Middle School Phenomenon Model Course III – Bundle 1
The Earth Affects Life

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

Bundle 1 Question: This bundle is assembled to address the question "How have Earth processes changed populations of organisms?"

Summary

The bundle organizes performance expectations with a focus on helping students begin to understand how populations change in response to environmental factors. 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

The geologic time scale interpreted from rock strata provides a way to organize Earth's history (ESS1.C as in MS-ESS1-4). The collection of fossils and their placement in chronological order 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 (LS4.A as in MS-LS4-1). Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale (ESS1.C as in MS-ESS1-4). 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). Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy (LS4.A as in MS-LS4-3).

Natural selection leads to the predominance of certain traits in a population, and the suppression of others (LS4.B as in MS-LS4-4). 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 (LS4.C as in MS-LS4-6). Environmental conditions have changed over time and are affected by weather and climate, which are in turn are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns (ESS2.D as in MS-ESS2-6). The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns (ESS2.C as in MS-ESS2-5), which change the environment and affect living things.

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 models (MS-ESS2-6), planning and carrying out investigations (MS-ESS2-5), analyzing and interpreting data (MS-LS4-1 and MS-LS4-3), using mathematics and computational thinking (MS-LS4-6), and constructing explanations (MS-LS4-2, MS-LS4-4, MS-ESS1-4). 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-LS4-1, MS-LS4-2 and MS-LS4-3), Cause and Effect (MS-LS4-4, MS-LS4-6 and MS-ESS2-5), Scale, Proportion, and Quantity (MS-ESS1-4), and Systems and System Models (MS-ESS2-6). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations MS-LS4-6 is partially assessable.	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-LS4-6. **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.* MS-ESS1-4. **Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.** [Clarification Statement: Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of Earth's major events could range from being very recent (such as the last Ice Age or the earliest fossils of homo sapiens) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant volcanic eruptions.] [*Assessment Boundary: Assessment does not include recalling the names of specific periods or epochs and events within them.*] MS-ESS2-5. **Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.** [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]

Performance Expectations (Continued)	MS-ESS2-6. **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*]
Example Phenomena	Human embryos have tails. Fossils can be found of organisms that look very different from any organisms alive today.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that require sufficient and appropriate empirical evidence to answer. Students could *ask questions about the* ***traits*** [in different] ***populations*** [that show evidence of] ***adaptation to regional weather and climate***. MS-LS4-6 and MS-ESS2-6 **Developing and Using Models** • Develop a model to describe unobservable mechanisms Students could *develop a model to describe* [how] ***natural selection leads to the predominance of certain traits in a population***. MS-LS4-4 **Planning and Carrying Out Investigations** • Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *conduct an investigation* [with containers of sediment] *to produce data* [about how the relative] ***geologic time scale*** [can be] ***interpreted from rock strata.*** MS-ESS1-4 **Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data on* ***anatomical similarities and differences between various organisms*** *to provide evidence* [for] ***lines of descent***. MS-LS4-2 **Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use computers to analyze very large data sets for patterns* [in the] ***fossil record*** [of the] ***diversity of life forms throughout the history of life on Earth***. *(MS-LS4-1)* **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using a model* [of changing] ***weather and climate*** [affecting] ***the distribution of traits in a population***. MS-LS4-6 and MS-ESS2-6

Additional Practices Building to the PEs (Continued)	**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. Students could *present a written argument to support the explanation that* ***traits that support successful survival and reproduction become more common; those that do not become less common***. MS-LS4-6 **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 describe patterns in the* ***comparison of embryological development of different species***. MS-LS4-3
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Patterns in rates of change and other numerical relationships can provide information about natural systems. Students ask questions about *patterns* [in] ***rock strata and the fossil record*** [to obtain] *information about natural systems*. MS-ESS1-4 **Scale, Proportion, and Quantity** • Phenomena that can be observed at one scale may not be observable at another scale. Students could support claims with evidence [that] ***the change of many life forms throughout the history of life on Earth*** *may not be observable* [on the] *scale* [of a human lifetime, but that it can be observed on a much longer timespan]. MS-LS4-1 **Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. Students could obtain information about the *structure of* ***anatomical similarities and differences between various organisms*** *to infer the functions of the systems*. MS-LS4-2
Additional Connections to Nature of Science	**Science Investigations Use a Variety of Methods** • Scientific values function as criteria in distinguishing between science and non-science. Students could construct an argument that *scientific values are used as criteria in distinguishing between science and non-science* [when describing how scientists interpret] ***the fossil record***. MS-LS4-1 and MS-ESS1-4 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science carefully considers and evaluates anomalies in data and evidence. Students could obtain, evaluate, and communicate information about how *anomalies in data and evidence were considered* [in the development of scientific explanations about] ***natural selection***. MS-LS4-4

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.

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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.

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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	Disciplinary Core Ideas	Crosscutting Concepts
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.	**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.	**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	Disciplinary Core Ideas	Crosscutting Concepts
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.	**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.	**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	Disciplinary Core Ideas	Crosscutting Concepts
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.	**LS4.B: Natural Selection** • Natural selection leads to the predominance of certain traits in a population, and the suppression of others.	**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-LS4-6 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.

MS-ESS1-4 Earth's Place in the Universe

Students who demonstrate understanding can:

MS-ESS1-4. Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history. [Clarification Statement: Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of Earth's major events could range from being very recent (such as the last Ice Age or the earliest fossils of homo sapiens) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant volcanic eruptions.] [*Assessment Boundary: Assessment does not include recalling the names of specific periods or epochs and events within them.*]

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	Disciplinary Core Ideas	Crosscutting Concepts
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 a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.	**ESS1.C: The History of Planet Earth** • The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.	**Scale, Proportion, and Quantity** • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

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 the given phenomenon to a scientific idea, including how events in the Earth's 4.6 billion-year-old history are organized relative to one another using the geologic time scale.	
	b	Students use evidence and reasoning to construct an explanation. In their explanation, students describe* how the relative order of events is determined on the geologic time scale using:	
		i.	Rock strata and relative ages of rock units (e.g., patterns of layering).
		ii.	Major events in the Earth's history and/or specific changes in fossils over time (e.g., formation of mountain chains, formation of ocean basins, volcanic eruptions, glaciations, asteroid impacts, extinctions of groups of organism).
2	Evidence		
	a	Students identify and describe* the evidence necessary for constructing the explanation, including:	
		i.	Types and order of rock strata.
		ii.	The fossil record.
		iii.	Identification of and evidence for major event(s) in the Earth's history (e.g., volcanic eruptions, asteroid impacts, etc.).
	b	Students use multiple valid and reliable sources of evidence, which may include students' own experiments.	
	Reasoning		

3	a		Students use reasoning, 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 connect the evidence and support an explanation for how the geologic time scale is used to construct a timeline of the Earth's history. Students describe* the following chain of reasoning for their explanation:
		i.	Unless they have been disturbed by subsequent activity, newer rock layers sit on top of older rock layers, allowing for a relative ordering in time of the formation of the layers (i.e., older sedimentary rocks lie beneath younger sedimentary rocks).
		ii.	Any rocks or features that cut existing rock strata are younger than the rock strata that they cut (e.g., a younger fault cutting across older, existing rock strata).
		iii.	The fossil record can provide relative dates based on the appearance or disappearance of organisms (e.g., fossil layers that contain only extinct animal groups are usually older than fossil layers that contain animal groups that are still alive today, and layers with only microbial fossils are typical of the earliest evidence of life).
		iv.	Specific major events (e.g., extensive lava flows, volcanic eruptions, asteroid impacts) can be used to indicate periods of time that occurred before a given event from periods that occurred after it.
		v.	Using a combination of the order of rock layers, the fossil record, and evidence of major geologic events, the relative time ordering of events can be constructed as a model for Earth's history, even though the timescales involved are immensely vaster than the lifetimes of humans or the entire history of humanity.

MS-ESS2-5 Earth's Systems

Students who demonstrate understanding can:

MS-ESS2-5. **Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.** [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]

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	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions. • Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. **ESS2.D: Weather and Climate** • Because these patterns are so complex, weather can only be predicted probabilistically.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:		
1	Identifying the phenomenon under investigation	
	a	From the given investigation plan, students describe* the phenomenon under investigation, which includes the relationships between air mass interactions and weather conditions.
	b	Students identify the purpose of the investigation, which includes providing evidence to answer questions about how motions and complex interactions of air masses result in changes in weather conditions [note: expectations of students regarding mechanisms are limited to relationships between patterns of activity of air masses and changes in weather].
2	Identifying the evidence to address the purpose of the investigation	
	a	From a given investigation plan, students describe* the data to be collected and the evidence to be derived from the data that would indicate relationships between air mass movement and changes in weather, including:
		i. Patterns in weather conditions in a specific area (e.g., temperature, air pressure, humidity, wind speed) over time.
		ii. The relationship between the distribution and movement of air masses and landforms, ocean temperatures, and currents.

		iii. The relationship between observed, large-scale weather patterns and the location or movement of air masses, including patterns that develop between air masses (e.g., cold fronts may be characterized by thunderstorms).
	b	Students describe* how the evidence to be collected will be relevant to determining the relationship between patterns of activity of air masses and changes in weather conditions.
	c	Students describe* that because weather patterns are so complex and have multiple causes, weather can be predicted only probabilistically.
3	Planning the investigation	
	a	Students describe* the tools and methods used in the investigation, including how they are relevant to the purpose of the investigation.
4	Collecting the data	
	a	According to the provided investigation plan, students make observations and record data, either firsthand and/or from professional weather monitoring services.

MS-ESS2-6 Earth's Systems

Students who demonstrate understanding can:

MS-ESS2-6. **Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.** [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*]

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

ESS2.C: The Roles of Water in Earth's Surface Processes

- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a phenomenon, students develop a model in which they identify the relevant components of the system, with inputs and outputs, including:	
		i.	The rotating Earth.
		ii.	The atmosphere.
		iii.	The ocean, including the relative rate of thermal energy transfer of water compared to land or air.
		iv.	Continents and the distribution of landforms on the surface of Earth.
		v.	Global distribution of ice.
		vi.	Distribution of living things.
		vii.	Energy.
			1. Radiation from the sun as an input.
			2. Thermal energy that exists in the atmosphere, water, land, and ice (as represented by temperature).

2	Relationships	
	a	In the model, students identify and describe* the relationships between components of the system, including:
		i. Differences in the distribution of solar energy and temperature changes, including:
		1. Higher latitudes receive less solar energy per unit of area than do lower latitudes, resulting in temperature differences based on latitude.
		2. Smaller temperature changes tend to occur in oceans than on land in the same amount of time.
		3. In general, areas at higher elevations have lower average temperatures than do areas at lower elevations.
		4. Features on the Earth's surface, such as the amount of solar energy reflected back into the atmosphere or the absorption of solar energy by living things, affect the amount of solar energy transferred into heat energy.
		ii. Motion of ocean waters and air masses (matter):
		1. Fluid matter (i.e., air, water) flows from areas of higher density to areas of lower density (due to temperature or salinity). The density of a fluid can vary for several different reasons (e.g., changes in salinity and temperature of water can each cause changes in density). Differences in salinity and temperature can, therefore, cause fluids to move vertically and, as a result of vertical movement, also horizontally because of density differences.
		iii. Factors affecting the motion of wind and currents:
		1. The Earth's rotation causes oceanic and atmospheric flows to curve when viewed from the rotating surface of Earth (Coriolis force).
		2. The geographical distribution of land limits where ocean currents can flow.
		3. Landforms affect atmospheric flows (e.g., mountains deflect wind and/or force it to higher elevation).
		iv. Thermal energy transfer:
		1. Thermal energy moves from areas of high temperature to areas of lower temperature either through the movement of matter, via radiation, or via conduction of heat from warmer objects to cooler objects.
		2. Absorbing or releasing thermal energy produces a more rapid change in temperature on land compared to in water.
		3. Absorbing or releasing thermal energy produces a more rapid change in temperature in the atmosphere compared to either on land or in water so the atmosphere is warmed or cooled by being in contact with land or the ocean.
3	Connections	
	a	Students use the model to describe*:
		i. The general latitudinal pattern in climate (higher average annual temperatures near the equator and lower average annual temperatures at higher latitudes) caused by more direct light (greater energy per unit of area) at the equator (more solar energy) and less direct light at the poles (less solar energy).
		ii. The general latitudinal pattern of drier and wetter climates caused by the shift in the amount of air moisture during precipitation from rising moisture-rich air and the sinking of dry air.
		iii. The pattern of differing climates in continental areas as compared to the oceans. Because water can absorb more solar energy for every degree change in temperature compared to land, there is a greater and more rapid temperature change on land than in the ocean. At the centers of landmasses, this leads to conditions typical of continental climate patterns.
		iv. The pattern that climates near large water bodies, such as marine coasts, have comparatively smaller changes in temperature relative to the center of the landmass. Land near the oceans can exchange thermal energy through the air, resulting in smaller changes in temperature. At the edges of landmasses, this leads to marine climates.
		v. The pattern that climates at higher altitudes have lower temperatures than climates at lower altitudes. Because of the direct relationship between temperature and pressure, given the same amount of thermal energy, air at lower pressures (higher altitudes) will have lower temperatures than air at higher pressures (lower altitudes).

		vi. Regional patterns of climate (e.g., temperature or moisture) related to a specific pattern of water or air circulation, including the role of the following in contributing to the climate pattern:
		1. Air or water moving from areas of high temperature, density, and/or salinity to areas of low temperature, density, and/or salinity.
		2. The Earth's rotation, which affects atmospheric and oceanic circulation.
		3. The transfer of thermal energy with the movement of matter.
		4. The presence of landforms (e.g., the rain shadow effect).
	b	Students use the model to describe* the role of each of its components in producing a given regional climate.