High School Life Sciences

Students in high school develop understanding of key concepts that will help them make sense of life science. The ideas are built upon students’ science understanding of disciplinary core ideas, science and engineering practices, and crosscutting concepts from earlier grades. There are four life science disciplinary core ideas in high school: 1) From Molecules to Organisms: Structures and Processes, 2) Ecosystems: Interactions, Energy, and Dynamics, 3) Heredity: Inheritance and Variation of Traits, 4) Biological Evolution: Unity and Diversity. The performance expectations for high school life science blend core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge that can be applied across the science disciplines. While the performance expectations in high school life science couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices underlying the performance expectations.

The performance expectations in **LS1: From Molecules to Organisms: Structures and Processes** help students formulate an answer to the question, “How do organisms live and grow?” The LS1 Disciplinary Core Idea from the *NRC Framework* is presented as three sub-ideas: Structure and Function, Growth and Development of Organisms, and Organization for Matter and Energy Flow in Organisms. In these performance expectations, students demonstrate that they can use investigations and gather evidence to support explanations of cell function and reproduction. They understand the role of proteins as essential to the work of the cell and living systems. Students can use models to explain photosynthesis, respiration, and the cycling of matter and flow of energy in living organisms. The cellular processes can be used as a model for understanding of the hierarchical organization of organism. Crosscutting concepts of matter and energy, structure and function, and systems and system models provide students with insights to the structures and processes of organisms.

The performance expectations in **LS2: Ecosystems: Interactions, Energy, and Dynamics** help students formulate an answer to the question, “How and why do organisms interact with their environment, and what are the effects of these interactions?” The LS2 Disciplinary Core Idea includes four sub-ideas: Interdependent Relationships in Ecosystems, Cycles of Matter and Energy Transfer in Ecosystems, Ecosystem Dynamics, Functioning, and Resilience, and Social Interactions and Group Behavior. High school students can use mathematical reasoning to demonstrate understanding of fundamental concepts of carrying capacity, factors affecting biodiversity and populations, and the cycling of matter and flow of energy among organisms in an ecosystem. These mathematical models provide support of students’ conceptual understanding of systems and their ability to develop design solutions for reducing the impact of human activities on the environment and maintaining biodiversity. Crosscutting concepts of systems and system models play a central role in students’ understanding of science and engineering practices and core ideas of ecosystems.

The performance expectations in **LS3: Heredity: Inheritance and Variation of Traits** help students formulate answers to the questions: “How are characteristics of one generation passed to the next? How can individuals of the same species and even siblings have different characteristics?” The LS3 Disciplinary Core Idea from the *NRC Framework* includes two sub-ideas: Inheritance of Traits, and Variation of Traits. Students are able to ask questions, make and defend a claim, and use concepts of probability to explain the genetic variation in a
population. Students demonstrate understanding of why individuals of the same species vary in how they look, function, and behave. Students can explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expression. Crosscutting concepts of patterns and cause and effect are called out as organizing concepts for these core ideas.

The performance expectations in **LS4: Biological Evolution: Unity and Diversity** help students formulate an answer to the question, “What evidence shows that different species are related? The LS4 Disciplinary Core Idea involves four sub-ideas: Evidence of Common Ancestry and Diversity, Natural Selection, Adaptation, and Biodiversity and Humans. Students can construct explanations for the processes of natural selection and evolution and communicate how multiple lines of evidence support these explanations. Students can evaluate evidence of the conditions that may result in new species and understand the role of genetic variation in natural selection. Additionally, students can apply concepts of probability to explain trends in populations as those trends relate to advantageous heritable traits in a specific environment. The crosscutting concepts of cause and effect and systems and system models play an important role in students’ understanding of the evolution of life on Earth.
The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

**Science and Engineering Practices**

Developing and Using Models
- Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-2)
- Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-4, LS1-5, LS1-7)

Planning and Carrying Out Investigations
- Planning and carrying out 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 evidence (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS1-6)

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.
- 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-LS1-6)

**Disciplinary Core Ideas**

**LS1.A: Structure and Function**
- Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1)
- 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 combine to make up the aggregate of the work of cells. (HS-LS1-1) (Note: This disciplinary core idea is also addressed by HS-LS3-1.)
- Multicellular organisms have a hierarchical structural organization, in which any one system is composed of numerous parts and is itself a component of the next level. (HS-LS1-2)
- Feedback mechanisms maintain a living system’s internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3)

**LS1.B: Growth and Development of Organisms**
- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, each with parent cell passing identical genetic material the components of each chromosome pair) to both daughter. 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. (HS-LS1-4)
- 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. (HS-LS1-6)
- A matter and energy flow through different

**LS1.C: Organization for Matter and Energy Flow in Organisms**
- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)
- 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. (HS-LS1-6)

**Crosscutting Concepts**

**Systems and System Models**
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows within and between systems at different scales. (HS-LS1-2)
- Energy and Matter
  - Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5, HS-LS1-6)
  - 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)

**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)

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

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

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**HS-LS1 From Molecules to Organisms: Structures and Processes**

**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)

- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another and release energy to the surrounding environment and to maintain body temperature. Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. (HS-LS1-7)

**Connections to other DCIs in this grade-band:** **HS.PS1.B** (HS-LS1-5),(HS-LS1-6),(HS-LS1-7); **HS.PS2.B** (HS-LS1-7); **HS.LS3.A** (HS-LS1-1); **HS.PS3.B** (HS-LS1-5),(HS-LS1-7)

**Articulation to DCIs across grade-bands:** **MS.PS1.A** (HS-LS1-6); **HS.PS1.B** (HS-LS1-5),(HS-LS1-6),(HS-LS1-7); **MS.PS3.D** (HS-LS1-5),(HS-LS1-6),(HS-LS1-7); **MS.LS1.A** (HS-LS1-2),(HS-LS1-3),(HS-LS1-4); **MS.LS1.B** (HS-LS1-4); **MS.LS1.C** (HS-LS1-5),(HS-LS1-6),(HS-LS1-7); **MS.LS2.B** (HS-LS1-5),(HS-LS1-7); **MS.ESS2.E** (HS-LS1-6);

**MS.LS3.A** (HS-LS1-1),(HS-LS1-4); **MS.LS3.B** (HS-LS1-1)

**Common Core State Standards Connections:**

**ELA/Literacy –**

- RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-1),(HS-LS1-6)
- WHST.9–12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS-1-1),(HS-LS1-6)
- WHST.9–12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS1-6)
- WHST.9–12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS1-3)
- WHST.11–12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-LS1-3)
- WHST.9–12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-1),(HS-LS1-6)
- SL.11–12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1-2),(HS-LS1-4),(HS-LS1-5),(HS-LS1-7)

**Mathematics –**

- MP.4 Model with mathematics. (HS-LS1-4)
- HSF-IF.C.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-LS1-4)
- HSF-BF.A.1 Write a function that describes a relationship between two quantities. (HS-LS1-4)

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

HS-LS2  Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

HS-LS2.1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. [Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.]

HS-LS2.2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. [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: A 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 the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. [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.]

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.]

HS-LS2.8. Evaluate the 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.]

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses in using, synthesizing, and developing models to predict and show how relationships among variables between systems and their components in the natural and designed world.

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

Using Mathematics and Computational Thinking
Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses in using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

• Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HS-LS2-1)
• Use mathematical representations of phenomena or design solutions to support and revise explanations. (HS-LS2-2)
• Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4)

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

• Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including 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.

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
• Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms could 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. (HS-LS2-1), (HS-LS2-2)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
• Photosynthesis and cellular respiration (including aerobic and anaerobic processes) provide most of the energy for life processes. (HS-LS2-3)
• 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, and productivity rate increase 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. (HS-LS2-4)
• Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
• A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2), (HS-LS2-6)

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-8)
• Scale, Proportion, and Quantity
• The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1)
• 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)

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-LS2-5)

Energy and Matter
• Energy cannot be created or destroyed— it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS2-4)
• Energy drives the cycling of matter within and between systems. (HS-LS2-3)

Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-4), (HS-LS2-7)

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


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and will continue to do so in the future. (HS-LS2-3)

- 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)

**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 research and reasoning.

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)
- Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. (HS-LS2-8)

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### 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-LS2-2), (HS-LS2-3)
- 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), (HS-LS2-8)

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**LS2.E: Energy in Chemical Processes**

- Model with mathematics. (HS-LS2-6), (HS-LS2-2), (HS-LS2-7)
- Recognize that the chemical properties of elements are determined by the number of protons, but their physical states are determined by the interactions among the particles, such as lattice energy. (HS-LS2-8)
- Cite specific textual evidence to support analysis of chemical reactions, including energy changes. (HS-LS2-1), (HS-LS2-2), (HS-LS2-3), (HS-LS2-6), (HS-LS2-8)

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**LSS.B: Developing Possible Solutions**

- When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (secondary to HS-LS2-7)

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**ETSL.B: Engaging in Argument from Evidence**

- Model with mathematics. (HS-LS2-6), (HS-LS2-2), (HS-LS2-7)
- Evaluate claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)
- Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. (HS-LS2-8)

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### Common Core State Standards Connections:

**ELA/Literacy**

- **RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem. (HS-LS2-6), (HS-LS2-7), (HS-LS2-8)
- **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS2-1), (HS-LS2-2), (HS-LS2-3), (HS-LS2-6), (HS-LS2-8)
- **RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g. quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-LS2-6), (HS-LS2-7), (HS-LS2-8)
- **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data with other sources of information. (HS-LS2-6), (HS-LS2-7), (HS-LS2-8)
- **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS2-1), (HS-LS2-2), (HS-LS2-3)
- **WHST.9-12.5** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most important for a specific purpose and audience. (HS-LS2-3)
- **WHST.9-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS2-7)

**Mathematics**

- **MP.2** Reason abstractly and quantitatively. (HS-LS2-1), (HS-LS2-2), (HS-LS2-3), (HS-LS2-4), (HS-LS2-5), (HS-LS2-6), (HS-LS2-7)
- **MP.4** Model with mathematics. (HS-LS2-1), (HS-LS2-2), (HS-LS2-4)
- **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data display s. (HS-LS2-1), (HS-LS2-2), (HS-LS2-3), (HS-LS2-4), (HS-LS2-6), (HS-LS2-8)
- **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (HS-LS2-1), (HS-LS2-2), (HS-LS2-3), (HS-LS2-4), (HS-LS2-7)
- **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-LS2-1), (HS-LS2-2), (HS-LS2-3), (HS-LS2-4), (HS-LS2-7)
- **HSS-ID.A.1** Represent data with plots on the real number line. (HS-LS2-6)
- **HSS-IC.A.1** Understand statistics as a process for making inferences about population parameters based on a random sample from that population. (HS-LS2-6)

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

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# HS-LS3 Heredity: Inheritance and Variation of Traits

## Science and Engineering Practices

<table>
<thead>
<tr>
<th>Asking Questions and Defining Problems</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
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<tbody>
<tr>
<td>A question that arises from examining models or a theory to clarify relationships. (HS-LS3-1)</td>
<td><strong>LS1.A: Structure and Function</strong></td>
<td></td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>• All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary to HS-LS3-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)</td>
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<tr>
<td><strong>Engaging in Argument from Evidence</strong></td>
<td><strong>LS3.A: Inheritance of Traits</strong></td>
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<tr>
<td>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.</td>
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<tr>
<td><strong>LS3.B: Variation of Traits</strong></td>
<td>• 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. (HS-LS3-1)</td>
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<tr>
<td>• 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. (HS-LS3-2)</td>
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<tr>
<td>• 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. (HS-LS3-2)</td>
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</tr>
</tbody>
</table>

## Connections to other DCIs in this grade-band: HS.LS2.A (HS-LS3-1); HS.LS2.C (HS-LS3-1); HS.LS4.A (HS-LS3-1); HS.LS4.C (HS-LS3-1)

## Articulation across grade-bands: MS.LS2.A (HS-LS3-3); MS.LS3.A (HS-LS3-1),(HS-LS3-2); MS.LS3.B (HS-LS3-1),(HS-LS3-2),(HS-LS3-3); MS.LS3.D (HS-LS3-1),(HS-LS3-2),(HS-LS3-3); MS.LS4.C (HS-LS3-3)

## Common Core State Standards Connections:

**ELA/Literacy**

- **RST.11-12.1**: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS3-1),(HS-LS3-2)
- **RST.11-12.9**: Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-LS3-1)
- **WHST.9-12.1**: Write arguments focused on discipline-specific content. (HS-LS3-2)

**Mathematics**

- **MP.2**: Reason abstractly and quantitatively. (HS-LS3-2),(HS-LS3-3)

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HS-LS4 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

**HS-LS4-1.** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]

**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 evolution 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 that 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 mathematical analysis. A 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.]

**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.]

**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 designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

**Science and Engineering Practices**

*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-LS4-3)

*Using Mathematics and Computational Thinking*

Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using more advanced mathematical and computational 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. (HS-LS4-6)

*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.

- 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, 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)

**Disciplinary Core Ideas**

*LS4.A: Evidence of Common Ancestry and Diversity*

- Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the overlapping 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. (HS-LS4-1)

*LS4.B: Natural Selection*

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

- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3)

*LS4.C: Adaptation*

- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment’s limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2)

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and phylogenetically 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. (HS-LS4-3, HS-LS4-4)

*LS4.D: Evidence of Common Ancestry and Diversity*

- Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3)

- 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. (HS-LS4-5, HS-LS4-6)

*Crosscutting Concepts*

**Patterns**

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-1, HS-LS4-3)

**Cause and Effect**

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-2, HS-LS4-4, HS-LS4-5, HS-LS4-6)

**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. (HS-LS4-1, HS-LS4-4)

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<table>
<thead>
<tr>
<th><strong>Connections to Nature of Science</strong></th>
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<td>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. (HS-LS4-1)</td>
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| **Connections to other DCIs in this grade-band:** |

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| **Articulation across grade-bands:** |

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| **Common Core State Standards Connections:** |
| **ELA/Literacy –** |
| RST.11-12.1 | Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS4-1), (HS-LS4-2), (HS-LS4-3), (HS-LS4-4) |
| RST.11-12.8 | Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS4-5) |
| WHST.9-12.2 | Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. (HS-LS4-1), (HS-LS4-2), (HS-LS4-3), (HS-LS4-4) |
| WHST.9-12.5 | Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS4-6) |
| WHST.9-12.7 | Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS4-6) |
| WHST.9-12.9 | Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-LS4-1), (HS-LS4-2) |

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| **Mathematics –** |
| MP.2 | Reason abstractly and quantitatively. (HS-LS4-1), (HS-LS4-2), (HS-LS4-3), (HS-LS4-4), (HS-LS4-5) |
| MP.4 | Model with mathematics. (HS-LS4-2) |

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