INTRODUCTION TO PERFORMANCE EXPECTATIONS

"The NGSS are standards or goals, that reflect what a student should know and be able to do; they do not dictate the manner or methods by which the standards are taught. . . . Curriculum and assessment must be developed in a way that builds students' knowledge and ability toward the PEs [performance expectations]" (Next Generation Science Standards, 2013, page xiv).

This chapter shows how the NGSS Performance Expectations are bundled in the **Heredity and Adaptation Course** to provide a coherent set of instructional materials for teaching and learning. This chapter also provides details about how this FOSS course fits into the matrix of the FOSS Program (page 41). Each FOSS module K–5 and middle school course 6–8 has a functional role in the FOSS conceptual frameworks that were developed based on a decade of research on science education and the influence of *A Framework for K–12 Science Education* (2012) and *Next Generation Science Standards* (NGSS, 2013).

The FOSS curriculum provides a coherent vision of science teaching and learning in the three ways described by the NRC *Framework*. First, FOSS is designed around learning as a developmental progression, providing experiences that allow students to continually build on their initial notions and develop more complex science and engineering knowledge. Students develop functional understanding over time by building on foundational elements (intermediate knowledge). That progression is detailed in the conceptual frameworks.

Second, FOSS limits the number of core ideas, choosing depth of knowledge over broad shallow coverage. Those core ideas are addressed at multiple grade levels in ever greater complexity. FOSS investigations at each grade level focus on elements of core ideas that are teachable and learnable at that grade level.

Third, FOSS investigations integrate engagement with scientific ideas (content) and the practices of science and engineering by providing firsthand experiences.

Teach the course with the confidence that the developers have carefully considered the latest research and have integrated into each investigation the three dimensions of the NRC *Framework* and NGSS, and have designed powerful connections to the Common Core State Standards for English Language Arts.

Contents

The NGSS Performance Expectations bundled in this course include

Life Sciences
MS-LS3-1
MS-LS3-2
MS-LS4-1
MS-LS4-2
MS-LS4-3
MS-LS4-4
MS-LS4-5
MS-LS4-6

Earth and Space Sciences
MS-ESS1-4 (foundational)

DISCIPLINARY CORE IDEAS

A Framework for K–12 Science Education has four core ideas in life sciences.

LS1: From molecules to organisms: Structures and processes

LS2: Ecosystems: Interactions, energy, and dynamics

LS3: Heredity: Inheritance and variation of traits

LS4: Biological evolution: Unity and diversity

The questions and descriptions of the core ideas in the text on these pages are taken from the NRC *Framework* for the grade 6–8 grade band to keep the core ideas in a rich and useful context.

The performance expectations related to each core idea are taken from the NGSS for grades 6–8.

Disciplinary Core Ideas Addressed

The **Heredity and Adaptation Course** connects with the NRC *Framework* grades 6–8 grade band and the NGSS performance expectations for the middle school grades. The course focuses on core ideas for life sciences.

Life Sciences

Framework core idea LS3: Heredity: Inheritance and variation of traits—How are characteristics of one generation passed to the next? How can individuals of the same species and even siblings have different characteristics?

- **LS3.A: Inheritance of traits**
  How are the characteristics of one generation related to the previous generation? [Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of a specific protein, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

  Sexual reproduction provides for transmission of genetic information to offspring through egg and sperm cells. These cells, which contain only one chromosome of each parent's chromosome pair, unite to form a new individual (offspring). Thus offspring possess one instance of each parent's chromosome pair (forming a new chromosome pair). Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited or (more rarely) from mutations. (Boundary: The stress here is on the impact of gene transmission in reproduction, not the mechanism.)]

- **LS3.B: Variation of traits**
  Why do individuals of the same species vary in how they look, function, and behave? [In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.]

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

The following NGSS grades 6–8 performance expectations for LS3 are derived from the Framework disciplinary core ideas above.

- **MS-LS3-1.** Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.
- **MS-LS3-2.** Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

Framework core idea LS4: Biological evolution: Unity and diversity—How can there be so many similarities among organisms yet so many different kinds of plants, animals, and microorganisms? How does biodiversity affect humans?

- **LS4.A: Evidence of common ancestry and diversity**
  What evidence shows that different species are related? [Fossils are mineral replacements, preserved remains, or traces of organisms that lived in the past. Thousands of layers of sedimentary rock not only provide evidence of the history of Earth itself but also of changes in organisms whose fossil remains have been found in those layers. 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. Because of the conditions necessary for their preservation, not all types of organisms that existed in the past have left fossils that can be retrieved. 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. Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully formed anatomy.]

- **LS4.B Natural selection**
  How does genetic variation among organisms affect survival and reproduction? [Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection. It leads to the predominance of certain traits in a population and the suppression of others. In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.]

- **LS4.C: Adaptation**
  How does the environment influence populations of organisms over multiple generations? [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. In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to become separate species.]

The following NGSS grades 6–8 performance expectations for LS4 are derived from the Framework disciplinary core ideas above.

- **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.

- **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.

- **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.

- **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.

- **MS-LS4-5.** Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.
- **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.

Earth and Space Sciences

Framework core idea ESS1: Earth's place in the universe: What is the universe, and what is Earth's place in it?

- **ESS1.C: The history of planet Earth**
  How do people reconstruct and date events in Earth's planetary history? [The geological time scale interpreted from rock strata provides a way to organize Earth's history. Major historical events include the formation of mountain chains and ocean basins, the evolution and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and development of watersheds and rivers through glaciation and water erosion. Analysis of rock strata and the fossil record provide only relative dates, not an absolute scale.]

The following NGSS grades 6–8 performance expectations for ESS1 is derived from the Framework disciplinary core idea above.

- **MS-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geological timescale is used to organize Earth's 4.6-billion-year-old history.

DISCIPLINARY CORE IDEAS

A Framework for K–12 Science Education has three core ideas in Earth and space sciences.

ESS1: Earth's place in the universe

ESS2: Earth's systems

ESS3: Earth and human activity

The questions and descriptions of the core ideas in the text on these pages are taken from the NRC *Framework* for the grade 6–8 grade band to keep the core ideas in a rich and useful context.

The performance expectations related to each core idea are taken from the NGSS for grades 6–8.

SCIENCE AND ENGINEERING PRACTICES

A Framework for K–12 Science Education (National Research Council, 2012) describes eight science and engineering practices as essential elements of a K–12 science and engineering curriculum. Six of these practices are incorporated into the learning experiences in the **Heredity and Adaptation Course**.

The learning progression for this dimension of the framework is addressed in *Next Generation Science Standards* (National Academies Press, 2013), volume 2, appendix F. Elements of the learning progression for practices recommended for grades 6–8 as described in the performance expectations appear in bullets below each practice.

Science and Engineering Practices Addressed

1. ***Asking questions***
    - Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
2. ***Developing and using models***
    - Develop and/or use a model to predict and/or describe phenomena.
3. ***Planning and carrying out investigations***
    - Collect data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
4. ***Analyzing and interpreting data***
    - Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
    - Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
    - Analyze and interpret data to provide evidence for phenomena.
5. ***Using mathematics and computational thinking***
    - Use mathematical representations to describe and/or support scientific conclusions and design solutions.
    - Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.
6. ***Constructing explanations***
    - Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
    - Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.
7. ***Engaging in argument from evidence***
    - Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
    - Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

8. *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).
- Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.
- Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.

Crosscutting Concepts Addressed

Patterns: *Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.*

- Patterns in rates of change and other numerical relationships can provide information about natural and human-designed systems.
- Patterns can be used to identify cause-and-effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.

Cause and effect: *Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.*

- Cause-and-effect relationships may be used to predict phenomena in natural or designed systems.
- Phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability.

Scale, proportion, and quantity: *In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.*

- The observed function of natural and designed systems may change with scale.
- Phenomena that can be observed at one scale may not be observable at another scale.

CROSSCUTTING CONCEPTS

A Framework for K–12 Science Education describes seven crosscutting concepts as essential elements of a K–12 science and engineering curriculum. The learning progression for this dimension of the framework is addressed in volume 2, appendix G, of the NGSS. Elements of the learning progression for crosscutting concepts recommended for grades 6–8, as described in the performance expectations, appear after bullets below each concept.

Systems and system models: *A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.*

- Models are limited in that they only represent certain aspects of the system under study.

Stability and change: *For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of the system are critical elements of study.*

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.
- Small changes in one part of a system might cause large changes in another part.
- Stability might be disturbed either by sudden events or gradual changes that accumulate over time.
- Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.

CONNECTIONS

See volume 2, appendix H and appendix J, in the NGSS for more on these connections.

Connections to the Nature of Science

- **Scientific knowledge is based on empirical evidence.** Scientific knowledge is based on logical and conceptual connections between evidence and explanations. Science disciplines share common rules of obtaining and evaluating empirical evidence.
- **Scientific knowledge is open to revision in light of new evidence.** The certainty and durability of scientific findings vary. Scientific findings are frequently revised and/or reinterpreted based on new evidence.
- **Science models, laws, mechanisms, and theories explain natural phenomena.** Theories are explanations for observable phenomena. Scientific theories are based on a body of evidence developed over time. The term "theory" as used in science is very different from the common use outside 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. Science carefully considers and evaluates anomalies in data and evidence.
- **Science is a human endeavor.** Men and women from different social, cultural, and ethnic backgrounds work as scientists and engineers. Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination, and creativity. Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. Advances in technology influence the progress of science, and science has influenced advances in technology.
- **Science addresses questions about the natural and material world.** Scientific knowledge is constrained by human capacity, technology, and materials. Science limits its explanations to systems that lend themselves to observation and empirical evidence. Scientific knowledge can describe consequences of actions but is not responsible for society's decisions.

Connections to Engineering, Technology, and Applications of Science

- **Interdependence of science, engineering, and technology.** Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. Science and technology drive each other forward.

FOSS CONCEPTUAL FRAMEWORK

FOSS has conceptual structure at the course level. The concepts are carefully selected and organized in a sequence that makes sense to students when presented as intended. In the last half decade, research has focused on learning progressions. The idea behind a learning progression is that **core ideas** in science are complex and wide-reaching—ideas such as the structure of matter or the relationship between the distribution and function of organisms. From the age of awareness throughout life, matter and organisms are important to us. There are things we can and should understand about them in our primary school years, and progressively more complex and sophisticated things we should know about them as we gain experience and develop our cognitive abilities. When we as educators can determine those logical progressions, we can develop meaningful and effective curriculum.

FOSS has elaborated learning progressions for core ideas in science for kindergarten through grade 8. Developing the learning progressions involves identifying successively more sophisticated ways of thinking about core ideas over multiple years. "If mastery of a core idea in a science discipline is the ultimate educational destination, then a well-designed learning progression provides a map of the routes that can be taken to reach that destination" (National Research Council, *A Framework for K–12 Science Education*, 2012, page 26).

The FOSS modules (grades K–5) and courses (grades 6–8) are organized into three domains: physical science, earth science, and life science. Each domain is subdivided into two strands, each representing a core scientific idea, as shown in the columns in the table: matter/energy and change, atmosphere and Earth/rocks and landforms, structure and function/complex systems. The sequence of modules and courses in each strand relates to the core ideas described in the national framework. Modules at the bottom of the table form the foundation in the primary grades. The core ideas develop in complexity as they proceed up the columns.

In addition to the science content framework, every course provides opportunities for students to engage in and understand science practices, and many courses explore issues related to engineering practices and the use of natural resources.

The science content used to develop the FOSS courses describes what we want students to learn; the science and engineering practices describe how we want students to learn; and crosscutting concepts stitch the whole effort into a coherent fabric describing the whole natural world. Practices involve a number of habits of mind and philosophical orientations, and these, too, will develop in richness and complexity as students advance through their science studies. Science and engineering practices involve behaviors, so they can be best assessed while in progress. Thus, assessment of practices is based on teacher observation. The indicators of progress include students involved in the many aspects of active thinking, students motivated to learn, and students taking responsibility for their own learning.

FOSS Next Generation—K–8 Sequence

	PHYSICAL SCIENCE		EARTH SCIENCE		LIFE SCIENCE	
	MATTER	ENERGY AND CHANGE	ATMOSPHERE AND EARTH	ROCKS AND LANDFORMS	STRUCTURE/ FUNCTION	COMPLEX SYSTEMS
6–8	Waves; Gravity and Kinetic Energy Chemical Interactions Electromagnetic Force		Planetary Science Earth History Weather and Water		Heredity and Adaptation Populations and Ecosystems Diversity of Life; Human Systems Interactions	
5	Mixtures and Solutions		Earth and Sun		Living Systems	
4		Energy		Soils, Rocks, and Landforms	Environments	
3	Motion and Matter		Water and Climate		Structures of Life	
2	Solids and Liquids			Pebbles, Sand, and Silt	Insects and Plants	
1		Sound and Light	Air and Weather		Plants and Animals	
K	Materials and Motion		Trees and Weather		Animals Two by Two	

BACKGROUND FOR THE CONCEPTUAL FRAMEWORK *in Heredity and Adaptation*

Science seeks explanations for what we observe in the natural world around us. What explanation can account for the vast diversity of life that exists today, for the similarity of genetic codes of diverse organisms, for fossils that point to a long history of life on Earth? Hundreds of years of scientific observation has led to the theory of biological evolution as the unifying explanation for these observations. Biological evolution has been validated time and again by found evidence. We can group that evidence into two broad categories: the fossil record preserved in Earth's rock and the laws of heredity housed in the cells of all living organisms. These lines of evidence suggest a long progression of adaptation and natural selection.

The Fossil Record

The fossil record is the nearly 3.5-billion year story of life written in Earth's rock layers. Most fossils are found in sedimentary rock as representations of the hard parts of organisms such as skeletons, mineral replacements such as shells, or trace fossils such as footprints and trackways. The principle of superposition maintains that older layers of sedimentary rock were deposited first and younger layers deposited on top of them. It follows that the fossils found in lower layers are older than the fossils found in upper layers. This principle allows paleontologists to determine relative ages of fossil organisms. Absolute or radiologic dating has allowed scientists to determine the actual age of rock, leading to the actual dating of fossils found in the rock. Putting it all together, paleontologists and geologists have constructed a time sequence of life throughout the ages. And as new discoveries and fresh information come to light, the time-life sequence is revised—science at its best.

The fossil record reveals evidence of several mass extinctions through history, times when a significant number of species disappeared in a geologically short period of time. As an example, let's say that in rock layers that are older than 440 million years, we find fossils of organisms A–Z. And in rock layers that are younger than 440 million years, we find only fossils of organisms A and B. We can infer that organisms C–Z became extinct somewhere around 440 million years ago. One extinction event, 250 million years ago, wiped out nearly 96 percent of all life-forms on Earth. That 4 percent prevailed and flourished, diversifying and surviving two more mass extinctions. This is testament to life's persistence and resilience.

Comparing the current rate of species extinctions to mass extinctions in the past has led many scientists to infer that Earth is in the process of a potentially catastrophic major extinction event due to human activity.

Tracking the change of life-forms through the fossil record continues to deepen our understanding of how life has evolved throughout Earth's history. We can compare anatomical similarities and differences in fossils and living organisms and infer ancestral and evolutionary relationships. The evolution of vertebrate tetrapods is one example of this. The record is becoming ever clearer as gaps are being filled by the recent discovery of fossil life-forms such as Tiktaalik, a transitional organism between ancient fish and modern four-limbed vertebrates.

CONCEPTUAL FRAMEWORK
Life Science, Focus on Complex Systems: Heredity and Adaptation

Structure and Function

Concept A All living things need food, water, a way to dispose of waste, and an environment in which they can live.

- Animals and plants have structures and behaviors that serve various functions in growth, survival, and reproduction.

Concept B Reproduction is essential to the continued existence of every kind of organism. Organisms have diverse life cycles.

- Organisms reproduce asexually and sexually and transfer genetic information to their offspring.

Complex Systems

Concept B Ecosystems are dynamic and change over time.

- When the environment changes, some organisms and populations survive, thrive, and reproduce; others move, decline, or die.

Concept C Heredity involves passing information from one generation to the next and introducing variation in traits between individuals in a population.

- Genes on chromosomes in each cell code for proteins, which are responsible for an organism's traits. Every cell of any individual organism contains the identical set of chromosomes.
- In sexually reproducing organisms, genetic variation in offspring is a result of the inheritance of different variants of the same gene (alleles) from each parent. In both sexually and asexually reproducing organisms, genetic variation can also result from mutations to genes producing traits that can have harmful, helpful, or neutral effects on an organism.
- An adaptation is an inherited trait that increases an organism's chances of surviving in an environment to pass on its genes.

Concept D Biological evolution, the process by which all living things have evolved over many generations from common ancestors, explains both the unity and diversity of species.

- The chronological fossil record documents the existence, diversity, extinction, and change of life-forms throughout the history of life on Earth.
- Structural similarities between ancient and modern organisms are one piece of evidence from which we can infer relatedness; embryological development is another.
- Adaptation by natural selection is a process by which individuals in a population best adapted to their environment tend to survive and pass on their traits to subsequent generations, leading to a change in the distribution of traits in the population.
- Humans are impacting evolution both by increasing the rate of extinction of organisms and influencing inheritance of traits using technology.

Heredity

If life-forms have changed continuously throughout time, there must be a mechanism that is driving that change. The mechanism is found in the genetic information that resides within cells. The genetic information of an organism is stored in nucleic acids, specifically deoxyribonucleic acid (DNA). DNA is packaged in chromosomes and contains the genes that code for the manufacture of protein molecules. These molecules are responsible for an organism's traits.

When organisms reproduce, they pass their genetic information to their offspring. When an asexual, single-celled organism reproduces, it copies its DNA, and when the cell divides, an identical copy of DNA ends up in each daughter cell. When sexual organisms reproduce, their offspring receive one set of chromosomes from the female (the egg) and one set of chromosomes from the male (the sperm). Different variants of the genes (alleles) are in each set of chromosomes. The expression of traits in the offspring depends upon the variety of genes in the parent DNA. Thus, the offspring of sexually reproducing organisms are similar to their parents, but not identical to them.

Though the environment has a role in gene expression, the possibility for variation of traits among the members of a population of organisms, even asexual organisms, springs most directly from its genes. This is because, though the DNA-copying process is almost perfect and has built-in correction mechanisms, mistakes happen. These errors, called mutations, are the root source of differences in the genes that code for proteins. Sometimes mutations can lead to the death of a cell. Sometimes mutations do not appear to have any effect on protein production—they are neutral. But sometimes a mutation can affect the structure of a protein, making it different and more effective. If a mutation occurs in a sex cell and is neutral or helpful, it is likely to remain in a species, leading to natural variation of genetic makeup and possibly of traits.

Adaptation and Natural Selection

If genetic variation exists in a population, it stands to reason that some variations may promote survival better than others. Individuals with traits that produce better adaptations for success in a particular environment will have a better chance of surviving to produce offspring. If this is the case, then over generations, those particular traits will become more common. This is the essence of natural selection. If trait variation does not affect reproductive success, then the distribution of that trait in a population will most likely not change.

But let's say the environment in which a population lives changes. Different traits might provide advantage, changing the distribution of traits. However, if the change in environment is too drastic or too rapid, a species may become extinct if it does not have the genetic variability that will allow some members of the population to succeed.

Over time, natural selection and reproductive isolation due to environmental circumstance can lead to the evolution of new species. If a population becomes isolated geographically from others in its species, perhaps by a river changing course, volcanic eruption, a change in timing of migration patterns, or some other kind of time or space isolation, the two groups may evolve additional variations until they are no longer able to mate with each other. Over the course of generations, the two groups may become behaviorally or structurally different enough that they evolve into different species.

Scientists have observed cases of natural selection leading to speciation over the course of a single human lifetime. The finches on the Galápagos Islands off the coast of Ecuador are one famous example. Usually this kind of evolutionary change occurs over incredibly long periods of time. And evidence for this dramatic change is found in the fossil record.

What a fascinating natural world humans are a part of. Our capacity and desire to seek knowledge and explanations have led us on a path that does not discard the philosophical nor ethical nor spiritual. Instead, the theory of evolution gives us the physical framework from which we can continue to pursue understanding of life. Charles Darwin (1809–1882) finished *On the Origin of Species by Means of Natural Selection* in this way: "There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved."

Life Science Content Sequence

This table shows all the modules and courses for grades 2–8 in the FOSS content sequence for life science, with an emphasis on the modules that inform the complex systems strand. The supporting elements in these modules (somewhat abbreviated) are listed. The elements for the **Heredity and Adaptation Course** are expanded to show how they fit into the sequence.

	LIFE SCIENCE	
Module or course	**Structure and Function**	**Complex Systems**
Heredity and Adaptation (middle school)		
Populations and Ecosystems (middle school)	• Reproduction is essential to the continued existence of every kind of organism. • Plants, algae, and many microorganisms use energy from light to make sugars from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. • Animals obtain food from eating plants or eating other animals.	• An ecosystem is a web of interactions and relationships among the organisms and abiotic factors in an area. • Food webs are models that demonstrate how matter and energy transfer between producers, consumers, and decomposers.
Diversity of Life (middle school)	• All living things are made of cells (unicellular or multicellular). Special structures within cells are responsible for various functions. • Cells have the same needs and perform the same functions as more complex organisms. • All living things need food, water, a way to dispose of waste, and an environment in which they can live (macro- and microlevel). • Plants reproduce in a variety of ways, sometimes depending on animal behaviors and specialized features for reproduction.	• Adaptations are structures or behaviors of organisms that enhance their chances to survive and reproduce in their environment. • Biodiversity is the wide range of existing life-forms that have adapted to the variety of conditions on Earth, from terrestrial to marine ecosystems.
Structures of Life (grade 3)	• A seed is a living organism. • Plants and animals have structures that function in growth, survival, and reproduction. • Reproduction is essential to the continued existence of every kind of organism. • Plants and animals grow and change and have predictable characteristics at different stages. • Bones have several functions: support, protection, and movement.	• Organisms are related in food chains. • Animals exhibit different kinds of behaviors. • Different organisms can live in different environments; organisms have adaptations that allow them to survive in that environment. • Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful. • A skeleton is a system of interacting bones. The skeletons of humans and other mammals have many similarities.
Insects and Plants (grade 2)	• Plants and insects have structures that function in survival and reproduction. • Reproduction is essential to the continued existence of every kind of organism. • Plants and insects grow and change and have predictable characteristics at different stages of development. • Adult plants and animals can have offspring.	• Bees and other insects help some plants by moving pollen from flower to flower. • There is variation in traits within one kind of organism. • Many characteristics of organisms are inherited from parents; other characteristics result from interaction with the environment.

Structure and Function	Complex Systems
• The chronological fossil record documents the existence, diversity, extinction, and change of life-forms throughout the history of life on Earth. • The fossil record is incomplete because of the nature of fossilization. • Structural similarities between ancient and modern organisms are one piece of evidence from which we can infer relatedness. • Embryological development can be used to identify relationships not evident in adults of different species. • Genes on DNA code for proteins that are responsible for an organism's traits. Alleles are different versions of the same gene, one of each pair inherited from each parent.	• Sexual reproduction results in offspring with genetic variation. Mutations in genes can lead to changes in proteins that can change organisms' traits. • An adaptation is an inherited trait that increases an organism's chances of surviving in an environment long enough to pass on its genes. • Natural selection is a process by which individuals best adapted to their environment tend to survive and pass their traits to subsequent generations. • Change in populations by means of natural selection is the basis for the theory of evolution, which best explains the biodiversity on Earth. • Humans use genetic technologies to influence inheritance.

Heredity and Adaptation

NOTE

See the Assessment chapter in this *Investigations Guide* for more details on how the FOSS embedded and benchmark assessment opportunities align with the conceptual frameworks and the learning progressions. In addition, the Assessment chapter describes specific connections between the FOSS assessments and the NGSS performance expectations.

The NGSS Performance Expectations addressed in this course include:

Life Sciences
MS-LS3-1
MS-LS3-2
MS-LS4-1
MS-LS4-2
MS-LS4-3
MS-LS4-4
MS-LS4-5
MS-LS4-6

Earth Sciences
MS-ESS1-4 (foundational)

See pages 32–35 in this chapter for more details on the grades 6–8 NGSS performance expectations.

CONNECTIONS TO NGSS BY INVESTIGATION

	Science and Engineering Practices	Connections to Common Core State Standards—ELA
Inv. 1: The History of Life	Asking questions Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations Engaging in argument from evidence Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite specific textual evidence to support analysis of science and technical texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. 5. Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic. 6. Analyze the author's purpose in provi ding an explanation, describing a procedure, or discussing an experiment in a text. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). 8. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. 10. Read and comprehend science/technical texts in the grades 6–8 text complexity band independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 5. With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed. 7. Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. 8. Gather relevant information from multiple print and digital sources, using search terms effectively. 9. Draw evidence from informational texts to support analysis reflection, and research. **Speaking and Listening** 1. Engage effectively in a range of collaborative discussions with diverse partners on middle school topics, texts, and issues, building on others' ideas and expressing their own clearly. 4. Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence.

Disciplinary Core Ideas		Crosscutting Concepts
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. **(MS-LS4-1)** • 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. **(MS-LS4-2**)	**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 fossil record provide only relative dates, not an absolute scale. **(MS-ESS1-4)**	Patterns Scale, proportion, and quantity Structure and function Stability and change

Inv. 2: Heredity

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Developing and using models Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. 3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics. 6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. 10. Read and comprehend science/technical texts in the grades 6–8 text complexity band independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 8. Gather relevant information from multiple print and digital sources, using search terms effectively. 9. Draw evidence from informational texts to support analysis reflection, and research. **Speaking and Listening** 1. Engage effectively in a range of collaborative discussions with diverse partners on middle school topics, texts, and issues, building on others' ideas and expressing their own clearly. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
LS3.A: Inheritance of traits • Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. **(MS-LS3-1)** • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. **(MS-LS3-2)** **LS3.B: Variation of traits** • In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. **(MS-LS3-2)** **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. **(MS-LS4-2)** • Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully formed anatomy. **(MS-LS4-3)**		Patterns Cause and effect

Inv. 3: Evolution

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations Engaging in argument from evidence Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite specific textual evidence to support analysis of science and technical texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. 5. Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. 10. Read and comprehend science/technical texts in the grades 6–8 text complexity band independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 5. With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed. 8. Gather relevant information from multiple print and digital sources, using search terms effectively. 9. Draw evidence from informational texts to support analysis reflection, and research. **Speaking and Listening** 1. Engage effectively in a range of collaborative discussions with diverse partners on middle school topics, texts, and issues, building on others' ideas and expressing their own clearly. 4. Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence. 6. Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas

LS3.A: Inheritance of traits

- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. **(MS-LS3-1)**

LS3.B: Variation of traits

- In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism. **(MS-LS3-1)**

LS4.B: Natural selection

- Natural selection leads to the predominance of certain traits in a population, and the suppression of others. **(MS-LS4-4)**
- In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. **(MS-LS4-5)**

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. **(MS-LS4-6)**

Crosscutting Concepts

Patterns
Cause and effect
Systems and system models
Stability and change

RECOMMENDED FOSS NEXT GENERATION K–8 SCOPE AND SEQUENCE

<table>
<tr><th>Grade</th><th colspan="7">Integrated Middle Grades</th></tr>
<tr><td rowspan="3">6–8</td><td>Heredity and Adaptation*</td><td>Electromagnetic Force*</td><td colspan="2">Gravity and Kinetic Energy*</td><td>Waves*</td><td colspan="2">Planetary Science</td></tr>
<tr><td colspan="2">Chemical Interactions</td><td colspan="3">Earth History</td><td colspan="2">Populations and Ecosystems</td></tr>
<tr><td colspan="3">Weather and Water</td><td colspan="3">Diversity of Life</td><td>Human Systems Interactions*</td></tr>
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**Half-length courses* *Physical Science content* *Earth Science content* *Life Science content* *Engineering content*

Grade	Physical Science	Earth Science	Life Science
5	Mixtures and Solutions	Earth and Sun	Living Systems
4	Energy	Soils, Rocks, and Landforms	Environments
3	Motion and Matter	Water and Climate	Structures of Life
2	Solids and Liquids	Pebbles, Sand, and Silt	Insects and Plants
1	Sound and Light	Air and Weather	Plants and Animals
K	Materials and Motion	Trees and Weather	Animals Two by Two