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 **Populations and Ecosystems 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 49). 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-LS1-6
MS-LS1-7
MS-LS2-1
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MS-LS2-4
MS-LS2-5

Life Sciences
MS-PS3-4 (foundational)

Earth and Space Sciences
MS-ESS3-3
MS-ESS3-4

Engineering, Technology, and Applications of Science
MS-ETS1-1
MS-ETS1-2

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 grades 6–8 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 middle school.

Disciplinary Core Ideas Addressed

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

Life Sciences

Framework core idea LS1: From molecules to organisms: Structures and processes—How do organisms live, grow, respond to their environment, and reproduce?

- **LS1.C: Organization for matter and energy flow in organisms**
  How do organisms obtain and use the matter and energy they need to live and grow? [Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. Animals obtain food from eating plants or eating other animals. Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. In most animals and plants, oxygen reacts with carbon-containing molecules (sugars) to provide energy and produce carbon dioxide; anaerobic bacteria achieve their energy needs in other chemical processes that do not require oxygen.]

The following NGSS grades 6–8 performance expectations for LS1 are derived from the Framework disciplinary core idea above.

- **MS-LS1-6.** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]
- **MS-LS1-7.** Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.]

Framework core idea LS2: Ecosystems: Interactions, energy, and dynamics— How and why do organisms interact with their environment and what are the effects of these interactions?

- **LS2.A: Interdependent relationships in ecosystems**
  How do organisms interact with the living and nonliving environments to obtain matter and energy? [Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.]
- **LS2.B: Cycles of matter and energy transfer in ecosystems**
  How do matter and energy move through an ecosystem? [Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.]
- **LS2.C: Ecosystem dynamics, functioning, and resilience**
  What happens to ecosystems when the environment changes? [Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations.

REFERENCES

National Research Council. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: National Academies Press, 2012.

NGSS Lead States. *Next Generation Science Standards: For States, by States.* Washington, DC: National Academies Press, 2013.

National Governors Association Center for Best Practices and Council of Chief State School Officers. *Common Core State Standards for English Language Arts and Literacy in History/Social Studies, Science, and Technical Subjects*. Washington, DC: 2010.

Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.]

The following NGSS grades 6–8 performance expectations for LS2 are derived from the Framework disciplinary core ideas above.

- **MS-LS2-1.** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause-and-effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.]
- **MS-LS2-2.** Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.]
- **MS-LS2-3.** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.]
- **MS-LS2-4.** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]
- **MS-LS2-5.** Evaluate competing design solutions for maintaining biodiversity and ecosystem services. [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

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.D: Biodiversity and humans**
  What is biodiversity, how do humans affect it, and how does it affect humans? [Biodiversity is the wide range of existing life forms that have adapted to the variety of conditions on Earth, from terrestrial to marine ecosystems. Biodiversity includes genetic variation within a species, in addition to species variation in different habitats and ecosystem types (e.g., forests, grasslands, wetlands). Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.]

Earth and Space Sciences

Framework core idea ESS3: Earth and human activity—How do Earth's surface processes and human activities affect each other?

- **ESS3.C: Human impacts on Earth systems**
  How do humans change the planet? [Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of many other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically, as human populations and per capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.]

The following NGSS grades 6–8 performance expectations for ESS3 are derived from the Framework disciplinary core ideas above.

- **MS-ESS3-3**. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

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 grades 6–8 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 middle school.

- **MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

Physical Sciences

Framework core idea PS3: Energy—How is energy transferred and conserved?

- **PS3.D: Energy in chemical processes and everyday life** *How do food and fuel provide energy? If energy is conserved, why do people say it is produced or used?* [The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (Boundary: Further details of the photosynthesis process are not taught at this grade level.) Both the burning of fuel and cellular digestion in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.]

The following NGSS grade 6 performance expectation for PS3 is derived from the Framework disciplinary core idea above.

- **MS-PS3-4.** Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]

  NOTE: This standard is also a main focus of the **FOSS Gravity and Kinetic Energy Course**.

DISCIPLINARY CORE IDEAS

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

- PS1: Matter and its interactions
- PS2: Motion and stability: Forces and interactions
- PS3: Energy
- PS4: Waves and their applications in technologies for information transfer

The questions and descriptions of the core ideas in the text on these pages are taken from the NRC *Framework* for grades 6–8 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.

Engineering, Technology, and Applications of Science

Framework core idea ETS1: Engineering design—How do engineers solve problems?

- **ETS1.A: Defining and delimiting an engineering problem**
  What is a design for? What are the criteria and constraints of a successful solution? [The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (e.g., familiarity with the local climate may rule out certain plants for the school garden).]

- **ETS1.B: Developing possible solutions**
  What is the process for developing potential design solutions? [A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. In any case, it is important to be able to communicate and explain solutions to others. Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the model based on peer and leader (e.g., teacher) feedback.]

The following NGSS grade 6 performance expectations for ETS1 are derived from the Framework disciplinary core ideas above.

- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

- **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

DISCIPLINARY CORE IDEAS

A Framework for K–12 Science Education has two core ideas in engineering, technology, and applications of science.

ETS1: Engineering design

ETS2: Links among engineering, technology, science, and society

The questions and descriptions of the core ideas in the text on these pages are taken from the NRC *Framework* for grades 6–8 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.

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 and defining problems*

- Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
- Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument.
- Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.
- Ask questions that require sufficient and appropriate empirical evidence to answer.
- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.

2. *Developing and using models*

- Evaluate limitations of a model for a proposed object or tool.
- Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.
- Use and/or develop a model of simple systems with uncertain and less predictable factors.
- Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
- Develop and/or use a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.

3. *Planning and carrying out investigations*

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meets the goals of the investigation.
- 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.
- Analyze and interpret data to provide evidence for phenomena.
- Analyze and interpret data to determine similarities and differences in findings.

5. Using mathematics and computational thinking

- 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 and designing solutions

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict and/or describe phenomena.
- Construct an explanation using models or representations.
- Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.
- Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

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.
- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.
- Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.

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.

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.*

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
- Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

- Scientific relationships can be represented through the use of algebraic expressions and equations.

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.*

- Systems may interact with other systems; they may have subsystems and be a part of larger complex systems.
- Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems.

Energy and matter: *Tracking energy and matter flows into, out of, and within systems helps one understand their system's behavior.*

- Matter is conserved because atoms are conserved in physical and chemical processes.
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
- Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).
- The transfer of energy can be tracked as energy flows through a designed or natural system.

Structure and function: *The way an object is shaped or structured determines many of its properties and functions.*

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Stability and change: *For both designed and natural systems, conditions that effect stability and factors that control rates of change are critical elements to consider and understand.*

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes 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 to the Nature of Science

- **Scientific investigations use a variety of methods.** Scientific investigations are guided by a set of values to ensure accuracy of measurements, observations, and objectivity of findings. Science depends on evaluating proposed explanations. Scientific values function as criteria in distinguishing between science and nonscience.
- **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. Laws are regularities or mathematical descriptions of natural phenomena. A hypothesis is used by scientists as an idea that may contribute important new knowledge for the evaluation of a scientific theory. The term "theory" as used in science is very different from the common use outside of science.
- **Science is a way of knowing.** Science is both a body of knowledge and the processes and practices used to add to that body of knowledge. Scientific knowledge is cumulative, and many people from many generations and nations have contributed to scientific knowledge. Science is a way of knowing used by many people, not just scientists.
- **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.

CONNECTIONS

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

For details on learning connections to Common Core State Standards English Language Arts and Math, see the chapters FOSS and Common Core ELA and FOSS and Common Core Math in *Teacher Resources*.

- **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

- **Influence of engineering, technology, and science on society and the natural world.** All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

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 well-designed learning progressions provide 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 Populations and Ecosystems*

Life on Earth

Life is everywhere, represented by innumerable kinds of individuals and in astronomically large numbers. Each unit of free-living life is an organism. A microscopic single-celled bacterium has equal status with the blue whale and the giant sequoia tree in this regard.

Organisms live in essential relationships with others of their kind in units called populations. Populations are reproducing groups of organisms of the same species living together. Every organism is a member of a population.

Populations always live in relationships with other populations in communities, not for companionship, but for the resources needed to maintain life. These resources, including energy and chemical building blocks, are essential for every organism. Organisms have functions that benefit other organisms, not for altruistic reasons, but because the consequences of self-serving actions have secondary effects that benefit others.

Communities of organisms exist in an environment. The totality of the community and the environment in which organisms live constitutes an ecosystem. Ecosystems are large, complex units of organization in the study of life. Ecologists are the scientists who try to understand the interactions among all the factors in the ecosystem. They try to determine the lines of influence between the organisms and the physical factors in the environment.

At the start of this course, the word *population* may be synonymous with human population in students' minds. They know that the world is filled with lots of different kinds of organisms—spiders, blueberry bushes, fish, bacteria, on and on—but the notion that they, too, are organized into populations may be a fresh concept. They will discover that populations can be dynamic, changing in response to the availability of resources.

Students will observe a pair of milkweed bugs reproduce to form a small population. As the offspring grow up and engage in typical activities, the population will take on a character of its own. Students will get to know a population very different from the population of *Homo sapiens*, but at the same time a population with which we share a great many similarities, including the continual striving for the fundamental requirements of life: gases, water, energy, and space.

Through direct observations of living organisms, video field trips, simulations, and readings, students will become aware of countless other populations. Time and again students will encounter the same issues concerning the survival of those populations.

The larger picture places populations in the environments that support them. The complex interactions between organisms and their environment define an ecosystem. The handful of ecosystems that students will visit in this course is a minute sampling of the chaos of different ecosystems found around the globe.

Every organism engages in actions in the ecosystem, the most important of which may be its role in energy transfer. Energy drives life. Energy passes through the ecosystem. Energy originates in the environment (nearly always from sunshine),

CONCEPTUAL FRAMEWORK
Life Science, Focus on Complex Systems:
Populations and Ecosystems

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.

- All organisms exhibit common characteristics of life and have certain requirements.
- Aerobic cellular respiration is the process by which energy stored in food molecules is converted into usable energy for cells.

Complex Systems

Concept A Organisms and populations of organisms depend on their environmental interactions both with other living things and with nonliving factors.

- An ecosystem is the interactions of organisms with one another and the abiotic environment.
- The Sun provides energy that plants use to produce food molecules from carbon dioxide and water. The energy in food molecules is processed in the cells of most organisms to drive life processes.
- Matter and energy cycle through ecosystems through photosynthesis, feeding relationships, growth, and reproduction.
- Organisms interact in feeding relationships (food chains and food webs).
- Populations of organisms that have similar requirements for life in an ecosystem will compete for resources in the ecosystem.
- Reproductive potential of an organism or population is limited by access to resources.

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.
- Humans depend on healthy ecosystems for resources and ecosystem services.
- As the human population grows, humans may change ecosystems in positive and negative ways.

Concept C 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.

- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems; it is a measure of the health of the system.
- Humans are impacting evolution by increasing the rate of extinction of organisms and changing ecosystems.

is transformed into organic-chemical bonds during photosynthesis, passes from organism to organism in trophic (feeding) relationships, and ultimately dissipates back into the environment as heat. Energy passes through an ecosystem only once, whereas matter recycles.

The basic building blocks of life are recycled. Simple chemicals—water, gases, and minerals—are taken up from the environment by organisms, used to construct the incredibly complex structures typical of life, and systematically disassembled into simple chemicals, which are redistributed in the environment. The matter from which life is manufactured recycles. The big idea that we expect to shine through the experience is that trophic relationships are universal—they happen pretty much the same in every ecosystem.

As students learn about different ecosystems and the complex organization of biotic and abiotic factors, they will discover that the balance of a healthy ecosystem is fragile. Human interactions with the environment can disrupt this balance. But human interactions can also restore the balance. Students will investigate how scientists have engineered solutions to human-caused problems. They will be given the opportunity to evaluate and decide on a course of action they deem appropriate to combat these problems.

The most important thing to remember is that the investigations are designed to support the kind of classroom environment in which teachers and students learn together. Relax and enjoy your brief excursion into the most wonderful and provocative subject for inquiry: life. Keep in the back of your mind the big ideas you will uncover as you go along.

CONCEPTUAL FRAMEWORK
Earth Science, Rocks and Landforms:
Populations and Ecosystems

Structure of Earth

Concept C Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources.

- Minerals, fresh water, and other natural resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.
- As human populations and use of resources increase, so do the negative impacts on Earth. The burning of fossil fuels are major factors causing global warming. Humans can use scientific knowledge and engineering design to reduce the impact of Earth's natural hazards.

- Individuals in a population vary.
- The population indicates the condition of a species.
- The biotic and abiotic environments affect the character of an ecosystem.
- Energy passes through ecosystems in trophic relationships; matter recycles.
- Biodiversity is essential for a healthy ecosystem.
- Humans are a part of the ecosystem and have the ability to change the ecosystem.
- Humans can engineer solutions to problems and attempt to restore ecosystem health.

Engineering Design

An understanding of the big idea of ecosystem is one element of 21st-century citizenship. Ecosystems are relatively closed complex systems composed of multitudes of interacting organisms in a specific environment. They have evolved over extended periods of time and have unique ways of accomplishing their essential functions. They may be thrown into disequilibrium by change. Part of a responsible relationship with life on Earth is respecting the diversity of ecosystems and making decisions that honor and protect the natural systems in which we act.

CONCEPTUAL FRAMEWORK
Engineering Design: Populations and Ecosystems

Concept A Defining and delimiting engineering problems.

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions.

Concept B Developing possible solutions.

- A solution needs to be tested and then modified on the basis of the test results, in order to improve it.
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.
- Models of all kinds are important for testing solutions.

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 **Populations and Ecosystems Course** are expanded to show how they fit into the sequence.

	LIFE SCIENCE	
Module or course	**Structure and Function**	**Complex Systems**
Populations and Ecosystems (middle school)		
Heredity and Adaptation (middle school)	• The fossil record documents 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 can be used to identify relationships. • Genes on DNA code for proteins that are responsible for an organism's traits.	• Sexual reproduction results in offspring with genetic variation. Mutations in genes 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 the best-adapted individuals pass their traits to subsequent generations, resulting in evolution and biodiversity on Earth.
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 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
Populations and Ecosystems	
• All organisms exhibit common characteristics of life and have certain requirements. • 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. • Aerobic cellular respiration is the process by which energy stored in food molecules is converted into usable energy for cells.	• An ecosystem is the interactions of organisms with one another and the abiotic environment. • Food webs are models that demonstrate how matter and energy transfer between producers, consumers, and decomposers. • The Sun provides energy that plants use to produce food molecules from carbon dioxide and water. The energy in food molecules is processed in the cells of most organisms to drive life processes. • Matter and energy cycle through ecosystems through photosynthesis, feeding relationships, growth, and reproduction. • Populations of organisms that have similar requirements for life in an ecosystem will compete for resources in the ecosystem, which can limit reproductive potential. • Humans rely on healthy ecosystems for ecosystem services, and obtaining these resources may change the ecosystem.

NOTE

See the Assessment chapter in this *Investigations Guide* for more details on how the FOSS embedded and benchmark assessment opportunities align to 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 bundled in this course include

Life Sciences
MS-LS1-6
MS-LS1-7
MS-LS2-1
MS-LS2-2
MS-LS2-3
MS-LS2-4
MS-LS2-5

Physical Sciences
MS-PS3-4 (foundational)

Earth and Space Sciences
MS-ESS3-3
MS-ESS3-4

Engineering, Technology, and Applications of Science
MS-ETS1-1
MS-ETS1-2

See pages 36–41 in this chapter for more details on the grades 6–8 NGSS performance expectations.

CONNECTIONS TO NGSS BY INVESTIGATION

Inv. 1: Milkweed Bugs

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Asking questions Developing and using models Planning and carrying out investigations Analyzing and interpreting data 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. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text. 8. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. 10. Read and comprehend science/technical texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. 5. Develop and strengthen writing. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 1. Engage in collaborative discussions. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning.

Disciplinary Core Ideas		Crosscutting Concepts
LS2.A: Interdependent relationships in ecosystems • Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. **(MS-LS2-1)**		Patterns Scale, proportion, and quantity Systems and system models Structure and function Stability and change

Inv. 2: Sorting Out Life

Science and Engineering Practices	Connections to Common Core State Standards—ELA
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 evidence to support analysis of science texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 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. 10. Read and comprehend science texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. 7. Conduct short research projects to answer a question. 8. Gather relevant information from multiple print and digital sources. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 1. Engage in collaborative discussions. 4. Present claims and findings. **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
LS2.A: Interdependent relationships in ecosystems • Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. **(MS-LS2-1)**		Cause and effect Scale, proportion, and quantity Systems and system models

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Asking questions Developing and using models Analyzing and interpreting data Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite evidence to support analysis of science texts. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment 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 texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/ explanatory texts. 4. Produce clear and coherent writing. 5. Develop and strengthen writing. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 5. Include multimedia and visual displays. **Language** 4. Determine or clarify the meaning of unknown words or phrases.

Disciplinary Core Ideas		Crosscutting Concepts
LS2.A: Interdependent relationships in ecosystems • Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. **(MS-LS2-1)** • Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. **(MS-LS2-2)**	**LS2.B: Cycles of matter and energy transfer in ecosystems** • Food webs are models that demonstrate how matter and energy are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. **(MS-LS2-3)**	Patterns Cause and effect Systems and system models Energy and matter Stability and change

Inv. 4: Minihabitats

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite evidence to support analysis of science texts. 2. Determine the control ideas or conclusions of a text; provide accurate summary. 6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/ explanatory texts. 4. Produce clear and coherent writing. 7. Conduct short research projects. 8. Gather relevant information from multiple print and digital sources. **Speaking and Listening** 1. Engage in collaborative discussions. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
LS2.A: Interdependent relationships in ecosystems • Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. **(MS-LS2-1)** • Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. **(MS-LS2-2)**	**LS2.C: Ecosystem dynamics, functioning, and resilience** • Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. **(MS-LS2-4)**	Cause and effect Systems and system models Structure and function Stability and change

Inv. 5: Producers

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 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. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 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 texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/ explanatory texts. 4. Produce clear and coherent writing. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 1. Engage in collaborative discussions. 4. Present claims and findings. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning.

Disciplinary Core Ideas		Crosscutting Concepts
LS1.C: Organization for matter and energy flow in organisms • Plants, algae, (including phytoplankton) and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. **(MS-LS1-6)** • Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. **(MS-LS1-7)** **LS2.B: Cycles of matter and energy transfer in ecosystems** • Transfers of matter into and out of the physical environment occur at every level. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. **(MS-LS2-3)**	**PS3.D: Energy in chemical processes and everyday life** • The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. **(secondary to MS-LS1-6)** • Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. **(secondary to MS-LS1-7)**	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Asking questions 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 evidence to support analysis of science texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 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 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. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/ explanatory texts. 4. Produce clear and coherent writing. 5. Develop and strengthen writing. **Speaking and Listening** 1. Engage in collaborative discussions. 4. Present claims and findings. 5. Include multimedia and visual displays. **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
LS1.C: Organization for matter and energy flow in organisms • Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. **(MS-LS1-7)** **LS2.A: Interdependent relationships in ecosystems** • Growth of organisms and population increases are limited by access to resources. **(MS-LS2-1)** • Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. **(MS-LS2-2)**	**LS2.B: Cycles of matter and energy transfer in ecosystems** • Food webs are models that demonstrate how matter and energy are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. **(MS-LS2-3)** **LS2.C: Ecosystem dynamics, functioning, and resilience** • Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. **(MS-LS2-4)**	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Stability and change

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Asking questions 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 evidence to support analysis of science texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 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. 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 texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/ explanatory texts. 4. Produce clear and coherent writing. **Speaking and Listening** 1. Engage in collaborative discussions. 4. Present claims and findings. **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
LS2.A: Interdependent relationships in ecosystems • Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. **(MS-LS2-1)** • In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. **(MS-LS2-1)** • Growth of organisms and population increases are limited by access to resources. **(MS-LS2-1)** • Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. **(MS-LS2-2)**	**LS2.C: Ecosystem dynamics, functioning, and resilience** • Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. **(MS-LS2-4)**	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Stability and change

Inv. 8: Human Impact

Science and Engineering Practices	Connections to Common Core State Standards—ELA
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** 2. Determine the central ideas or conclusions of a text; provide an accurate summary. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment 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 texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/ explanatory texts. 4. Produce clear and coherent writing. 8. Gather relevant information. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 1. Engage in collaborative discussions. 2. Analyze the purpose of information presented in diverse media and formats and evaluate the motives behind it presentation. 4. Present claims and findings. **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.

<table>
<tr><th colspan="2">Disciplinary Core Ideas</th><th>Crosscutting Concepts</th></tr>
<tr>
<td>
LS2.A: Interdependent relationships in ecosystems

Growth of organisms and population increases are limited by access to resources. (MS-LS2-1)
In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1)
Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. (MS-LS2-2)

LS2.C: Ecosystem dynamics, functioning, and resilience

Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)
Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5)
Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. (MS-LS2-5)

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<td>
ESS3.C: Human impacts on Earth systems

Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)
Typically as human populations and per capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3, MS-ESS3-4)

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Patterns
Cause and effect
Scale, proportion, and quantity
Systems and system models
Stability and change
</td>
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Inv. 9: Ecoscenarios

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Asking questions and defining problems Planning and carrying out investigations Analyzing and interpreting data Constructing explanations and designing solutions Engaging in argument from evidence Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 10. Read and comprehend science texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 2. Write informative/ explanatory texts. 8. Gather relevant information from multiple print and digital sources. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 4. Present claims and findings. 5. Include multimedia and visual displays.

Disciplinary Core Ideas		Crosscutting Concepts
LS2.C: Ecosystem dynamics, functioning, and resilience • Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. **(MS-LS2-4)** **LS4.D: Biodiversity and humans** • Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. **(MS-LS2-5)** **ESS3.C: Human impacts on Earth systems** • Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. **(MS-ESS3-3)** • Typically as human populations and per capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. **(MS-ESS3-3, MS-ESS3-4)**	**ETS1.A: Defining and delimiting an engineering problem** • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. **(MS-ETS1-1)** **ETS1.B: Developing possible solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. **(MS-ETS1-2, MS-ETS1-3)**	Cause and effect Systems and system models Stability and change

RECOMMENDED FOSS NEXT GENERATION K–8 SCOPE AND SEQUENCE

Grade	Integrated Middle Grades				
6–8	Heredity and Adaptation*	Electromagnetic Force*	Gravity and Kinetic Energy*	Waves*	Planetary Science
	Chemical Interactions		Earth History		Populations and Ecosystems
	Weather and Water		Diversity of Life		Human Systems Interactions*

*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