

High School Modified Domains Model Course III – Life Sciences

Bundle 5: Ecosystems and Biodiversity

This is the fifth bundle of the High School Domains Model Course III – Life Sciences. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart](#).

Bundle 5 Question: This bundle is assembled to address the question “how does biodiversity affect us?”

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how the environment influences populations of organisms over multiple generations. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

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. 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 (LS2.B as in HS-LS2-4). Matter and energy are conserved at each step in a food web (LS2.B as in HS-LS2-4), limiting the amount of resources in the environment. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources have carrying capacities. This fundamental tension affects the abundance of species in any given ecosystem (LS2.A as in HS-LS2-1 and HS-LS2-2).

Because of the fundamental tension between population size and carrying capacity, 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, the system may return to its more or less original status while extreme fluctuations in conditions can challenge the functioning of ecosystems in terms of resources and habitat availability (LS2.C as in HS-LS2-2 and HS-LS2-6). Additionally, group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives (LS2.D as in LS2-8) in a given ecosystem.

Since resources are finite (LS2.A as in HS-LS2-1), changes in the physical environment, whether naturally occurring or human induced, have 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 (LS4.C as in HS-LS4-5). Natural selection leads to the differential survival and reproduction of organisms in a population that have an advantageous heritable trait which 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 (LS4.C as in HS-LS4-3). However, natural selection occurs only if there is both variation in the genetic information between organisms in a population and variation in the expression of that genetic information that leads to differences in performance among individuals (LS4.B as in HS-LS4-2 and HS-LS4-3).

The engineering design idea that criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them (ETS1.A as in HS-ETS1-1) could connect to many different science ideas, including how environments including living and nonliving resources are finite and thus limit population sizes (LS2.A as in HS-LS2-1 and HS-LS2-2). Connections could be made through engineering design tasks such as evaluating the criteria and constraints related to influencing local hunting practices of overpopulated animals or to expanding the habitats of endangered animals.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions and defining problems (HS-ETS1-1), analyzing and interpreting data (HS-LS4-3), using mathematics and computational thinking (HS-LS2-1, HS-LS2-2, and HS-LS2-4), and engaging in argument from evidence (HS-LS2-8 and HS-LS4-5). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (HS-LS4-3), Cause and Effect (HS-LS2-8 and HS-LS4-5), Scale, Proportion, and Quantity (HS-LS2-1 and HS-LS2-2), Energy and Matter (HS-LS2-4), and Stability and Change (HS-LS2-6). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	<p>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.]</p> <p>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.]</p> <p>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.]</p> <p>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.]</p> <p>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.]</p> <p>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.]</p>
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Performance Expectations (Continued)	<p>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. <i>[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.]</i></p> <p>HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.</p>
Example Phenomena	<p>Large numbers of deer are hit by cars each year.</p> <p>There are 10 times as many calories in a pound of cheese as there are in a pound of green beans.</p>
Additional Practices Building to the PEs	<p>Asking Questions and Defining Problems</p> <ul style="list-style-type: none"> Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. <p>Students could <i>ask questions</i> [about] <i>the resilience of ecosystems that can be investigated within the scope of the school laboratory.</i> HS-LS2-2 and HS-LS2-6</p> <p>Developing and Using Models</p> <ul style="list-style-type: none"> Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. <p>Students could <i>develop a model based on evidence to predict the relationships between ecosystem carrying capacities and the availability of living and nonliving resources.</i> HS-LS2-1</p> <p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. <p>Students could <i>make directional hypotheses that specify what happens to the numbers and types of organisms when an ecosystem</i> [experiences] <i>extreme fluctuations in conditions in terms of resources and habitat availability.</i> HS-LS2-6</p> <p>Analyzing and Interpreting Data</p> <ul style="list-style-type: none"> Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. <p>Students could <i>analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims</i> [that] <i>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.</i> HS-LS2-4</p> <p>Using Mathematical and Computational Thinking</p> <ul style="list-style-type: none"> Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. <p>Students could <i>revise a computational simulation of natural selection to represent</i> [that] <i>natural selection occurs only if there is both variation in the genetic information between organisms in a population and variation in the expression of that genetic information that leads to differences in performance among individuals.</i> HS-LS4-3</p>

<p>Additional Practices Building to the PEs (Continued)</p>	<p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. <p>Students could <i>design, evaluate, and/or refine a solution, including satisfying criteria and constraints set forth by society</i>, [to the problem that] <i>changes in the physical environment have contributed to the decline or extinction of some species</i>. HS-LS4-5 and HS-ETS1-1</p> <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. <p>Students could construct, use, and/or present an oral and written argument or counter-argument based on data and evidence [that] <i>predation, competition, and disease</i> [affect] <i>ecosystem carrying capacities</i>. HS-LS2-1</p> <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. <p>Students could <i>critically read scientific literature to obtain scientific information</i> [about how] <i>group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives</i>. HS-LS2-8</p>
<p>Additional Crosscutting Concepts Building to the PEs</p>	<p>Cause and Effect</p> <ul style="list-style-type: none"> Changes in systems may have various causes that may not have equal effects. <p>Students could communicate that <i>changes in systems may have various causes that may not have equal effects</i>, [including that] <i>living and nonliving resources, predation, competition, and disease</i> [all affect] <i>ecosystem carrying capacity</i> [to different degrees]. HS-LS2-1</p> <p>Systems and System Models</p> <ul style="list-style-type: none"> 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. <p>Students could describe the <i>use of a model to simulate ecosystems and interactions within ecosystems</i>, [including the] <i>conservation of matter and energy at each link in an ecosystem</i>. HS-LS2-4</p> <p>Stability and Change</p> <ul style="list-style-type: none"> Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes can be irreversible. <p>Students could analyze [how] <i>change and rates of change can be quantified and modeled over very short or very long periods of time</i> [for] <i>ecosystems carrying capacities that change over time due to predation</i>. HS-LS2-1</p>

<p>Additional Connections to Nature of Science</p>	<p>Scientific Knowledge is Open to Revision in Light of New Evidence</p> <ul style="list-style-type: none"> Scientific explanations can be probabilistic. <p>Students could analyze data [to determine if] <i>probability can be</i> [used] <i>to explain</i> [that] <i>organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite</i>. HS-LS2-1</p> <p>Science is a Human Endeavor</p> <ul style="list-style-type: none"> Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. <p>Students could obtain, evaluate, and communicate information <i>from other nations and cultures that have contributed to science</i> [understanding of how] <i>modest biological or physical disturbances to an ecosystem may return the ecosystem to its more or less original status</i>. HS-LS2-2 and HS-LS2-6</p>
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HS-LS2-1

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.]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. <ul style="list-style-type: none"> Use mathematical and/or computational representations of phenomena or design solutions to support explanations. 	LS2.A: Interdependent Relationships in Ecosystems <ul style="list-style-type: none"> Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. 	Scale, Proportion, and Quantity <ul style="list-style-type: none"> The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

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

1	Representation
a	Students identify and describe* the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that are relevant to supporting given explanations of factors that affect carrying capacities of ecosystems at different scales. The components include: <ol style="list-style-type: none"> The population changes gathered from historical data or simulations of ecosystems at different scales; and Data on numbers and types of organisms as well as boundaries, resources, and climate.
b	Students identify the given explanation(s) to be supported, which include the following ideas: Factors (including boundaries, resources, climate, and competition) affect carrying capacity of an ecosystem, and: <ol style="list-style-type: none"> Some factors have larger effects than do other factors. Factors are interrelated. The significance of a factor is dependent on the scale (e.g., a pond vs. an ocean) at which it occurs.
2	Mathematical and/or computational modeling
a	Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) of ecosystem factors to identify changes over time in the numbers and types of organisms in ecosystems of different scales.

3	Analysis	
	a	Students analyze and use the given mathematical and/or computational representations
		<ul style="list-style-type: none">i. To identify the interdependence of factors (both living and nonliving) and resulting effect on carrying capacity; andii. 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

Students who demonstrate understanding can:

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.]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematics and Computational Thinking</p> <p>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.</p> <ul style="list-style-type: none"> Use mathematical representations of phenomena or design solutions to support and revise explanations. <hr/> <p>Connections to Nature of Science</p> <p>Scientific Knowledge is Open to Revision in Light of New Evidence</p> <ul style="list-style-type: none"> Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. 	<p>LS2.A: Interdependent Relationships in Ecosystems</p> <ul style="list-style-type: none"> 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. <p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience</p> <ul style="list-style-type: none"> 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. 	<p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

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

1	Representation
a	Students identify and describe* the components in the given mathematical representations (which include trends, averages, and graphs of the number of organisms per unit of area in a stable system) that are relevant to supporting and revising the given explanations about factors affecting biodiversity and ecosystems, including:

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

HS-LS2-4

Students who demonstrate understanding can:

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.]*

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematical and Computational Thinking</p> <p>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.</p> <ul style="list-style-type: none"> Use mathematical representations of phenomena or design solutions to support claims. 	<p>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems</p> <ul style="list-style-type: none"> Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. 	<p>Energy and Matter</p> <ul style="list-style-type: none"> Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

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

1	Representation
a	Students identify and describe* the components in the mathematical representations that are relevant to supporting the claims. The components could include relative quantities related to organisms, matter, energy, and the food web in an ecosystem.
b	Students identify the claims about the cycling of matter and energy flow among organisms in an ecosystem.
2	Mathematical modeling
a	Students describe* how the claims can be expressed as a mathematical relationship in the mathematical representations of the components of an ecosystem
b	Students use the mathematical representation(s) of the food web to:
i.	Describe* the transfer of matter (as atoms and molecules) and flow of energy upward between organisms and their environment;

	ii.	Identify the transfer of energy and matter between trophic levels; and
	iii.	Identify the relative proportion of organisms at each trophic level by correctly identifying producers as the lowest trophic level having the greatest biomass and energy and consumers decreasing in numbers at higher trophic levels.
3	Analysis	
	a	Students use the mathematical representation(s) to support the claims that include the idea that matter flows between organisms and their environment.
	b	Students use the mathematical representation(s) to support the claims that include the idea that energy flows from one trophic level to another as well as through the environment.
	c	Students analyze and use the mathematical representation(s) to account for the energy not transferred to higher trophic levels but which is instead used for growth, maintenance, or repair, and/or transferred to the environment, and the inefficiencies in transfer of matter and energy.

HS-LS2-6

Students who demonstrate understanding can:

- 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.]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>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.</p> <ul style="list-style-type: none"> Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. <hr/> <p>Connections to Nature of Science</p> <p>Scientific Knowledge is Open to Revision in Light of New Evidence</p> <ul style="list-style-type: none"> 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. 	<p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience</p> <ul style="list-style-type: none"> 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. 	<p>Stability and Change</p> <ul style="list-style-type: none"> Much of science deals with constructing explanations of how things change and how they remain stable.

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

1	Identifying the given explanation and the supporting claims, evidence, and reasoning.
a	Students identify the given explanation that is supported by the claims, evidence, and reasoning to be evaluated, and which includes the following idea: The complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
b	From the given materials, students identify:
i.	The given claims to be evaluated;
ii.	The given evidence to be evaluated; and
iii.	The given reasoning to be evaluated.
2	Identifying any potential additional evidence that is relevant to the evaluation
a	Students identify and describe* additional evidence (in the form of data, information, or other appropriate forms) that was not provided but is relevant to the explanation and to evaluating the given claims, evidence, and reasoning:
i.	The factors that affect biodiversity;
ii.	The relationships between species and the physical environment in an ecosystem; and
iii.	Changes in the numbers of species and organisms in an ecosystem that has been

		subject to a modest or extreme change in ecosystem conditions.
3	Evaluating and critiquing	
	a	Students describe* the strengths and weaknesses of the given claim in accurately explaining a particular response of biodiversity to a changing condition, based on an understanding of the factors that affect biodiversity and the relationships between species and the physical environment in an ecosystem.
	b	Students use their additional evidence to assess the validity and reliability of the given evidence and its ability to support the argument that resiliency of an ecosystem is subject to the degree of change in the biological and physical environment of an ecosystem.
	c	Students assess the logic of the reasoning, including the relationship between degree of change and stability in ecosystems, and the utility of the reasoning in supporting the explanation of how:
		i. Modest biological or physical disturbances in an ecosystem result in maintenance of relatively consistent numbers and types of organisms.
		ii. Extreme fluctuations in conditions or the size of any population can challenge the functioning of ecosystems in terms of resources and habitat availability, and can even result in a new ecosystem.

HS-LS2-8

Students who demonstrate understanding can:

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.]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>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.</p> <ul style="list-style-type: none"> Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. <p>-----</p> <p>Connections to Nature of Science</p> <p>Scientific Knowledge is Open to Revision in Light of New Evidence</p> <ul style="list-style-type: none"> 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. 	<p>LS2.D: Social Interactions and Group Behavior</p> <ul style="list-style-type: none"> Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

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

1	Identifying the given explanation and the supporting evidence
a	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.
b	Students identify the given evidence to be evaluated.
2	Identifying any potential additional evidence that is relevant to the evaluation
a	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.
3	Evaluating and critiquing
a	Students use their additional evidence to assess the validity, reliability, strengths, and weaknesses of the given evidence along with its ability to support logical and reasonable arguments about the outcomes of group behavior.
b	Students 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).
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HS-LS4-3

Students who demonstrate understanding can:

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.]

The performance expectation above was developed using the following elements from *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.

Disciplinary Core Ideas**LS4.B: Natural Selection**

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

LS4.C: Adaptation

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
- Adaptation also means that the distribution of traits in a population can change when conditions change.

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.

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

1	Organizing data	
	a	Students organize data (e.g., using tables, graphs and charts) by the distribution of genetic traits over time.
	b	Students describe* what each dataset represents
2	Identifying relationships	
	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.
3	Interpreting data	
	a	Students use the data analyses as evidence to support explanations about the following:
		i. Positive or negative effects on survival and reproduction of individuals as relating to their expression of a variable trait in a population;
		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
		iii. The changes in distribution of adaptations of anatomical, behavioral, and physiological traits in a population.

HS-LS4-5

Students who demonstrate understanding can:

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 expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science. <ul style="list-style-type: none"> Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. 	LS4.C: Adaptation <ul style="list-style-type: none"> Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. 	Cause and Effect <ul style="list-style-type: none"> Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

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

1	Identifying the given claims and evidence to be evaluated
a	Students identify the given claims, which include the idea that changes in environmental conditions may result in: <ol style="list-style-type: none"> Increases in the number of individuals of some species; The emergence of new species over time; and The extinction of other species.
b	Students identify the given evidence to be evaluated.
2	Identifying any potential additional evidence that is relevant to the evaluation
a	Students identify and describe* additional evidence (in the form of data, information, models, or other appropriate forms) that was not provided but is relevant to the claims and to evaluating the given evidence, including: <ol style="list-style-type: none"> Data indicating the change over time in: <ol style="list-style-type: none"> The number of individuals in each species; The number of species in an environment; and The environmental conditions. Environmental factors that can determine the ability of individuals in a species to survive and reproduce.

3	Evaluating and critiquing	
	a	Students use their additional evidence to assess the validity, reliability, strengths, and weaknesses of the given evidence, along with its ability to support logical and reasonable arguments about the outcomes of group behavior.
	b	Students assess the ability of the given evidence to be used to determine causal or correlational effects between environmental changes, the changes in the number of individuals in each species, the number of species in an environment, and/or the emergence or extinction of species.
4	Reasoning and synthesis	
	a	Students evaluate the degree to which the given empirical evidence can be used to construct logical arguments that identify causal links between environmental changes and changes in the number of individuals or species based on environmental factors that can determine the ability of individuals in a species to survive and reproduce

HS-ETS1-1

Students who demonstrate understanding can:

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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. <ul style="list-style-type: none"> Analyze complex real-world problems by specifying criteria and constraints for successful solutions. 	ETS1.A: Defining and Delimiting Engineering Problems <ul style="list-style-type: none"> Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. 	<p>-----</p> Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World <ul style="list-style-type: none"> New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

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

1	Identifying the problem to be solved
a	Students analyze a major global problem. In their analysis, students: <ul style="list-style-type: none"> i. Describe* the challenge with a rationale for why it is a major global challenge; ii. Describe*, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and iii. Document background research on the problem from two or more sources, including research journals.
2	Defining the process or system boundaries, and the components of the process or system
a	In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem.
b	In their analysis, students describe* societal needs and wants that are relative to the problem (e.g., for controlling CO ₂ emissions, societal needs include the need for cheap energy).
3	Defining the criteria and constraints
a	Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.