Minimum depth of coverage</i></li> <li>- Photosynthesis and cellular respiration provide most of the energy for life processes. Only a fraction of matter consumed at the lower level of a food web is transferred up, resulting in fewer organisms at higher levels. At each link in an ecosystem elements are combined in different ways and matter and energy are conserved. Photosynthesis and cellular respiration are key components of the global carbon cycle. (<a href="#">Appendix E</a>)</li> </ul>	<ul style="list-style-type: none"> <li>- <i>To include suggested extensions to investigations</i></li> <li>- <i>Increased depth</i></li> <li>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 2.A.1-2, 3, 2.D.1, 4.A.6</a>)</li> <li>- Modeling the process of photosynthesis and respiration with students' own investigations</li> </ul>
Assessments	
<p>Required assessments: To be determined</p> <p>Suggested assessments:</p>	

- Traditional assessment: multiple choice and free response questions, or
- The above project(s) using the eight science and engineering practice standards, or
- A combination of traditional assessment with project, or
- Other format of teacher's choice

## LS2.C: ECOSYSTEM DYNAMICS, FUNCTIONING, AND RESILIENCE

([HS-LS2-2](#), [HS-LS2-6](#), [HS-LS2-7](#))

(For HS-LS2-2, see [HS-LS2A](#))

Supporting question: *What happens to ecosystems when the environment changes?*

### Suggested Content-Vocabulary in bold

- Ecosystems are dynamic in nature; their characteristics fluctuate over time, depending on changes in the environment and in the populations of various species. Disruptions in the physical and biological components of an ecosystem—which can lead to shifts in the types and numbers of the ecosystem's organisms, to the maintenance or the **extinction of species**, to the **migration of species** into or out of the region, or to the formation of new species (**speciation**)—occur for a variety of natural reasons. Changes may derive from the fall of canopy trees in a forest, for example, or from cataclysmic events, such as volcanic eruptions. But many changes are induced by human activity, such as **resource extraction**, **adverse land use patterns**, **pollution**, **introduction of nonnative species**, and **global climate change**. Extinction of species or evolution of new species may occur in response to significant ecosystem disruptions.
- Species in an environment develop behavioral and physiological patterns that facilitate their survival under the prevailing conditions, but these patterns may be maladapted when conditions change or new species are introduced. Ecosystems with a wide variety of species—that is, greater **biodiversity**—tend to be more **resilient** to change than those with few species.

### Disciplinary Core Ideas

### Observable features of student performance

\*Unless otherwise specified, "descriptions" referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.

- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively

### [HS-LS2-6](#)

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



constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. ([HS-LS2-6](#)). Note: this core idea is also addressed by [HS-LS2-2](#))

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. ([HS-LS2-7](#))  
Note: [HS-LS2-7](#) is also

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.
- [HS-LS2-7](#)
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

<p>addressed by: <a href="#">LS4.D: Biodiversity and Humans</a> and <a href="#">ETS1.B: Developing Possible Solutions</a>. LS4.D: 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.</p>	<p>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:</p> <ul style="list-style-type: none"> <li>i. Overpopulation;</li> <li>ii. Overexploitation;</li> <li>iii. Habitat destruction;</li> <li>iv. Pollution;</li> <li>v. Introduction of invasive species; and</li> <li>vi. Changes in climate.</li> </ul> <ul style="list-style-type: none"> <li>b. Students describe* the ways the proposed solution decreases the negative effects of human activity on the environment and biodiversity.</li> </ul> <ol style="list-style-type: none"> <li>2. Describing criteria and constraints, including quantification when appropriate       <ul style="list-style-type: none"> <li>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.</li> </ul> </li> <li>3. Evaluating potential solutions       <ul style="list-style-type: none"> <li>a. Students evaluate the proposed solution for its impact on overall environmental stability and changes.</li> <li>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.</li> </ul> </li> <li>4. Refining and/or optimizing the design solution       <ul style="list-style-type: none"> <li>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.</li> </ul> </li> </ol>
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(secondary). ETS1.B: 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)

### Crosscutting Concepts

#### Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6) and (HS-LS2-7)

### Science and Engineering Practices

#### 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.
  - Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)

#### Constructing Explanations and Designing Solutions

- Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
  - 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. (HS-LS2-7)

### Connections to Nature of Science

#### Scientific Knowledge is Open to Revision in Light of New Evidence

- 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. (HS-LS2-6)

### Grade Band Endpoint for LS2.C

#### *By the end of grade 12:*

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. 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.

#### K-12 Endpoint Progression

### Activities

Required activities: To be determined

Suggested activities:

- [Ecology Disrupted - Bighorn Sheep and Their Environment](#) - Students learn about human impact on bighorn sheep and design potential solutions to other specific ecological disruptions caused by humans.
- [Uncovering Wildlife](#) - Using cover boards to create microhabitats, models of ecosystems, students investigate interactions under different and/or changing environmental conditions. The 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate) is used in the actual design of the project.
- [Have Food, Will Travel](#) - The food consumed during a typical dinner may have traveled over 10,000 cumulative miles. How might we use our understanding of the environmental and social costs and benefits of global food distribution to identify aspects of the food system to redesign? (Science and engineering practice: Analyzing and interpreting data and using mathematics and computational thinking)
- [NGSS-HUB \(project ideas\)](#)- link to various activities

### Modifications to Content/Differentiation

Priority	Enrichment
<ul style="list-style-type: none"> <li>- To include suggestions regarding depth of coverage</li> <li>- Minimum depth of coverage</li> <li>- If a biological or physical disturbance to an ecosystem occurs, including one induced by human activity, the ecosystem may return to its more or less original state or become a very different ecosystem, depending on the complex set of interactions within the ecosystem. (<a href="#">Appendix E</a>)</li> </ul>	<ul style="list-style-type: none"> <li>- To include suggested extensions to investigations</li> <li>- Increased depth</li> <li>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 1.A.1-2</a>, <a href="#">1.C.1</a>, <a href="#">2.D.1</a>, <a href="#">3</a>, <a href="#">4.A.5-6</a>, <a href="#">4.B.3-4</a>)</li> <li>- Designing, evaluating, and refining a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</li> </ul>
Assessments	
<p>Required assessments: To be determined</p> <p>Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> <li>• A combination of traditional assessment with project, or</li> <li>• Other format of teacher's choice</li> </ul>	

### [LS2.D: SOCIAL INTERACTIONS AND GROUP BEHAVIOR](#)

([HS-LS2-8](#))

Supporting question: *How do organisms interact in groups so as to benefit individuals?*

#### Suggested Content-Vocabulary in bold

- **Group behaviors** are found in organisms ranging from **unicellular slime molds** to ants to **primates**, including humans. Many species, with a strong drive for **social affiliation**, live in groups formed on the basis of genetic relatedness, physical proximity, or other recognition mechanisms (which may be species specific). Group behavior evolved because group membership can increase the chances of survival for individuals and their relatives. While some groups are stable over long periods of time, others are fluid, with members moving in and out. Groups often dissolve if their size or operation becomes **counterproductive**, if **dominant members** lose their place, or if other **key members** are removed from the group. Group inter-dependence is so strong that animals that usually live in groups suffer, behaviorally as well as physiologically, when reared in isolation, even if all of their physical needs are met.

Disciplinary Core Ideas	Observable features of student performance *Unless otherwise specified, “descriptions” referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.
<ul style="list-style-type: none"> <li>Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (<a href="#">HS-LS2-8</a>)</li> </ul>	<p><a href="#">HS-LS2-8</a></p> <ol style="list-style-type: none"> <li>Identifying the given explanation and the supporting evidence               <ol style="list-style-type: none"> <li>Students identify the given explanation that is supported by the evidence to be evaluated, and which includes the following idea: Group behavior can increase the chances for an individual and a species to survive and reproduce.</li> <li>Students identify the given evidence to be evaluated.</li> </ol> </li> <li>Identifying any potential additional evidence that is relevant to the evaluation               <ol style="list-style-type: none"> <li>Students identify 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 evidence, and which includes evidence for causal relationships between specific group behaviors (e.g., flocking, schooling, herding, cooperative hunting, migrating, swarming) and individual survival and reproduction rates.</li> </ol> </li> <li>Evaluating and critiquing               <ol style="list-style-type: none"> <li>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.</li> <li>Students evaluate the given evidence for the degree to which it supports a causal claim that group behavior can have a survival advantage for some species, including how the evidence allows for distinguishing between causal and correlational relationships, and how it supports cause and effect relationships between various kinds of group behavior and individual survival rates (for example, the relationship between moving in a group and individual survival rates, compared to the survival rate of individuals of the same species moving alone or outside of the group).</li> </ol> </li> </ol>
Crosscutting Concepts	
<b>Cause and Effect</b> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</li> </ul>	

## Science and Engineering Practices

### 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.
  - Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.

### Connections to Nature of Science

### Scientific Knowledge is Open to Revision in Light of New Evidence

- 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.

## Grade Band Endpoint for LS2.D

### [By the end of grade 12:](#)

Animals, including humans, having a strong drive for social affiliation with members of their own species and will suffer, behaviorally as well as physiologically, if reared in isolation, even if all of their physical needs are met. Some forms of affiliation arise from the bonds between offspring and parents. Other groups form among peers. Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.

### [K-12 Endpoint Progression](#)

## Activities

Required activities: To be determined

Suggested activities:

- [Prairie Dogs: America's Meerkats – Language](#) - This nine-minute video shows the phenomenon of prairie dog vocalizations to a variety of threats to their population. The video provides evidence, using sonograms and prairie dog behavioral responses, that each vocalization contains discrete pieces of information that are understood by the local prairie dog population.
- [NGSS-HUB \(project ideas\)](#)- link to various activities

Modifications to Content/Differentiation	
Priority	Enrichment
<ul style="list-style-type: none"> <li>- To include suggestions regarding depth of coverage</li> <li>- Minimum depth of coverage</li> <li>- Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (<a href="#">Appendix E</a>)</li> </ul>	<ul style="list-style-type: none"> <li>- To include suggested extensions to investigations</li> <li>- Increased depth</li> <li>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 2.E.3</a>, <a href="#">3.E.1</a>, <a href="#">4.B.3</a>)</li> <li>- Evaluating evidence of advantages of group behavior using a real animal example</li> </ul>
Assessments	
<p>Required assessments: To be determined</p> <p>Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> <li>• A combination of traditional assessment with project, or</li> <li>• Other format of teacher's choice</li> </ul>	

### Core Idea : LS3: Heredity: Inheritance and Variation of Traits (20 class periods)

**Compelling Questions: How are characteristics of one generation passed to the next? How can individuals of the same species and even siblings have different characteristics?**

Heredity explains why offspring resemble, but are not identical to, their parents and is a unifying biological principle. Heredity refers to specific mechanisms by which characteristics or traits are passed from one generation to the next via genes. Genes encode the information for making specific proteins, which are responsible for the specific traits of an individual. Each gene can have several variants, called alleles, which code for different variants of the trait in question. Genes reside in a cell's chromosomes, each of which contains many genes. Every cell of any individual organism contains the identical set of chromosomes. When organisms reproduce, genetic information is transferred to their offspring. In species that reproduce sexually, each cell contains two variants of each chromosome, one inherited from each parent. Thus sexual reproduction gives rise to a new combination of chromosome pairs with variations between parent and offspring. Very rarely, mutations also cause variations, which may be harmful, neutral, or occasionally advantageous for an individual. Environmental as well as



genetic variation and the relative dominance of each of the genes in a pair play an important role in how traits develop within an individual. Complex relationships between genes and interactions of genes with the environment determine how an organism will develop and function.	
<u>Component Ideas</u>	<u>NGSS Performance Expectations</u>
<u>LS3.A: INHERITANCE OF TRAITS</u> Supporting question: <i>How are the characteristics of one generation related to the previous generation?</i>	<a href="#">HS-LS3-1</a> , <a href="#">HS-LS1-1</a>
<u>LS3.B: VARIATION OF TRAITS</u> Supporting question: <i>Why do individuals of the same species vary in how they look, function, and behave?</i>	<a href="#">HS-LS3-2</a> , <a href="#">HS-LS3-3</a>
<b>NGSS Performance Expectations</b> <i>Students who demonstrate understanding can:</i>	
<a href="#">HS-LS3-1</a> Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. Clarification Statement: N/A Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.	
<a href="#">HS-LS3-2</a> Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs. Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.	

HS-LS3-3

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

**Clarification Statement:** Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.

**Assessment Boundary:** Assessment does not include Hardy-Weinberg calculations.

LS3.A: INHERITANCE OF TRAITS

([HS-LS3-1](#), [HS-LS1-1](#))

(For HS-LS1-1, see [LS1.A](#))

**Supporting question:** *How are the characteristics of one generation related to the previous generation?*

**Suggested Content-Vocabulary in bold**

- In all organisms, the genetic instructions for forming species' characteristics are carried in the **chromosomes**. Each chromosome consists of a single very long **DNA molecule**, and each **gene** on the chromosome is a particular segment of that DNA. DNA molecules contain four different kinds of building blocks, called **nucleotides**, linked together in a sequential chain. The sequence of nucleotides spells out the information in a gene. Before a cell divides, the DNA sequence of its chromosomes is replicated and each daughter cell receives a copy. DNA controls the **expression of proteins** by being transcribed into a "**messenger**" RNA, which is translated in turn by the cellular machinery into a protein.
- In effect, proteins build an organism's identifiable **traits**. When organisms reproduce, genetic information is transferred to their offspring, with half coming from each parent in sexual reproduction. **Inheritance** is the key factor causing the similarity among individuals in a species population.

Disciplinary Core Ideas

Observable features of student performance

\*Unless otherwise specified, "descriptions" referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.

- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a

HS-LS3-1

- Addressing phenomena or scientific theories
  - Students use models of DNA to formulate questions, the answers to which would clarify:
    - The cause and effect relationships (including distinguishing between causal and correlational

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. ([HS-LS3-1](#))

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.

### Crosscutting Concepts

#### Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

### Science and Engineering Practices

#### 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.
  - Ask questions that arise from examining models or a theory to clarify relationships.

## Grade Band Endpoint for LS3.A

By the end of grade 12:

In all organisms the genetic instructions for forming species' characteristics are carried in the chromosomes. 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.

K-12 Endpoint Progression

## Activities

Required activities: To be determined

Suggested activities:

- [Zebrafish Development \(Phenomenon\)](#) - This two-minute video provides brief background on zebrafish development, it helps students understand that even though all the cells of an organism arise from a single fertilized egg, they develop different characteristics as different genes are expressed within the cells.
- [Pedigrees and the Inheritance of Lactose Intolerance](#) - Students analyze a family's pedigrees to make a claim based on evidence about mode of inheritance of a lactose intolerance trait.
- [How do Siamese Cats Get Their Color?](#) - Students develop explanations by making connections among genes, proteins, and traits.
- [NGSS-HUB \(project ideas\)](#)- link to various activities

## Modifications to Content/Differentiation

Priority	Enrichment
<ul style="list-style-type: none"> <li>- To include suggestions regarding depth of coverage</li> <li>- Minimum depth of coverage</li> <li>- DNA carries instructions for forming species' characteristics. Each cell in an organism has the same genetic content, but genes expressed by cells can differ (<a href="#">Appendix E</a>)</li> </ul>	<ul style="list-style-type: none"> <li>- To include suggested extensions to investigations</li> <li>- Increased depth</li> <li>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 2.E.1</a>, <a href="#">3.A.1-3</a>, <a href="#">3.B.1</a>, <a href="#">4.A.3</a>)</li> <li>- Applying the genetic knowledge to explain patterns of genetic disease and traits displayed by offspring</li> </ul>

Assessments
<p>Required assessments: To be determined</p> <p>Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> <li>• A combination of traditional assessment with project, or</li> <li>• Other format of teacher's choice</li> </ul>

<u>LS3.B: VARIATION OF TRAITS</u> (HS-LS3-2, HS-LS3-3)	
Supporting question: <i>Why do individuals of the same species vary in how they look, function, and behave?</i>	
Suggested Content-Vocabulary in bold	
<ul style="list-style-type: none"> <li>• Variation among individuals of the same species can be explained by both genetic and environmental factors. Individuals within a species have similar but not identical genes. In <b>sexual reproduction</b>, variations in traits between parent and offspring arise from the particular set of chromosomes (and their respective multiple genes) inherited, with each parent contributing half of each chromosome pair. More rarely, such variations result from mutations, which are changes in the information that genes carry. Although genes control the general traits of any given organism, other parts of the DNA and external environmental factors can modify an individual's specific development, appearance, behavior, and likelihood of producing offspring. The set of variations of genes present, together with the interactions of genes with their environment, determines the distribution of variation of traits in a population.</li> </ul>	
<u>Disciplinary Core Ideas</u>	<u>Observable features of student performance</u>
<ul style="list-style-type: none"> <li>• In sexual reproduction, chromosomes can sometimes swap sections during the process of</li> </ul>	*Unless otherwise specified, "descriptions" referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.
	<u>HS-LS3-2</u> 1. Developing a claim <ol style="list-style-type: none"> <li>Students make a claim that includes the idea that inheritable genetic variations may result from:               <ol style="list-style-type: none"> <li>New genetic combinations through meiosis;</li> <li>Viable errors occurring during replication; and</li> </ol> </li> </ol>

meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. ([HS-LS3-2](#))

- 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:
      - a) errors during replication; and/or
      - b) 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.

#### [HS-LS3-3](#)

- 1. Organizing data
  - a. Students organize the given data by the frequency, distribution, and variation of expressed traits in

<ul style="list-style-type: none"> <li>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. (<a href="#">HS-LS3-2</a>) (<a href="#">HS-LS3-3</a>)</li> </ul>	<p>the population.</p> <ol style="list-style-type: none"> <li>Identifying relationships             <ol style="list-style-type: none"> <li>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.</li> </ol> </li> <li>Interpreting data             <ol style="list-style-type: none"> <li>Students analyze and interpret data to explain the distribution of expressed traits, including:                     <ol style="list-style-type: none"> <li>Recognition and use of patterns in the statistical analysis to predict changes in trait distribution within a population if environmental variables change; and</li> <li>Description* of the expression of a chosen trait and its variations as causative or correlational to some environmental factor based on reliable evidence.</li> </ol> </li> </ol> </li> </ol>
Crosscutting Concepts	
<p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-2)</li> </ul> <p><b>Scale, Proportion, and Quantity</b></p> <ul style="list-style-type: none"> <li>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). (HS-LS3-3)</li> </ul> <p style="text-align: center;"><u><b>Connections to Nature of Science</b></u></p> <p><b>Science is a Human Endeavor</b></p> <ul style="list-style-type: none"> <li>Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-3)</li> <li>Science and engineering are influenced by society and society is influenced by science and engineering. (HS-LS3-3)</li> </ul>	
Science and Engineering Practices	
<p><b>Engaging in Argument from Evidence</b></p> <ul style="list-style-type: none"> <li>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</li> </ul>	

from current scientific or historical episodes in science.

- Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated evidence. (HS-LS3-2)

### Analyzing and Interpreting Data

- Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
  - Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS3-3)

### Grade Band Endpoint for LS3.B

#### [By the end of grade 12:](#)

The information passed from parents to offspring is coded in the DNA molecules that form the chromosomes. 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 depend on both genetic and environmental factors.

#### [K-12 Endpoint Progression](#)

### Activities

Required activities: To be determined

Suggested activities:

- [Cell Division and Cancer Risk](#) - Data Points engage students in analyzing and interpreting data from primary literature in the biological sciences, providing authentic phenomena to spark student discussion and exploration.
- [Using Genetic Crosses to Analyze a Stickleback Trait](#) - In this HHMI Biointeractive hands-on activity, students use photos of stickleback fish to analyze the results of genetic crosses between fish with different traits.
- [Model of Inheritance: Which Model of Inheritance Best Explains How a Specific Trait is Inherited in Fruit Flies?](#) - Students apply their



<p>knowledge of models of inheritance (dominant-recessive, co-dominance, incomplete dominance, multiple alleles, and sex-linked) to determine how fruit flies inherit a specific trait.</p> <ul style="list-style-type: none"> <li>• <a href="#">NGSS-HUB (project ideas)</a>- link to various activities</li> </ul>	
Modifications to Content/Differentiation	
Priority	Enrichment
<ul style="list-style-type: none"> <li>- To include suggestions regarding depth of coverage</li> <li>- Minimum depth of coverage</li> <li>- The variation and distribution of traits in a population depend on genetic and environmental factors. Genetic variation can result from mutations caused by environmental factors or errors in DNA replication, or from chromosomes swapping sections during meiosis. (<a href="#">Appendix E</a>)</li> </ul>	<ul style="list-style-type: none"> <li>- To include suggested extensions to investigations</li> <li>- Increased depth</li> <li>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 1.A.1-2</a>, <a href="#">2.E.1</a>, <a href="#">3.A.1-3</a>, <a href="#">3.C.1-2</a>, <a href="#">4.A.3</a>, <a href="#">4C.2-3</a>)</li> <li>- Making probability predictions on human genetic diseases based on published data or student-generated data.</li> </ul>
Assessments	
<p>Required assessments: To be determined Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> <li>• A combination of traditional assessment with project, or</li> <li>• Other format of teacher's choice</li> </ul>	

Core Idea : LS4: Biological Evolution: Unity and Diversity (26 class periods)

**Compelling Questions: How can there be so many similarities among organisms yet so many different kinds of plants, animals, and microorganisms? How does biodiversity affect humans?**

Biological evolution explains both the unity and the diversity of species and provides a unifying principle for the history and diversity of life on Earth. Biological evolution is supported by extensive scientific evidence ranging from the fossil record to genetic relationships among species. Researchers continue to use new and different techniques, including DNA and protein sequence analyses, to test and further their understanding of evolutionary relationships. Evolution, which is continuous and ongoing, occurs when natural selection acts on the genetic

variation in a population and changes the distribution of traits in that population gradually over multiple generations. Natural selection can act more rapidly after sudden changes in conditions, which can lead to the extinction of species. Through natural selection, traits that provide an individual with an advantage to best meet environmental challenges and reproduce are the ones most likely to be passed on to the next generation. Over multiple generations, this process can lead to the emergence of new species. Evolution thus explains both the similarities of genetic material across all species and the multitude of species existing in diverse conditions on Earth—its biodiversity—which humans depend on for natural resources and other benefits to sustain themselves.

<u>Component Ideas</u>	<u>NGSS Performance Expectations</u>
<p><a href="#"><u>LS4.A: EVIDENCE OF COMMON ANCESTRY AND DIVERSITY</u></a></p> <p>Supporting question: <i>What evidence shows that different species are related?</i></p>	<p><a href="#"><u>HS-LS4-1</u></a></p>
<p><a href="#"><u>LS4.B: NATURAL SELECTION</u></a></p> <p>Supporting question: <i>How does genetic variation among organisms affect survival and reproduction?</i></p>	<p><a href="#"><u>HS-LS4-2</u></a>, <a href="#"><u>HS-LS4-3</u></a></p>
<p><a href="#"><u>LS4.C: ADAPTATION</u></a></p> <p>Supporting question: <i>How does the environment influence populations of organisms over multiple generations?</i></p>	<p><a href="#"><u>HS-LS4-2</u></a>, <a href="#"><u>HS-LS4-3</u></a>, <a href="#"><u>HS-LS4-4</u></a>, <a href="#"><u>HS-LS4-5</u></a>, <a href="#"><u>HS-LS4-6</u></a></p>
<p><a href="#"><u>LS4.D: BIODIVERSITY AND HUMANS</u></a></p> <p>Supporting question: <i>What is biodiversity, how do humans affect it, and how does it affect humans?</i></p>	<p><a href="#"><u>HS-LS4-6</u></a>, <a href="#"><u>HS-LS2-7</u></a></p>
<p align="center"><b>NGSS Performance Expectations</b> Students who demonstrate understanding can:</p>	
<p><a href="#"><u>HS-LS4-1</u></a></p> <p>Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. <b>Clarification Statement:</b> Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and</p>	

biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.

**Assessment Boundary:** N/A

#### [HS-LS4-2](#)

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

**Clarification Statement:** Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.

**Assessment Boundary:** Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.

#### [HS-LS4-3](#)

Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

**Clarification Statement:** Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.

**Assessment Boundary:** Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.

#### [HS-LS4-4](#)

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

**Clarification Statement:** Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.

**Assessment Boundary:** N/A

[HS-LS4-5](#)

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

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

**Assessment Boundary:** N/A

[HS-LS4-6](#)

Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.\*

**Clarification Statement:** Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.

**Assessment Boundary:** N/A

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

[LS4.A: EVIDENCE OF COMMON ANCESTRY AND DIVERSITY](#)

([HS-LS4-1](#))

Supporting question: *What evidence shows that different species are related?*

Suggested Content-Vocabulary in **bold**

- **Biological evolution**, the process by which all living things have evolved over many generations from shared ancestors, explains both the unity and the diversity of species. The unity is illustrated by the similarities found between species; which can be explained by the inheritance of similar characteristics from related ancestors. The diversity of species is also consistent with common ancestry; it is explained by the branching and diversification of lineages as populations adapted, primarily through **natural selection**, to local circumstances.
- Evidence for common ancestry can be found in the fossil record, from comparative anatomy and **embryology**, from the similarities of cellular processes and structures, and from comparisons of **DNA sequences** between species. The understanding of evolutionary relationships has recently been greatly accelerated by using new molecular tools to study **developmental biology**, with researchers dissecting the genetic basis for some of the changes seen in the fossil record, as well as those that can be inferred to link living species

(e.g., the armadillo) to their ancestors (e.g., glyptodonts, a kind of extinct gigantic armadillo).

Disciplinary Core Ideas	Observable features of student performance <small>*Unless otherwise specified, “descriptions” referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.</small>
<ul style="list-style-type: none"> <li>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. (<a href="#">HS-LS4-1</a>)</li> </ul>	<p><a href="#">HS-LS4-1</a></p> <ol style="list-style-type: none"> <li>Communication style and format               <ol style="list-style-type: none"> <li>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.</li> </ol> </li> <li>Connecting the DCIs and the CCCs               <ol style="list-style-type: none"> <li>Students identify and communicate evidence for common ancestry and biological evolution, including:                   <ol style="list-style-type: none"> <li>Information derived from DNA sequences, which vary among species but have many similarities between species;</li> <li>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;</li> <li>Patterns in the fossil record (e.g., presence, location, and inferences possible in lines of evolutionary descent for multiple specimens); and</li> <li>The pattern of anatomical and embryological similarities.</li> </ol> </li> <li>Students identify and communicate connections between each line of evidence and the claim of common ancestry and biological evolution.</li> <li>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.</li> </ol> </li> </ol>
Crosscutting Concepts	
<p><b>Patterns</b></p> <ul style="list-style-type: none"> <li>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.</li> </ul>	

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

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

**Science and Engineering Practices****Obtaining, Evaluating, and Communicating Information**

- Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.
  - Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Connections to Nature of Science

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.

**Grade Band Endpoint for LS4.A**

*By the end of grade 12:*

Genetic information, like the fossil record, also 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.

[K-12 Endpoint Progression](#)

Activities	
<p>Required activities: To be determined</p> <p>Suggested activities:</p> <ul style="list-style-type: none"> <li>• <a href="#">Thermoregulation in Dinosaurs</a> - Students interpret a graph which illustrates the correlation between resting metabolic rates and mass for living vertebrate species with different thermoregulation strategies (endotherms, exotherms, and mesotherms) and extinct species of dinosaurs.</li> <li>• <a href="#">Evolutionary Relationships in Mammals (Genetics and Evolution)</a> - The lesson engages students in an argumentation cycle in which they use evidence from their analysis of the amino acid sequences 1-40 for the hemoglobin subunit alpha protein for nine mammals to make an argument for which of these mammals are the most closely related.</li> <li>• <a href="#">Stickleback Evolution Virtual Lab</a> - This virtual evolution lab utilizes data collection and analysis to allow students to study evolutionary processes using modern stickleback fish and fossil specimens.</li> <li>• <a href="#">NGSS-HUB (project ideas)</a>- link to various activities</li> </ul>	
Modifications to Content/Differentiation	
Priority	Enrichment
<ul style="list-style-type: none"> <li>- <i>To include suggestions regarding depth of coverage</i></li> <li>- <i>Minimum depth of coverage</i></li> <li>- The ongoing branching that produces multiple lines of descent can be inferred by comparing DNA sequences, amino acid sequences, and anatomical and embryological evidence of different organisms.</li> </ul> <p><a href="#">(Appendix E)</a></p>	<ul style="list-style-type: none"> <li>- <i>To include suggested extensions to investigations</i></li> <li>- <i>Increased depth</i></li> <li>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 1.A.4</a>, <a href="#">1.B.2</a>, <a href="#">1.C.3</a>)</li> <li>- Identifying and communicating evidence for common ancestry and biological evolution</li> </ul>
Assessments	
<p>Required assessments: To be determined</p> <p>Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> <li>• A combination of traditional assessment with project, or</li> <li>• Other format of teacher's choice</li> </ul>	

**LS4.B: NATURAL SELECTION**

(HS-LS4-2, HS-LS4-3)

Supporting question: *How does genetic variation among organisms affect survival and reproduction?***Suggested Content-Vocabulary in bold**

- **Genetic variation** in a species results in individuals with a range of traits. In any particular environment individuals with particular traits may be more likely than others to survive and produce offspring. This process is called natural selection and may lead to the predominance of certain inherited traits in a population and the suppression of others. Natural selection occurs only if there is variation in the genetic information within a population that is expressed in traits that lead to differences in survival and reproductive ability among individuals under specific environmental conditions. If the trait differences do not affect **reproductive success**, then natural selection will not favor one trait over others.

**Disciplinary Core Ideas****Observable features of student performance**

\*Unless otherwise specified, “descriptions” referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information — that is, trait variation — that leads to differences in performance among individuals. (HS-LS4-2) and (HS-LS4-3)

**HS-LS4-2**

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).



<ul style="list-style-type: none"> <li>• The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (<a href="#">HS-LS4-3</a>)</li> <li>• 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</li> </ul>	<ol style="list-style-type: none"> <li>3. Reasoning             <ol style="list-style-type: none"> <li>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:                 <ol style="list-style-type: none"> <li>i. Genetic variation can lead to variation of expressed traits in individuals in a population.</li> <li>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.</li> <li>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.</li> <li>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.</li> </ol> </li> <li>b. Students use the evidence to describe* the following in their explanation:                 <ol style="list-style-type: none"> <li>i. The difference between natural selection and biological evolution (natural selection is a process, and biological evolution can result from that process); and</li> <li>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.</li> </ol> </li> </ol> <p><a href="#">HS-LS4-3</a></p> <ol style="list-style-type: none"> <li>1. Organizing data             <ol style="list-style-type: none"> <li>a. Students organize data (e.g., using tables, graphs and charts) by the distribution of genetic traits over time.</li> <li>b. Students describe* what each dataset represents</li> </ol> </li> <li>2. Identifying relationships             <ol style="list-style-type: none"> <li>a. Students perform and use appropriate statistical analyses of data, including probability measures, to determine patterns of change in numerical distribution of traits over various time and population scales.</li> </ol> </li> <li>3. Interpreting data             <ol style="list-style-type: none"> <li>a. Students use the data analyses as evidence to support explanations about the following:                 <ol style="list-style-type: none"> <li>i. Positive or negative effects on survival and reproduction of individuals as relating to their expression of a variable trait in a population;</li> </ol> </li> </ol> </li> </ol> </li></ol>
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<p>that do not.</p> <ul style="list-style-type: none"> <li>Adaptation also means that the distribution of traits in a population can change when conditions change.</li> </ul>	<ul style="list-style-type: none"> <li>ii. Natural selection as the cause of increases and decreases in heritable traits over time in a population, but only if it affects reproductive success; and</li> <li>iii. The changes in distribution of adaptations of anatomical, behavioral, and physiological traits in a population.</li> </ul>
Crosscutting Concepts	
<p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-2)</li> </ul> <p><b>Patterns</b></p> <ul style="list-style-type: none"> <li>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-3)</li> </ul>	
Science and Engineering Practices	
<p><b>Constructing Explanations and Designing Solutions</b></p> <ul style="list-style-type: none"> <li>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.             <ul style="list-style-type: none"> <li>Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-2)</li> </ul> </li> </ul> <p><b>Analyzing and Interpreting Data</b></p> <ul style="list-style-type: none"> <li>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.             <ul style="list-style-type: none"> <li>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. (HS-LS4-3)</li> </ul> </li> </ul>	

## Grade Band Endpoint for LS4.B

[By the end of grade 12:](#)

Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. The traits that positively affect survival are more likely to be reproduced and thus are more common in the population.

[K-12 Endpoint Progression](#)

## Activities

Required activities: To be determined

Suggested activities:

- [Developing an Explanation for Mouse Fur Color](#) - Students summarize the evidence for evolution by natural selection presented in the film and in figures from a scientific paper, to understand how to collect and analyze evidence.
- [The Biology of Skin Color](#) - Students use the data presented in the film to make predictions about how skin color has evolved over time to include the variety of pigments we see around the world today.
- [Why Don't Antibiotics Work Like They Used To? \[v1.0\] Storyline](#) - This three-dimensional storyline unit consists of three “bends” that engage students in a series of phenomena related to natural selection and evolution.
- [NGSS-HUB \(project ideas\)](#)- link to various activities

## Modifications to Content/Differentiation

## Priority

- *To include suggestions regarding depth of coverage*
- *Minimum depth of coverage*
- Natural selection occurs only if there is variation in the genes and traits between organisms in a population. Traits that positively affect survival can become more common in a population. ([Appendix E](#))

## Enrichment

- *To include suggested extensions to investigations*
- *Increased depth*
- [Concepts connected for AP Biology](#) ([EK 1.A.1-2](#), [3.C.1](#), [3.E.1](#))
- Making a presentation to explain how an existing trait in a population can become an advantage in natural selection due to environmental changes.

## Assessments

Required assessments: To be determined

Suggested assessments:

- Traditional assessment: multiple choice and free response questions, or

- The above project(s) using the eight science and engineering practice standards, or
- A combination of traditional assessment with project, or
- Other format of teacher's choice

#### LS4.C: ADAPTATION

([HS-LS4-2](#), [HS-LS4-3](#), [HS-LS4-4](#), [HS-LS4-5](#), [HS-LS4-6](#))

Supporting question: *How does the environment influence populations of organisms over multiple generations?*

#### Suggested Content-Vocabulary in **bold**

- When an environment changes, there can be subsequent shifts in its supply of resources or in the physical and biological challenges it imposes. Some individuals in a population may have morphological, physiological, or behavioral traits that provide a **reproductive advantage** in the face of the shifts in the environment. Natural selection provides a mechanism for species to adapt to changes in their environment. The resulting selective pressures influence the survival and reproduction of organisms over many generations and can change the distribution of traits in the population. This process is called **adaptation**.
- Adaptation can lead to organisms that are better suited for their environment because individuals with the traits adaptive to the environmental change pass those traits on to their offspring, whereas individuals with traits that are less adaptive produce fewer or no offspring. Over time, adaptation can lead to the formation of new species. In some cases, however, traits that are adaptive to the changed environment do not exist in the population and the species becomes extinct. Adaptive changes due to natural selection, as well as the net result of speciation minus extinction, have strongly contributed to the planet's biodiversity.
- Adaptation by natural selection is ongoing. For example it is seen in the emergence of antibiotic-resistant bacteria. Organisms like bacteria, in which multiple generations occur over shorter time spans, evolve more rapidly than those for which each generation takes multiple years.

#### Disciplinary Core Ideas

#### Observable features of student performance

\*Unless otherwise specified, "descriptions" referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are

For [HS-LS4-2](#) and [HS-LS4-3](#), see [LS4.B HS-LS4-4](#)

1. Articulating the explanation of phenomena
  - a. Students construct an explanation that identifies the cause and effect relationship between natural selection and adaptation.

<p>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. (<a href="#">HS-LS4-4</a>)</p> <ul style="list-style-type: none"> <li>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</li> </ul>	<ol style="list-style-type: none"> <li>2. Evidence             <ol style="list-style-type: none"> <li>a. Students identify and describe* the evidence to construct their explanation, including:                 <ol style="list-style-type: none"> <li>i. Changes in a population when some feature of the environment changes;</li> <li>ii. Relative survival rates of organisms with different traits in a specific environment;</li> <li>iii. The fact that individuals in a species have genetic variation (through mutations and sexual reproduction) that is passed on to their offspring; and</li> <li>iv. The fact that individuals can have specific traits that give them a competitive advantage relative to other individuals in the species.</li> </ol> </li> <li>b. Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, peer review, students' own investigations)</li> </ol> </li> <li>3. Reasoning             <ol style="list-style-type: none"> <li>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:                 <ol style="list-style-type: none"> <li>i. Biotic and abiotic differences in ecosystems contribute to changes in gene frequency over time through natural selection.</li> <li>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.</li> <li>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.</li> </ol> </li> </ol> </li> </ol> <p><a href="#">HS-LS4-5</a></p> <ol style="list-style-type: none"> <li>1. Identifying the given claims and evidence to be evaluated             <ol style="list-style-type: none"> <li>a. Students identify the given claims, which include the idea that changes in environmental conditions may result in:                 <ol style="list-style-type: none"> <li>i. Increases in the number of individuals of some species;</li> <li>ii. The emergence of new species over time; and</li> <li>iii. The extinction of other species.</li> </ol> </li> <li>b. Students identify the given evidence to be evaluated.</li> </ol> </li> <li>2. Identifying any potential additional evidence that is relevant to the evaluation             <ol style="list-style-type: none"> <li>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</li> </ol> </li> </ol>
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<p>the extinction — of some species. (<a href="#">HS-LS4-5</a>) (<a href="#">HS-LS4-6</a>)</p> <ul style="list-style-type: none"> <li>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. (<a href="#">HS-LS4-5</a>)</li> </ul>	<p>given evidence, including:</p> <ol style="list-style-type: none"> <li>Data indicating the change over time in: <ol style="list-style-type: none"> <li>The number of individuals in each species;</li> <li>The number of species in an environment; and</li> <li>The environmental conditions.</li> </ol> </li> <li>Environmental factors that can determine the ability of individuals in a species to survive and reproduce.</li> </ol> <ol style="list-style-type: none"> <li>Evaluating and critiquing <ol style="list-style-type: none"> <li>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.</li> <li>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.</li> </ol> </li> <li>Reasoning and synthesis <ol style="list-style-type: none"> <li>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.</li> </ol> </li> </ol> <p>For <a href="#">HS-LS4-6</a>, see <a href="#">LS4.D</a></p>
Crosscutting Concepts	
<p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-4) (HS-LS4-5)</li> </ul> <p style="text-align: center;"><u><b>Connections to Nature of Science</b></u></p> <p>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</p> <ul style="list-style-type: none"> <li>Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-LS4-4)</li> </ul>	

**Science and Engineering Practices****Constructing Explanations and Designing Solutions**

- Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
  - Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-4)

**Engaging in Argument from Evidence**

- Engaging in argument from evidence in 9- 12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science.
  - Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5)

**Grade Band Endpoint for LS4.C***By the end of grade 12:*

Natural selection is the result of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. 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. Adaptation also means that the distribution of traits in a population can change when conditions change.

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 too drastic, the opportunity for the species' evolution is lost.

### K-12 Endpoint Progression

Activities	
<p>Required activities: To be determined</p> <p>Suggested activities:</p> <ul style="list-style-type: none"> <li>• <a href="#">Peppered Moth Simulation</a> - Students experience how a population can change based on changes to the environment by using their own data from an interactive simulation during the industrial revolution.</li> <li>• <a href="#">To Survive Poachers, Many African Elephants Born Tuskless</a> - This short video introduces tusklessness (due to poaching) and would allow the teacher the opportunity to drive the instruction of the class to figure out many scientific concepts including: natural selection, adaptation, genetics, ecology, and human impact.</li> <li>• <a href="#">HHMI Data Point: Effects of Natural Selection on Finch Beak Size</a> - Data Points engage students in analyzing and interpreting data from primary literature in the biological sciences. The resources are intended to provide authentic phenomena to spark student discussion and exploration.</li> <li>• <a href="#">NGSS-HUB (project ideas)</a>- link to various activities</li> </ul>	
Modifications to Content/Differentiation	
Priority	Enrichment
<p>- <i>To include suggestions regarding depth of coverage</i></p> <p>- <i>Minimum depth of coverage</i></p> <p>- Evolution results primarily from genetic variation of individuals in a species, competition for resources, and proliferation of organisms better able to survive and reproduce. Adaptation means that the distribution of traits in a population, as well as species expansion, emergence or extinction, can change when conditions change. (<a href="#">Appendix E</a>)</p>	<p>- <i>To include suggested extensions to investigations</i></p> <p>- <i>Increased depth</i></p> <p>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 1.A.1-2</a>, <a href="#">1.C.1-3</a>, <a href="#">2.E.3</a>, <a href="#">4.C.3-4</a>)</p> <p>- Applying concepts of natural selection and adaptation to explain genetic variations with evidence/models.</p>
Assessments	
<p>Required assessments: To be determined</p> <p>Suggested assessments:</p> <ul style="list-style-type: none"> <li>• Traditional assessment: multiple choice and free response questions, or</li> <li>• The above project(s) using the eight science and engineering practice standards, or</li> </ul>	



- A combination of traditional assessment with project, or
- Other format of teacher's choice

#### LS4.D: BIODIVERSITY AND HUMANS

([HS-LS4-6](#), and [HS-LS2-7](#))

(For HS-LS2-7, see [HS-LS2.C](#))

**Supporting question: *What is biodiversity, how do humans affect it, and how does it affect humans?***

#### **Suggested Content-Vocabulary in bold**

- Human beings are part of and depend on the natural world. **Biodiversity**—the multiplicity of genes, species, and ecosystems—provides humans with renewable resources, such as food, medicines, and clean water. Humans also benefit from “**ecosystem services**,” such as climate stabilization, decomposition of wastes, and pollination that are provided by healthy (i.e., diverse and resilient) ecosystems. The resources of biological communities can be used within sustainable limits, but in many cases humans affect these ecosystems in ways—including **habitat destruction**, pollution of air and water, **overexploitation of resources**, introduction of **invasive species**, and climate change—that prevent the sustainable use of resources and lead to ecosystem degradation, species extinction, and the loss of valuable ecosystem services.

#### Disciplinary Core Ideas

#### Observable features of student performance

\*Unless otherwise specified, “descriptions” referenced in the evidence statements could include but not limited to written, oral, pictorial, and kinesthetic descriptions.

- 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.

#### HS-LS4-6

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

<p>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. Note: This Disciplinary Core Idea is also addressed by <a href="#">HS-LS2-7</a>.</p> <ul style="list-style-type: none"><li>• Note: HS-LS 4-6 is also addressed by <a href="#">ETS1.B: Developing Possible Solutions</a>: 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) and,</li><li>• 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</li></ul>	<p>solutions, tradeoffs, or other decisions.</p> <ol style="list-style-type: none"><li>2. Computational modeling<ol style="list-style-type: none"><li>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.</li><li>b. Students use the simulation to identify possible negative consequences of solutions that would outweigh their benefits.</li></ol></li><li>3. Analysis<ol style="list-style-type: none"><li>a. Students compare the simulation results to expected results.</li><li>b. Students analyze the simulation results to determine whether the simulation provides sufficient information to evaluate the solution.</li><li>c. Students identify the simulation's limitations.</li><li>d. Students interpret the simulation results, and predict the effects of the specific design solutions on biodiversity based on the interpretation.</li></ol></li><li>4. Revision<ol style="list-style-type: none"><li>a. Students revise the simulation as needed to provide sufficient information to evaluate the solution.</li></ol></li></ol>
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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)

### Crosscutting Concepts

#### Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

### Science and Engineering Practices

#### 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.
  - Create or revise a simulation of a phenomenon, designed device, process, or system.

### Grade Band Endpoint for LS4.D

#### By the end of grade 12:

Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Biological extinction, being irreversible, is a critical factor in reducing the planet's natural capital.

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. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a

given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things. 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.

[K-12 Endpoint Progression](#)

Activities	
<p>Required activities: To be determined</p> <p>Suggested activities:</p> <ul style="list-style-type: none"> <li>• <a href="#">Farming for Ecosystem Services</a> - This board game engages students in three-dimensional learning as they explore the phenomenon of human impact on biodiversity and the environment.</li> <li>• <a href="#">SimRiver Simulation - Diatom Project</a> - The simulation models human impact on water quality of a river. It helps students to make sense of this phenomenon by allowing them to mimic changes in land use along the river, population size, the presence/absence of sewage treatment, and season of the year.</li> <li>• <a href="#">Native Species Restoration and its Impact on Local Populations</a> - In many parts of the country, native species have been driven out of their habitats by human activities leading some species to become endangered or even extinct. Today, several large animal species are being reintroduced to their native ecosystems. In this activity, students will try to restore the population of an endangered species of deer. (Science and engineering practice: Analyzing and interpreting data and using mathematics and computational thinking)</li> <li>• <a href="#">NGSS-HUB (project ideas)</a>- link to various activities</li> </ul>	
Modifications to Content/Differentiation	
Priority	Enrichment
<p>- To include suggestions regarding depth of coverage</p> <p>- Minimum depth of coverage</p> <p>- Biodiversity is increased by formation of new species and reduced by extinction. Humans depend on biodiversity but also have adverse impacts on it. Sustaining biodiversity is essential to supporting life on Earth. (<a href="#">Appendix E</a>)</p>	<p>- To include suggested extensions to investigations</p> <p>- Increased depth</p> <p>- <a href="#">Concepts connected for AP Biology</a> (<a href="#">EK 1.A.2</a>, <a href="#">2.D.3</a>, <a href="#">4.A.5-6</a>, <a href="#">4.B.3-4</a>)</p> <p>- Designing different ways of solving a problem of human impact on biodiversity and evaluating which one of the ways is most efficient or economical.</p>

Assessments
Required assessments: To be determined Suggested assessments: <ul style="list-style-type: none"><li>• Traditional assessment: multiple choice and free response questions, or</li><li>• The above project(s) using the eight science and engineering practice standards, or</li><li>• A combination of traditional assessment with project, or</li><li>• Other format of teacher's choice</li></ul>

Pacing Guide	
<ul style="list-style-type: none"> <li>Suggested/tentative timeline</li> <li>Class periods: 83 min/block instructional time</li> <li>Total class periods: 90 over two semesters</li> </ul>	
Suggested span of instructional time	Content
20 class periods	<b>Core Idea LS1: From Molecules to Organisms: Structures and Processes</b> <ul style="list-style-type: none"> <li>LS1.A: Structure and Function</li> <li>LS1.B: Growth and Development of Organisms</li> <li>LS1.C: Organization for Matter and Energy Flow in Organisms</li> <li>LS1.D: Information Processing (N/A: there is a description in the framework, but none in NGSS Performance Expectations)</li> </ul>
26 class periods	<b>Core Idea LS2: Ecosystems: Interactions, Energy, and Dynamics</b> <ul style="list-style-type: none"> <li>LS2.A: Interdependent Relationships in Ecosystems</li> <li>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems</li> <li>LS2.C: Ecosystem Dynamics, Functioning, and Resilience</li> <li>LS2.D: Social Interactions and Group Behavior</li> </ul> <b>Review and midterm exam</b>
20 class periods	<b>Core Idea LS3: Heredity: Inheritance and Variation of Traits</b> <ul style="list-style-type: none"> <li>LS3.A: Inheritance of Traits</li> <li>LS3.B: Variation of Traits</li> </ul>

24 class periods	<p><b>Core Idea LS4: Biological Evolution: Unity and Diversity</b></p> <ul style="list-style-type: none"><li>• LS4.A: Evidence of Common Ancestry and Diversity</li><li>• LS4.B: Natural Selection</li><li>• LS4.C: Adaptation</li><li>• LS4.D: Biodiversity and Humans</li></ul> <p><b>Review and final exam</b></p>
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