

# ZOOLOGY

Zoology builds on Biology with added emphasis on animal taxa, basic body plans, symmetry, and behavior. The emerging field of bioethics provides information on the proper care and ethical treatment of laboratory animals. Laboratory investigations, including dissection as well as computer simulations, provide students with adequate exposure to the comparative anatomy of representative animal species. Field studies encourage student interest and provide a means to study animals in their natural surroundings. Teachers are encouraged to expand the curriculum beyond the minimum content of this core, accommodating specific community interests and utilizing unique local resources.

This core should encourage critical thinking, use of the scientific method, integration of technology, and application of knowledge and skills learned to practical questions and problems. It is also essential that students place theories and discoveries of significant persons into a historical perspective. Students should use clear and accurate language, keep accurate records, make reports, present oral and written projects, and participate in discussions regarding the results and conclusions of scientific investigations. Safe field and laboratory investigations should be used in instruction to the maximum extent possible to illustrate scientific concepts and principles and to support inquiry-based instruction.

The recommended prerequisite science course for Zoology is Biology.

## Structure and Function

Students will:

1. Define basic anatomical terminology associated with the study of animals. Examples: dorsal, superior, plantar, caudal, aboral
2. Distinguish among the acoelomate, pseudocoelomate, and coelomate body plans.
3. Identify the body symmetry of animals as radial, bilateral, or asymmetrical.
4. Use taxonomic groupings to differentiate the structure and physiology of invertebrates with dichotomous keys.
  - Identifying examples and characteristics of Porifera
  - Identifying examples and characteristics of Cnidaria
  - Identifying examples and characteristics of Mollusca
  - Identifying examples and characteristics of worms, including Platyhelminthes, Nematoda, and Annelida
  - Identifying examples, characteristics, and life cycles of Arthropoda
  - Identifying examples and characteristics of Echinodermata
5. Use taxonomic groupings to differentiate structure and physiology of vertebrates with dichotomous keys.
  - Identifying examples and characteristics of the three classes of fish
  - Identifying examples and characteristics of Amphibia
  - Identifying examples and characteristics of Reptilia
  - Identifying examples and characteristics of Aves
  - Identifying examples and characteristics of Mammalia

Students who demonstrate understanding can:

**HS-LS1-1** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

**HS-LS1-2** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

**HS-LS1-3** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

The performance expectations 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)

**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)

**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

**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 carry out most 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 made up 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)

**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)

**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)

<p>consistent with scientific ideas, principles, and theories.</p> <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-LS1-1)</li> </ul> <p>-----</p> <p><i>Connections to Nature of Science</i></p> <p><b><u>Scientific Investigations Use a Variety of Methods</u></b></p> <ul style="list-style-type: none"> <li>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)</li> </ul>		
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy -</i></p> <p><b><u>RST.11-12.1</u></b> 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)</p> <p><b><u>WHST.11-12.8</u></b> 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)</p> <p><b><u>WHST.9-12.9</u></b> Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-1)</p> <p><b><u>SL.11-12.5</u></b> 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)</p>		

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## Inheritance and Variation of Traits

Students will:

- Identify factors used to distinguish species, including behavioral differences and reproductive isolation.

Students who demonstrate understanding can:

- HS-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.**
- HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.**
- HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.]**
- 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.]**

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Asking Questions and Defining Problems</b> 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.</p> <ul style="list-style-type: none"> <li>Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1)</li> </ul> <p><b>Developing and Using Models</b> 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.</p> <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-LS1-4)</li> </ul> <p><b>Analyzing and Interpreting Data</b></p>	<p><b>LS1.A: Structure and Function</b></p> <ul style="list-style-type: none"> <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. (secondary to HS-LS3-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)</li> </ul> <p><b>LS1.B: Growth and Development of Organisms</b></p> <ul style="list-style-type: none"> <li>In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet</li> </ul>	<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-LS3-1),(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><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-LS1-4)</li> </ul> <p>-----</p>

<p><u>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.</u></p> <ul style="list-style-type: none"> <li>● <u>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)</u></li> </ul> <p><b><u>Engaging in Argument from Evidence</u></b>  <u>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.</u></p> <ul style="list-style-type: none"> <li>● <u>Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2)</u></li> </ul>	<p><u>the needs of the whole organism. (HS-LS1-4)</u></p> <p><b><u>LS3.A: Inheritance of Traits</u></b></p> <ul style="list-style-type: none"> <li>● <u>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)</u></li> </ul> <p><b><u>LS3.B: Variation of Traits</u></b></p> <ul style="list-style-type: none"> <li>● <u>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)</u></li> <li>● <u>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),(HS-LS3-3)</u></li> </ul>	<p><i>Connections to Nature of Science</i></p> <p><b><u>Science is a Human Endeavor</u></b></p> <ul style="list-style-type: none"> <li>● <u>Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-3)</u></li> <li>● <u>Science and engineering are influenced by society and society is influenced by science and engineering. (HS-LS3-3)</u></li> </ul>
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy -</i></p> <p><b><u>RST.11-12.9</u></b>      <u>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)</u></p> <p><b><u>WHST.9-12.1</u></b>      <u>Write arguments focused on discipline-specific content. (HS-LS3-2)</u></p> <p><b><u>SL.11-12.5</u></b>      <u>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-LS1-4)</u></p>		

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## Natural Selection and Adaptation

Students will:

7. Explain how species adapt to changing environments to enhance survival and reproductive success, including changes in structure, behavior, or physiology. Examples: aestivation, thicker fur, diurnal activity

Students who demonstrate understanding can:

- HS-LS4-1. Communicate scientific information that common ancestry and biological adaptation 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 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.]
- 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.]
- 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 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.]

The performance expectations 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

### Disciplinary Core Ideas

- LS4.A: Evidence of Common Ancestry and Diversity**
- Genetic information, like the fossil record, provides evidence of change over time. DNA sequences vary

### 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

<p>analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.</p> <ul style="list-style-type: none"> <li>● <u>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.</u> (HS-LS4-3)</li> </ul> <p><b><u>Constructing Explanations and Designing Solutions</u></b>  <u>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.</u></p> <ul style="list-style-type: none"> <li>● <u>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.</u> (HS-LS4-2),(HS-LS4-4)</li> </ul> <p><b><u>Engaging in Argument from Evidence</u></b>  <u>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.</u></p> <ul style="list-style-type: none"> <li>● <u>Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.</u> (HS-LS4-5)</li> </ul> <p><b><u>Obtaining, Evaluating, and Communicating Information</u></b>  <u>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.</u></p>	<p><u>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.</u> (HS-LS4-1)</p> <p><b><u>LS4.B: Natural Selection</u></b></p> <ul style="list-style-type: none"> <li>● <u>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.</u> (HS-LS4-2),(HS-LS4-3)</li> <li>● <u>The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.</u> (HS-LS4-3)</li> </ul> <p><b><u>LS4.C: Adaptation</u></b></p> <ul style="list-style-type: none"> <li>● <u>Adaptation 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.</u> (HS-LS4-2)</li> <li>● <u>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.</u> (HS-LS4-3),(HS-LS4-4)</li> <li>● <u>Adaptation also means that the distribution of traits in a population</u></li> </ul>	<p><u>explanations of phenomena.</u> (HS-LS4-1),(HS-LS4-3)</p> <p><b><u>Cause and Effect</u></b></p> <ul style="list-style-type: none"> <li>● <u>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</u> (HS-LS4-2),(HS-LS4-4),(HS-LS4-5)</li> </ul> <p>-----</p> <p><i>Connections to Nature of Science</i></p> <p><b><u>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</u></b></p> <ul style="list-style-type: none"> <li>● <u>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.</u> (HS-LS4-1),(HS-LS4-4)</li> </ul>
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<ul style="list-style-type: none"> <li>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). (HS-LS4-1)</li> </ul> <p>-----</p> <p style="text-align: center;"><i>Connections to Nature of Science</i></p> <p><b>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</b></p> <ul style="list-style-type: none"> <li>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)</li> </ul>	<p><u>can change when conditions change.</u> (HS-LS4-3)</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 the extinction—of some species. (HS-LS4-5)</li> <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' success is lost. (HS-LS4-5)</li> </ul>	
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy -</i></p> <p><b>RST-11.12.8</b> 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)</p> <p><b>WHST.9-12.2</b> 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)</p> <p><b>WHST.9-12.9</b> Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5)</p> <p><b>SL.11-12.4</b> 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)</p>		

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## Interdependent Relationships in Ecosystems

Students will:

8. Differentiate among organisms that are threatened, endangered, and extinct. Examples: threatened—bald eagle, endangered—California condor, extinct—dodo

- Identifying causative factors of decreasing population size Examples: overcrowding resulting in greater incidence of disease, fire destroying habitat and food sources

9. Analyze a field study of animal behavior patterns to determine the relationship of these patterns to an animal's niche.

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.]

**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.]

**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.]

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

## 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.

- 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)
- 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.

- 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

## 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 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. (HS-LS2-1),(HS-LS2-2)

### 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)
- 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)

### LS2.D: Social Interactions and Group Behavior

- Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (HS-LS2-8)

## Crosscutting Concepts

### Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-8),(HS-LS4-6)

### 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)

### Stability and Change

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

<p>designed world(s). Arguments may also come from current scientific or historical episodes in science.</p> <ul style="list-style-type: none"> <li>● Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)</li> <li>● Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. (HS-LS2-8)</li> </ul> <p>-----</p> <p style="text-align: center;"><i>Connections to Nature of Science</i></p> <p><b><u>Scientific Knowledge is Open to Revision in Light of New Evidence</u></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 evidence. (HS-LS2-2)</li> <li>● 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)</li> </ul>	<p><b><u>LS4.C: Adaptation</u></b></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 the extinction—of some species. (HS-LS4-6)</li> </ul> <p><b><u>LS4.D: Biodiversity and Humans</u></b></p> <ul style="list-style-type: none"> <li>● Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary to HS-LS2-7)</li> <li>● Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (secondary to HS-LS2-7),(HS-LS4-6.)</li> </ul> <p><b><u>ETS1.B: Developing Possible Solutions</u></b></p> <ul style="list-style-type: none"> <li>● 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),(secondary to HS-LS4-6)</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 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 to HS-LS4-6)</li> </ul>	
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*Common Core State Standards Connections:*

*ELA/Literacy -*

<b><u>RST.11-12.1</u></b>	<u>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.</u> (HS-LS2-1),(HS-LS2-2),(HS-LS2-6),(HS-LS2-8)
<b><u>RST.11-12.7</u></b>	<u>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.</u> (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)
<b><u>RST.11-12.8</u></b>	<u>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.</u> (HS-LS2-6),(HS-LS2-7),(HS-LS2-8)
<b><u>WHST.9-12.2</u></b>	<u>Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.</u> (HS-LS2-1),(HS-LS2-2)

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

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