High School Modified Domains Model Course III – Life Sciences
Bundle 3: Genetic Information Affects the Diversity of Life

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

Bundle 3 Question: This bundle is assembled to address the question "how are there so many different kinds of organisms?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how genes affect traits and the evolution of populations. 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

In multicellular organisms, individual cells grow and then divide via a process called mitosis, with each parent cell passing identical genetic material to both daughter cells. Cellular division and differentiation produce and maintain a complex organism (LS1.B as in HS-LS1-4) with systems of specialized cells that help them perform the essential functions of life (LS1.A as in HS-LS1-1). Genes are regions in the DNA that contain the instructions that code for the formation of proteins (LS1.A as in HS-LS1-1 and HS-LS3-1). In addition to protein formation, some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function (LS3.A as in HS-LS3-1).

Unlike mitosis, in sexual reproduction during the process of meiosis, chromosomes can sometimes swap sections, thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation (LS3.B as in HS-LS3-2). Environmental factors also affect expression of traits, thus the variation and distribution of traits observed in a population depends on both genetic and environmental factors (LS3.B as in HS-LS3-2 and HS-LS3-3).

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, then natural selection can occur (LS4.B as in HS-LS4-2), which can lead to evolution. Evolution can occur if a species has the potential to increase in number, there is genetic variation among individuals in the species due to mutation and sexual reproduction, there is competition for resources, and there is a proliferation of those organisms that are better able to survive and reproduce in that environment (LS4.C as in HS-LS4-2). Genetic information helps to provide evidence of evolution. Overlapping DNA sequences as well as similarities and differences in amino acid sequences, anatomy, and embryological development all serve as evidence (LS4.A as in HS-LS4-1).

The engineering design idea that criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them (ETS1.A as in HS-ETS1-1) could connect to several different science ideas, such as how the genes expressed by a cell may be regulated in different ways and some segments of DNA are involved in regulatory functions (LS3.A as in HS-LS3-1) and how cellular division and differentiation produce and maintain a complex organism (LS1.B as in HS-LS1-4). Connections could be made through engineering design tasks, such having students analyze the criteria and constraints for manipulating gene expression or the process of cell division to prevent or cure various genetic diseases.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions and defining problems (HS-LS3-

1 and HS-ETS1-1), developing and using models (HS-LS1-4), analyzing and interpreting data (HS-LS3-3), constructing explanations and designing solutions (HS-LS1-1 and HS-LS4-2), engaging in argument from evidence (HS-LS3-2), and obtaining, evaluating, and communicating information (HS-LS4-1). Many other crosscutting concept 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), Cause and Effect (HS-LS3-1, HS-LS3-2, and HS-LS4-2), Scale, Proportion, and Quantity (HS-LS3-3), Systems and System Models (HS-LS1-4), and Structure and Function (HS-LS1-1). Many other crosscutting concept elements can be used in instruction. *All instruction should be three-dimensional.*	
Performance Expectations	HS-LS1-1. **Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.** [Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.] HS-LS1-4. **Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.** [Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.] HS-LS3-1**. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.** [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.] HS-LS3-2. **Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.** [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.] HS-LS3-3. **Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.** [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.] 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-ETS1-1. **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**

Example Phenomena	Babies started out as a single cell, and then grow until adulthood, when they stop growing. Bloodhounds have long floppy ears, whereas other dogs look quite different.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation of phenomena to seek additional information* [about how] ***cellular differentiation produce a complex organism, composed of systems of tissues and organs***. HS-LS1-4 **Developing and Using Models** • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanisms, or system in order to select or revise a model that best fits the evidence or design criteria. Students could *evaluate the merits and limitations of two different models of the* ***process of meiosis*** *in order to select or revise a model that best fits the evidence* [for how] ***chromosomes can sometimes swap sections, thereby creating new genetic combinations and thus more genetic variation***. HS-LS3-2 **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 that specify what happens to the* ***expression of traits*** *when* ***environmental factors change***. HS-LS3-2 **Analyzing and Interpreting Data** • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. Students could *evaluate the impact of new data on a working model* [of] ***the ongoing branching that produces multiple lines of*** [evolutionary] ***descent***. HS-LS4-1 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could *use mathematical, representations of phenomena to support claims* that ***environmental factors affect expression of traits, and hence affect the probability of occurrences of traits in a population.*** HS-LS3-2 and HS-LS3-3 **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 to link evidence to the claims* that ***genetic information such as similarities and differences in amino acid sequences provide evidence of evolution***. HS-LS4-1

Additional Practices Building to the PEs (Continued)	**Engaging in Argument from Evidence** • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations to determine the merits of arguments. Students could *evaluate the evidence behind currently accepted explanations [that]* ***genes are regions in the DNA that contain the instructions that code for the formation of proteins***. HS-LS1-1 **Obtaining, Evaluating, and Communicating Information** • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. Students could *gather, read, and evaluate scientific information from multiple authoritative sources* [about how] ***the genes expressed by different cells*** [within the same organism] ***may be regulated in different ways***. HS-LS3-1
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Mathematical representations are needed to identify some patterns. Students could use *mathematical representations to represent patterns* [of how] ***the variation and distribution of traits observed depends on both genetic and environmental factors***. HS-LS3-3 **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 synthesize and communicate information about the *functions and properties of* ***DNA*** *including the shape and molecular substructure of its various parts* and communicate [why] ***not all DNA codes for proteins; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function***. HS-LS3-1 **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. Students could *construct an explanation* [for how] *DNA replication is tightly regulated and remarkably accurate* [allowing for] *stability*, ***yet errors do occur and result in mutations, which are also a source of genetic variation*** or *change*. HS-LS3-2
Additional Connections to Nature of Science	**Scientific Investigations Use a Variety of Methods** • Science investigations use diverse methods and do not always use the same set of procedures to obtain data. Students could obtain and evaluate information about *the diverse methods and procedures that science investigations use*, [including investigations of how] ***the genes expressed by the cell may be regulated in different ways***. HS-LS3-1 **Science is a Way of Knowing** • Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time. Students could obtain, evaluate, and communicate information about *the refinement of science knowledge over time* [about how] ***some segments of DNA are involved in regulatory or structural functions***. HS-LS3-1

HS-LS1-1

Students who demonstrate understanding can:

HS-LS1-1. **Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.** [*Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.*]

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.	**LS1.A: Structure and Function** • Systems of specialized cells within organisms help them perform the essential functions of life. • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. *(Note: This Disciplinary Core Idea is also addressed by HS-LS3-1.)*	**Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

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 the idea that regions of DNA called genes determine the structure of proteins, which carry out the essential functions of life through systems of specialized cells.	
2	Evidence		
	a	Students identify and describe* the evidence to construct their explanation, including that:	
		i.	All cells contain DNA;
		ii.	DNA contains regions that are called genes;
		iii.	The sequence of genes contains instructions that code for proteins; and
		iv.	Groups of specialized cells (tissues) use proteins to carry out functions that are essential to the organism.
	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 connect 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 in their explanation:	
		i.	Because all cells contain DNA, all cells contain genes that can code for the formation of proteins.
		ii.	Body tissues are systems of specialized cells with similar structures and functions, each of whose functions are mainly carried out by the proteins they produce.
		iii.	Proper function of many proteins is necessary for the proper functioning of the cells.
		iv.	Gene sequence affects protein function, which in turn affects the function of body tissues.

HS-LS1-4

Students who demonstrate understanding can:

HS-LS1-4. **Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.** [*Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.*]

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
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.B: Growth and Development of Organisms** • In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	From the given model, students identify and describe* the components of the model relevant for illustrating the role of mitosis and differentiation in producing and maintaining complex organisms, including:	
		i.	Genetic material containing two variants of each chromosome pair, one from each parent;
		ii.	Parent and daughter cells (i.e., inputs and outputs of mitosis); and
		iii.	A multi-cellular organism as a collection of differentiated cells.
2	Relationships		
	a	Students identify and describe* the relationships between components of the given model, including:	
		i.	Daughter cells receive identical genetic information from a parent cell or a fertilized egg.
		ii.	Mitotic cell division produces two genetically identical daughter cells from one parent cell.
		iii.	Differences between different cell types within a multicellular organism are due to gene expression — not different genetic material within that organism.
3	Connections		
	a	Students use the given model to illustrate that mitotic cell division results in more cells that:	
		i.	Allow growth of the organism;
		ii.	Can then differentiate to create different cell types; and
		iii.	Can replace dead cells to maintain a complex organism.
	b	Students make a distinction between the accuracy of the model and the actual process of cellular division.	

HS-LS3-1

Students who demonstrate understanding can:

HS-LS3-1. **Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.** [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

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

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining and evaluating empirically testable questions and design problems using models and simulations.

- Ask questions that arise from examining models or a theory to clarify relationships.

Disciplinary Core Ideas

LS1.A: Structure and Function

- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. *(secondary) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)*

LS3.A: Inheritance of Traits

- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

Crosscutting Concepts

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	Addressing phenomena or scientific theories	
	a	Students use models of DNA to formulate questions, the answers to which would clarify:
		i. The cause and effect relationships (including distinguishing between causal and correlational relationships) between DNA, the proteins it codes for, and the resulting traits observed in an organism;
		ii. That the DNA and chromosomes that are used by the cell can be regulated in multiple ways; and
		iii. The relationship between the non-protein coding sections of DNA and their functions (e.g., regulatory functions) in an organism.
2	Evaluating empirical testability	
	a	Students' questions are empirically testable by scientists.

HS-LS3-2

Students who demonstrate understanding can:

HS-LS3-2. **Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.** [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]

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

Science and Engineering Practices

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.

- Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated evidence.

Disciplinary Core Ideas

LS3.B: Variation of Traits

- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.

Crosscutting Concepts

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	Developing a claim	
	a	Students make a claim that includes the idea that inheritable genetic variations may result from:
		i. New genetic combinations through meiosis;
		ii. Viable errors occurring during replication; and
		iii. Mutations caused by environmental factors.
2	Identifying scientific evidence	
	a	Students identify and describe* evidence that supports the claim, including:
		i. Variations in genetic material naturally result during meiosis when corresponding sections of chromosome pairs exchange places.
		ii. Genetic mutations can occur due to:
		a) errors during replication; and/or
		b) environmental factors.
		iii. Genetic material is inheritable.
	b	Students use scientific knowledge, literature, student-generated data, simulations and/or other sources for evidence.
3	Evaluating and critiquing evidence	
	a	Students identify the following strengths and weaknesses of the evidence used to support the claim:

		i. Types and numbers of sources;
		ii. Sufficiency to make and defend the claim, and to distinguish between causal and correlational relationships; and
		iii. Validity and reliability of the evidence.
4	Reasoning and synthesis	
	a	Students use reasoning to describe* links between the evidence and claim, such as:
		i. Genetic mutations produce genetic variations between cells or organisms.
		ii. Genetic variations produced by mutation and meiosis can be inherited.
	b	Students use reasoning and valid evidence to describe* that new combinations of DNA can arise from several sources, including meiosis, errors during replication, and mutations caused by environmental factors.
	c	Students defend a claim against counter-claims and critique by evaluating counter-claims and by describing* the connections between the relevant and appropriate evidence and the strongest claim.

HS-LS3-3

Students who demonstrate understanding can:

HS-LS3-3. **Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.** [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [*Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.*]

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

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Disciplinary Core Ideas

LS3.B: Variation of Traits

- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.

Crosscutting Concepts

Scale, Proportion, and Quantity
Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

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Connections to Nature of Science

Science is a Human Endeavor

- Technological advances have influenced the progress of science and science has influenced advances in technology.
- Science and engineering are influenced by society and society is influenced by science and engineering.

Observable features of the student performance by the end of the course:			
1	Organizing data		
	a	Students organize the given data by the frequency, distribution, and variation of expressed traits in the population.	
2	Identifying relationships		
	a	Students perform and use appropriate statistical analyses of data, including probability measures, to determine the relationship between a trait's occurrence within a population and environmental factors.	
3	Interpreting data		
	a	Students analyze and interpret data to explain the distribution of expressed traits, including:	
		i.	Recognition and use of patterns in the statistical analysis to predict changes in trait distribution within a population if environmental variables change; and
		ii.	Description* of the expression of a chosen trait and its variations as causative or correlational to some environmental factor based on reliable evidence.

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

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).

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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.

Disciplinary Core Ideas

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.

Crosscutting Concepts

Patterns
Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

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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

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.

Disciplinary Core Ideas

LS4.B: Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information — that is, trait variation — that leads to differences in performance among individuals.

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.

Crosscutting Concepts

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-ETS1-1

Students who demonstrate understanding can:

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

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

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

- Analyze complex real-world problems by specifying criteria and constraints for successful solutions.

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Crosscutting Concepts

- -

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Observable features of the student performance by the end of the course:			
1	Identifying the problem to be solved		
	a	Students analyze a major global problem. In their analysis, students:	
		i.	Describe* the challenge with a rationale for why it is a major global challenge;
		ii.	Describe*, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and
		iii.	Document background research on the problem from two or more sources, including research journals.
2	Defining the process or system boundaries, and the components of the process or system		
	a	In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem.	
	b	In their analysis, students describe* societal needs and wants that are relative to the problem (e.g., for controlling CO_2 emissions, societal needs include the need for cheap energy).	
3	Defining the criteria and constraints		
	a	Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.	