High School Conceptual Progressions Model III – Bundle 2
Evolution of Life

This is the second bundle of the High School Conceptual Progressions Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 2 Question: This bundle is assembled to address the question "why do such different organisms have similar characteristics?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how organisms evolved on Earth. 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

Ecosystems have carrying capacities; organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite limiting the abundance of species in any given ecosystem (LS2.A as in HS-LS2-1 and HS-LS2-2). A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant, but 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). Thus, 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 of some species (LS4.C as in HS-LS4-5). Species become extinct because they can no longer survive and reproduce in their altered environment and if members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost (LS4.C as in HS-LS4-5).

Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically (LS4.C as in HS-LS4-3 and HS-LS4-4), behaviorally (LS2.D as in HS-LS2-8), and physiologically well suited to survive and reproduce in a specific environment (LS4.C as in HS-LS4-3 and HS-LS4-4). Adaptation also means that the distribution of traits in a population can change when conditions change (LS4.C as in HS-LS4-3). Therefore, 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 leads to differences in performance among individuals (LS4.B as in HS-LS4-2 and HS-LS4-3). The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population (LS4.B as in HS-LS4-3).

Genetic information including similarities and differences in amino acid sequences as well as anatomical and embryological data provides evidence of evolution (LS4.A as in HS-LS4-1). Thus, 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 (LS4.C as in HS-LS4-2).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of using mathematics and computational thinking (HS-LS4-3, HS-LS2-1, and HS-LS2-2), constructing explanations (HS-LS4-2 and HS-LS4-4), engaging in argument (HS-LS2-6, HS-LS2-8, and HS-LS4-5), and communicating information (HS-LS4-1). 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-LS4-1 and HS-LS4-3), Cause and Effect (HS-LS2-8, HS-LS4-2, HS-LS4-4, and HS-LS4-5), Scale, Proportion, and Quantity (HS-LS2-1 and HS-LS2-2), and Stability and Change (HS-LS2-6). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	
	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-LS2-6. 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-LS2-8. 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-LS4-1. 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 number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]

HS-LS4-3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.] |

Performance Expectations (Continued)	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.]
Example Phenomena	Doctors tell us to finish taking all of our antibiotic prescription, even after we feel better. The skeleton of a dinosaur looks a lot like the skeleton of a bird.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations. Students could *define a design problem that involves the development of a process* [related to how] ***changes in the physical environment have contributed to the expansion of some species***. HS-LS4-5 **Developing and Using Models** • Develop a complex model that allows for manipulation and testing of a proposed process or system. Students could *develop a complex model that allows for manipulation and testing of a proposed process* [for increasing the] ***carrying capacities of*** [an] ***ecosystem***. HS-LS2-1 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make directional hypotheses* [about how] ***extreme fluctuations in conditions can*** [affect] ***the functioning of ecosystems in terms of resources and habitat availability***. HS-LS2-2 **Analyzing and Interpreting Data** • 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. Students could *analyze data using tools and models to make valid and reliable scientific claims* [about how] ***changes in the physical environment have contributed to the decline—and sometimes the extinction—of some species***. HS-LS4-5 **Using Mathematical and Computational Thinking** • Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. Students could *revise a computational simulation* [of how] ***natural selection occurs 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***. HS-LS4-2 and HS-LS4-3

Additional Practices Building to the PEs (Continued)	**Constructing Explanations and Designing Solutions** • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. Students could *apply scientific reasoning and theory to link evidence to claims* [about how] ***the ongoing branching that produces multiple lines of*** [evolutionary] ***descent can be inferred by comparing the DNA sequences of different organisms***. HS-LS4-1 **Engaging in Argument from Evidence** • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. Students could *respectfully provide and receive critiques on scientific arguments* [about how] ***group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives***. HS-LS2-8 **Obtaining, Evaluating, and Communicating Information** • 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. Students could *critically read scientific literature to determine the central ideas or conclusions* [about how] ***group membership can increase the chances of survival for individuals and their genetic relatives***. HS-LS2-8
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Changes in systems may have various causes that may not have equal effects. Students could *obtain, evaluate, and communicate information about how changes in* ***ecosystems*** *may have various causes that may not have equal effects,* [and that] ***extreme fluctuations in conditions can challenge the functioning of ecosystems in terms of resources and habitat availability***. HS-LS2-2 and HS-LS2-6 **Scale, Proportion, and Quantity** • Patterns observable at one scale may not be observable or exist at other scales. Students could construct an argument for how *patterns observable at one scale may not be observable at other scales,* [describing observations on the scale of] ***the differential survival and reproduction of organisms in a population that have an advantageous heritable trait*** [to observations on the scale of the DNA itself]. HS-LS4-3 and HS-LS4-4

Additional Crosscutting Concepts Building to the PEs (Continued)	**Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Students could construct an argument for how *change and rates of change can be quantified over very short or very long periods of time* [related to how] ***evolution is a consequence of the interaction of (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
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific explanations can be probabilistic. Students could construct an argument that *scientific explanations can be probabilistic,* [giving as evidence the explanation that] ***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, modest biological or physical disturbances may return the ecosystem to its more or less original state, or extreme fluctuations in conditions can challenge the functioning of ecosystems in terms of resources and habitat availability***. HS-LS2-2 and HS-LS2-6 **Science is a Human Endeavor** • Science and engineering are influenced by society and society is influenced by science and engineering. Students could obtain, evaluate, and communicate information about how *science and engineering are influenced by society and society is influenced by science and engineering,* [describing examples related to] ***human induced changes in the physical environment*** [that have] ***contributed to the expansion of some species*** [and to our understanding of ecosystem dynamics]. HS-LS4-5

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. • Use mathematical and/or computational representations of phenomena or design solutions to support explanations.	**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.	**Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

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

3	Analysis		
	a	Students analyze and use the given mathematical and/or computational representations	
		i.	To identify the interdependence of factors (both living and nonliving) and resulting effect on carrying capacity; and
		ii.	As evidence to support the explanation and identify the factors that have the largest effect on the carrying capacity of an ecosystem for a given population.

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
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 representations of phenomena or design solutions to support and revise explanations. - ***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.	**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. **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.	**Scale, Proportion, and Quantity** • Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

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-LS2-6

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
Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. - ***Connections to Nature of Science*** **Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.	**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.	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.

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

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

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
Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. - *Connections to Nature of Science* **Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.	**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.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Observable features of the student performance by the end of the course:		
1		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).

HS-LS4-1

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.]

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
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). - ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.	**LS4.A: Evidence of Common Ancestry and Diversity** • Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.	**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. - ***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.

	Observable features of the student performance by the end of the course:	
1	Communication style and format	
	a	Students use at least two different formats (e.g., oral, graphical, textual and mathematical), to communicate scientific information, including that common ancestry and biological evolution are supported by multiple lines of empirical evidence. Students cite the origin of the information as appropriate.
2	Connecting the DCIs and the CCCs	
	a	Students identify and communicate evidence for common ancestry and biological evolution, including:
		i. Information derived from DNA sequences, which vary among species but have many similarities between species;
		ii. Similarities of the patterns of amino acid sequences, even when DNA sequences are slightly different, including the fact that multiple patterns of DNA sequences can code for

		the same amino acid;
	iii.	Patterns in the fossil record (e.g., presence, location, and inferences possible in lines of evolutionary descent for multiple specimens); and
	iv.	The pattern of anatomical and embryological similarities.
b		Students identify and communicate connections between each line of evidence and the claim of common ancestry and biological evolution.
c		Students communicate that together, the patterns observed at multiple spatial and temporal scales (e.g., DNA sequences, embryological development, fossil records) provide evidence for causal relationships relating to biological evolution and common ancestry.

HS-LS4-2

Students who demonstrate understanding can:

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 the number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [*Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.*]

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
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.	**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. **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.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Observable features of the student performance by the end of the course:	
1	Articulating the explanation of phenomena
	a	Students construct an explanation that includes a description* that evolution is caused primarily by one or more of the four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
2	Evidence
	a	Students identify and describe* evidence to construct their explanation, including that:
		i.	As a species grows in number, competition for limited resources can arise.

		ii.	Individuals in a species have genetic variation (through mutations and sexual reproduction) that is passed on to their offspring.
		iii.	Individuals can have specific traits that give them a competitive advantage relative to other individuals in the species.
	b		Students use a variety of valid and reliable sources for the evidence (e.g., data from investigations, theories, simulations, peer review).
3	Reasoning		
	a		Students use reasoning to connect the evidence, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to construct the explanation. Students describe* the following chain of reasoning for their explanation:
		i.	Genetic variation can lead to variation of expressed traits in individuals in a population.
		ii.	Individuals with traits that give competitive advantages can survive and reproduce at higher rates than individuals without the traits because of the competition for limited resources.
		iii.	Individuals that survive and reproduce at a higher rate will provide their specific genetic variations to a greater proportion of individuals in the next generation.
		iv.	Over many generations, groups of individuals with particular traits that enable them to survive and reproduce in distinct environments using distinct resources can evolve into a different species.
	b		Students use the evidence to describe* the following in their explanation:
		i.	The difference between natural selection and biological evolution (natural selection is a process, and biological evolution can result from that process); and
		ii.	The cause and effect relationship between genetic variation, the selection of traits that provide comparative advantages, and the evolution of populations that all express the trait.

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	Disciplinary Core Ideas	Crosscutting Concepts
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.	**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.	**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-LS4-4

Students who demonstrate understanding can:

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.]

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

Observable features of the student performance by the end of the course:	
1	Articulating the explanation of phenomena
a	Students construct an explanation that identifies the cause and effect relationship between natural selection and adaptation.
2	Evidence
a	Students identify and describe* the evidence to construct their explanation, including:
	i. Changes in a population when some feature of the environment changes;
	ii. Relative survival rates of organisms with different traits in a specific environment;
	iii. The fact that individuals in a species have genetic variation (through mutations and sexual reproduction) that is passed on to their offspring; and
	iv. The fact that individuals can have specific traits that give them a competitive advantage relative to other individuals in the species.
b	Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, peer review, students' own investigations)
3	Reasoning
a	Students use reasoning to synthesize the valid and reliable evidence to distinguish between cause and correlation to construct the explanation about how natural selection provides a mechanism for species to adapt to changes in their environment, including the following elements:
	i. Biotic and abiotic differences in ecosystems contribute to changes in gene frequency over time through natural selection.
	ii. Increasing gene frequency in a population results in an increasing fraction of the

			population in each successive generation that carries a particular gene and expresses a particular trait.
	iii.		Over time, this process leads to a population that is adapted to a particular environment by the widespread expression of a trait that confers a competitive advantage in that environment.

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. • Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.	**LS4.C: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species. • Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Observable features of the student performance by the end of the course:		
1		Identifying the given claims and evidence to be evaluated
	a	Students identify the given claims, which include the idea that changes in environmental conditions may result in:
		i. Increases in the number of individuals of some species;
		ii. The emergence of new species over time; and
		iii. The extinction of other species.
	b	Students identify the given evidence to be evaluated.
2		Identifying any potential additional evidence that is relevant to the evaluation
	a	Students identify and describe* additional evidence (in the form of data, information, models, or other appropriate forms) that was not provided but is relevant to the claims and to evaluating the given evidence, including:
		i. Data indicating the change over time in:
		a) The number of individuals in each species;
		b) The number of species in an environment; and
		c) The environmental conditions.
		ii. Environmental factors that can determine the ability of individuals in a species to survive and reproduce.

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