Middle School Topics Model Course III – Bundle 3
Mechanisms of Diversity

This is the third bundle of the Middle School Topics Model Course III. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 3 Question: This bundle is assembled to address the question "What makes organisms different from one another?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of *how there can be so many similarities among organisms and yet there is so much diversity*. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Genetic variation of traits enables populations to change over time. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes or mutations to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits (LS3.A as in MS-LS3-1). Some changes are beneficial, others harmful, and some neutral to the organism (LS3.B as in MS-LS3-1).

In *artificial* selection, humans can choose desired parental traits determined by genes, which are then passed on to offspring (LS4.B as in MS-LS4-5) while changing environmental conditions cause adaptation by *natural* selection acting over generations (LS4.C as in MS-LS4-6). Natural selection leads to the predominance of certain traits in a population, and the suppression of others (LS4.B as in MS-LS4-4). Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common (LS4.C as in MS-LS4-6).

Collection of fossils and their placement in chronological order is known as the fossil record, which documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth (LS4.A as in MS-LS4-1). Comparison of the embryological development of different species (LS4.A as in MS-LS4-3) and anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent (LS4.A as in MS-LS4-2), showing how populations have changed over time.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-LS3-1); analyzing and interpreting data (MS-LS4-1 and MS-LS4-3); using mathematics and computational thinking (MS-LS4-6); constructing explanations and designing solutions (MS-LS4-2 and MS-LS4-4); and obtaining, evaluating, and communicating information (MS-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 (MS-LS4-2, MS-LS4-1, and MS-LS4-3); Cause and Effect (MS-LS4-4, MS-LS4-5, and MS-LS4-6); and Structure and Function (MS-LS3-1). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations MS-LS4-1 and MS-LS4-2 are partially assessable	MS-LS3-1. **Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.** [Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.] [Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.] MS-LS4-1. **Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.** [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.] MS-LS4-2. **Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.** [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.] MS-LS4-3. **Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.** [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.] MS-LS4-4. **Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.** [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.] MS-LS4-5. **Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.** [Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.] MS-LS4-6. **Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.** [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [Assessment Boundary: Assessment does not include Hardy Weinberg calculations.]
Example Phenomena	The first ears of corn in the wild were small and didn't have many kernels. There are hundreds of different breeds of dogs that vary in size, strength, temperament, and speed.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. Students could *ask questions to identify evidence* [for how] ***the fossil record documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.*** MS-LS4-1

Additional Practices Building to the PEs (Continued)	**Developing and Using Models** • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Students could *develop a model to show relationships* [between] ***species changing over time*** [and] ***changes in environmental conditions***. MS-LS4-6 **Planning and Carrying Out Investigations** • Evaluate the accuracy of various methods for collecting data. Students could *evaluate the accuracy of various methods for collecting data* [about how] ***humans influence certain characteristics of organisms by selective breeding***. MS-LS4-5 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). Students could *consider limitations of data analysis* [for data on the] ***differences between various organisms living today***. MS-LS4-2 **Using Mathematical and Computational Thinking** • Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems. Students could *apply mathematical concepts and processes* [to describe how] ***certain characteristics of organisms are influenced by selective breeding***. MS-LS4-5 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using models* [describing that] ***proteins affect the structures and functions of the organisms and thereby change traits***. MS-LS3-1 **Engaging in Argument from Evidence** • Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. Students could *construct and present an oral argument supported by empirical evidence* [for how] ***mutations may result in changes to the structure and function of proteins***. MS-LS3-1

Additional Practices Building to the PEs (Continued)	**Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). Students could *critically read scientific texts to obtain scientific information* [about how] ***the fossil record documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth***. MS-LS4-1
Additional Crosscutting Concepts Building to the PEs	**Scale, Proportion, and Quantity** • Phenomena that can be observed at one scale may not be observable at another scale. Students could construct an argument for how ***natural selection,*** [which] ***leads to the predominance of certain traits in a population, and the suppression of others,*** *can be observed at one scale*, [but] *may not be observable at another scale*. MS-LS4-4 **Systems and System Models** • Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Students could develop and use a model describing how ***adaptation by natural selection*** [may affect parts of ecosystems and these] *systems may interact with other systems*. MS-LS4-6 **Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could communicate ideas about how ***many life forms*** [have] ***changed throughout the history of life on Earth*** and [that these] ***life forms*** *might* [have been] *disturbed either by sudden events or gradual changes that accumulate over time*. MS-LS4-1
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations. Students could obtain, evaluate, and communicate information about how *science knowledge* about ***adaptation by natural selection*** *is based on logical and conceptual connections between evidence and explanations*. MS-LS4-6 **Science is a Way of Knowing** • Science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge. Students could obtain, evaluate, and communicate information about how *many people have contributed to science knowledge* about how ***each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual***. MS-LS3-1

MS-LS3-1 Heredity: Inheritance and Variation of Traits

Students who demonstrate understanding can:

MS-LS3-1. **Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.**[Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.] [*Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.*]

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

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop and use a model to describe phenomena.

Disciplinary Core Ideas

LS3.A: Inheritance of Traits

- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

LS3.B: Variation of Traits

- In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.

Crosscutting Concepts

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	Students develop a model in which they identify the relevant components for making sense of a given phenomenon involving the relationship between mutations and the effects on the organism, including:	
		i.	Genes, located on chromosomes.
		ii.	Proteins.
		iii.	Traits of organisms.
2	Relationships		
	a	In their model, students describe* the relationships between components, including:	
		i.	Every gene has a certain structure, which determines the structure of a specific set of proteins.
		ii.	Protein structure influences protein function (e.g., the structure of some blood proteins allows them to attach to oxygen, the structure of a normal digestive protein allows it break down particular food molecules).
		iii.	Observable organism traits (e.g., structural, functional, behavioral) result from the activity of proteins.
3	Connections		
	a	Students use the model to describe* that structural changes to genes (i.e., mutations) may result in observable effects at the level of the organism, including why structural changes to genes:	
		i.	May affect protein structure and function.

		ii. May affect how proteins contribute to observable structures and functions in organisms.
		iii. May result in trait changes that are beneficial, harmful, or neutral for the organism.
	b	Students use the model to describe* that beneficial, neutral, or harmful changes to protein function can cause beneficial, neutral, or harmful changes in the structure and function of organisms.

MS-LS4-1 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

MS-LS4-1. **Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.** [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]

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

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze and interpret data to determine similarities and differences in findings.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.

Crosscutting Concepts

Patterns

- Graphs, charts, and images can be used to identify patterns in data.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Observable features of the student performance by the end of the course:			
1	Organizing data		
	a	Students organize the given data (e.g., using tables, graphs, charts, images), including the appearance of specific types of fossilized organisms in the fossil record as a function of time, as determined by their locations in the sedimentary layers or the ages of rocks.	
	b	Students organize the data in a way that allows for the identification, analysis, and interpretation of similarities and differences in the data.	
2	Identifying relationships		
	a	Students identify:	
		i.	Patterns between any given set of sedimentary layers and the relative ages of those layers.
		ii.	The time period(s) during which a given fossil organism is present in the fossil record.
		iii.	Periods of time for which changes in the presence or absence of large numbers of organisms or specific types of organisms can be observed in the fossil record (e.g., a fossil layer with very few organisms immediately next to a fossil layer with many types of organisms).
		iv.	Patterns of changes in the level of complexity of anatomical structures in organisms in the fossil record, as a function of time.
3	Interpreting data		
	a	Students analyze and interpret the data to determine evidence for the existence, diversity, extinction, and change in life forms throughout the history of Earth, using the assumption that natural laws operate today as they would have in the past. Students use similarities and differences in the observed patterns to provide evidence for:	
		i.	When mass extinctions occurred.
		ii.	When organisms or types of organisms emerged, went extinct, or evolved.
		iii.	The long-term increase in the diversity and complexity of organisms on Earth.

MS-LS4-2 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

MS-LS4-2. **Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.** [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events.

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.

Crosscutting Concepts

Patterns

- Patterns can be used to identify cause and effect relationships.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Observable features of the student performance by the end of the course:		
1	Articulating the explanation of phenomena	
	a	Students articulate a statement that relates a given phenomenon to scientific ideas, including the following ideas about similarities and differences in organisms and their evolutionary relationships:
		i. Anatomical similarities and differences among organisms can be used to infer evolutionary relationships, including:
		1. Among modern organisms.
		2. Between modern and fossil organisms.
	b	Students use evidence and reasoning to construct an explanation for the given phenomenon.
2	Evidence	
	a	Students identify and describe* evidence (e.g., from students' own investigations, observations, reading material, archived data, simulations) necessary for constructing the explanation, including similarities and differences in anatomical patterns in and between:
		i. Modern, living organisms (e.g., skulls of modern crocodiles, skeletons of birds; features of modern whales and elephants).
		ii. Fossilized organisms (e.g., skulls of fossilized crocodiles, fossilized dinosaurs).
3	Reasoning	
	a	Students use reasoning to connect the evidence to support an explanation. Students describe* the following chain of reasoning for the explanation:
		i. Organisms that share a pattern of anatomical features are likely to be more closely related than are organisms that do not share a pattern of anatomical features, due to the cause-and-effect relationship between genetic makeup and anatomy (e.g., although birds and insects both have wings, the organisms are structurally very different and not very closely related; the wings of birds and bats are structurally similar, and the organisms are more closely related; the limbs of horses and zebras are structurally very similar, and they are more closely related than are birds and bats or birds and insects).
		ii. Changes over time in the anatomical features observable in the fossil record can be used to infer lines of evolutionary descent by linking extinct organisms to living organisms through a series of fossilized organisms that share a basic set of anatomical features.

MS-LS4-3 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

MS-LS4-3. **Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.** [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]

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

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze displays of data to identify linear and nonlinear relationships.

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.

Crosscutting Concepts

Patterns

- Graphs, charts, and images can be used to identify patterns in data.

Observable features of the student performance by the end of the course:		
1	Organizing data	
	a	Students organize the given displays of pictorial data of embryos by developmental stage and by organism (e.g., early, middle, just prior to birth) to allow for the identification, analysis, and interpretation of relationships in the data.
2	Identifying relationships	
	a	Students analyze their organized pictorial displays to identify linear and nonlinear relationships, including:
		i. Patterns of similarities in embryos across species (e.g., early mammal embryos and early fish embryos both contain gill slits, whale embryos and the embryos of land animals — even some snakes — have hind limbs).
		ii. Patterns of changes as embryos develop (e.g., mammal embryos lose their gill slits, but the gill slits develop into gills in fish).
3	Interpreting data	
	a	Students use patterns of similarities and changes in embryo development to describe* evidence for relatedness among apparently diverse species, including similarities that are not evident in the fully formed anatomy (e.g., mammals and fish are more closely related than they appear to be based on their adult features, whales are related to land animals).

MS-LS4-4 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

MS-LS4-4. **Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.** [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]

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

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena.

Disciplinary Core Ideas

LS4.B: Natural Selection

- Natural selection leads to the predominance of certain traits in a population, and the suppression of others.

Crosscutting Concepts

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Observable features of the student performance by the end of the course:			
1	Articulating the explanation for phenomena		
	a	Students articulate a statement that relates the given phenomenon to scientific ideas about the cause-and-effect relationship between the inheritance of traits increasing the chances of successful reproduction and natural selection.	
	b	Students use evidence and reasoning to construct an explanation for the given phenomenon.	
2	Evidence		
	a	Students identify and describe* given evidence (e.g., from students' own investigations, observations, reading materials, archived data) necessary for constructing the explanation, including:	
		i.	Individuals in a species have genetic variation that can be passed on to their offspring.
		ii.	The probability of a specific organism surviving and reproducing in a specific environment.
		iii.	The traits (i.e., specific variations of a characteristic) and the cause-and-effect relationships between those traits and the probability of survival and reproduction of a given organism in a specific environment.
		iv.	The particular genetic variations (associated with those traits) that are carried by that organism.
3	Reasoning		
	a	Students use reasoning to connect the evidence and support an explanation that describes* the relationship between genetic variation and the success of organisms in a specific environment. Students describe* a chain of reasoning that includes:	
		i.	Any population in a given environment contains a variety of available, inheritable genetic traits.
		ii.	For a specific environment (e.g., different environments may have limited food availability, predators, nesting site availability, light availability), some traits confer advantages that make it more probable that an organism will be able to survive and reproduce there.
		iii.	In a population, there is a cause-and-effect relationship between the variation of traits and the probability that specific organisms will be able to survive and reproduce.
		iv.	Variation of traits is a result of genetic variations occurring in the population.
		v.	The proportion of individual organisms that have genetic variations and traits that are advantageous in a particular environment will increase from generation to generation due to

			natural selection because the probability that those individuals will survive and reproduce is greater.
		vi.	Similarly, the proportion of individual organisms that have genetic variations and traits that are disadvantageous in a particular environment will be less likely to survive, and the disadvantageous traits will decrease from generation to generation due to natural selection.

MS-LS4-5 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

MS-LS4-5. **Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.** [Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.]

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

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods.

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.

Disciplinary Core Ideas

LS4.B: Natural Selection

- In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.

Crosscutting Concepts

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Observable features of the student performance by the end of the course:		
1	Obtaining information	
	a	Students gather information about at least two technologies that have changed the way humans influence the inheritance of desired traits in plants and animals through artificial selection by choosing desired parental traits determined by genes, which are then often passed on to offspring. Examples could include gene therapy, genetic modification, and selective breeding of plants and animals.
	b	Students use at least two appropriate and reliable sources of information for investigating each technology.
2	Evaluating information	
	a	Students assess the credibility, accuracy, and possible bias of each publication and method used in the information they gather.
	b	Students use their knowledge of artificial selection and additional sources to describe* how the information they gather is or is not supported by evidence.

	c	Students synthesize the information from multiple sources to provide examples of how technologies have changed the ways that humans are able to influence the inheritance of desired traits in organisms.
	d	Students use the information to identify and describe* how a better understanding of cause-and-effect relationships in how traits occur in organisms has led to advances in technology that provide a higher probability of being able to influence the inheritance of desired traits in organisms.

MS-LS4-6 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

MS-LS4-6. **Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.** [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [*Assessment Boundary: Assessment does not include Hardy Weinberg calculations.*]

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

Science and Engineering Practices

Using Mathematics and Computational Thinking

Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical representations to support scientific conclusions and design solutions.

Disciplinary Core Ideas

LS4.C: Adaptation

- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Crosscutting Concepts

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Observable features of the student performance by the end of the course:		
1	Representation	
	a	Students identify the explanations for phenomena that they will support, which include:
		i. Characteristics of a species change over time (i.e., over generations) through adaptation by natural selection in response to changes in environmental conditions.
		ii. Traits that better support survival and reproduction in a new environment become more common within a population within that environment.
		iii. Traits that do not support survival and reproduction as well become less common within a population in that environment.
		iv. When environmental shifts are too extreme, populations do not have time to adapt and may become extinct.
	b	From given mathematical and/or computational representations of phenomena, students identify the relevant components, including:
		i. Population changes (e.g., trends, averages, histograms, graphs, spreadsheets) gathered from historical data or simulations.
		ii. The distribution of specific traits over time from data and/or simulations.
		iii. Environmental conditions (e.g., climate, resource availability) over time from data and/or simulations.
2	Mathematical Modeling	
	a	Students use the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) of the phenomenon to identify relationships in the data and/or simulations, including:
		i. Changes and trends over time in the distribution of traits within a population.
		ii. Multiple cause-and-effect relationships between environmental conditions and natural selection in a population.
		iii. The increases or decreases of some traits within a population can have more than one environmental cause.
3	Analysis	
	a	Students analyze the mathematical and/or computational representations to provide and describe* evidence that distributions of traits in populations change over time in response to changes in

		environmental conditions. Students synthesize their analysis together with scientific information about natural selection to describe* that species adapt through natural selection. This results in changes in the distribution of traits within a population and in the probability that any given organism will carry a particular trait.
	b	Students use the analysis of the mathematical and/or computational representations (including proportional reasoning) as evidence to support the explanations that:
		i. Through natural selection, traits that better support survival and reproduction are more common in a population than those traits that are less effective.
		ii. Populations are not always able to adapt and survive because adaptation by natural selection occurs over generations.
	c	Based on their analysis, students describe* that because there are multiple cause-and-effect relationships contributing to the phenomenon, for each different cause it is not possible to predict with 100% certainty what will happen.