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 Diversity of Life 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 Framework 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.

The NGSS Performance Expectations bundled in this course include:

Life Sciences
- MS-LS1-1
- MS-LS1-2
- MS-LS1-3
- MS-LS1-4
- MS-LS1-5
- MS-LS1-6 (foundational)
- MS-LS1-7 (foundational)
- MS-LS3-2
Disciplinary Core Ideas Addressed

The Diversity of Life 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 physical science 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.A: Structure and function**
  *How do the structures of organisms enable life's functions?*  
  [All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). Unicellular organisms (microorganisms), like multicellular organisms, need food, water, a way to dispose of waste, and an environment in which they can live.]

  Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues or organs that are specialized for particular body functions.]

- **LS1.B: Growth and development of organisms**
  *How do organisms grow and develop?*  
  [Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. Animals engage in characteristic behaviors that increase the odds of reproduction. Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (such as attractively colored flowers) for reproduction. Plant growth can continue throughout the plant’s life through production of plant matter in photosynthesis. Genetic factors as well as local conditions affect the size of the adult plant. The growth of an animal is controlled by genetic factors, food intake, and interactions with other organisms, and each species has a typical adult size range.]
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 expectation for LS1 are derived from the Framework disciplinary core ideas above.

- **MS-LS1-1.** Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells. [Clarification Statement: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living cells, and understanding that living things may be made of one cell or many and varied cells.]

- **MS-LS1-2.** Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. [Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.] [Assessment Boundary: Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane. Assessment of the function of the other organelles is limited to their relationship to the whole cell. Assessment does not include the biochemical function of cells or cell parts.]

- **MS-LS1-3.** Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells. [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.]
• **MS-LS1-4.** Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds; and, creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]

• **MS-LS1-5.** Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.]

• **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 those interactions?**

• **LS2.C:** Ecosystem dynamics, functioning, and resilience

  *What happens to ecosystems when the environment changes?*

  [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.]*
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 expectation for LS3 is derived from the Framework disciplinary core ideas above.

- **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.  
  *(Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.)*
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**
   - 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 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.
   - Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.

2. **Developing and using models**
   - 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**
   - 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**

- 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 using models or representations.
- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- 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**

- Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.
- 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.
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.

- 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.
- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

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

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.

• 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.

• 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. 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.

• **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.

• **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. Technology use varies over time and from region to region.
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).

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. 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

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<th>LIFE SCIENCE</th>
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<td>ATMOSPHERE AND EARTH</td>
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<td>6–8</td>
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<td>Planetary Science</td>
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<tr>
<td></td>
<td>Chemical Interactions</td>
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</tr>
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<td>Electromagnetic Force</td>
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<td>5</td>
<td>Mixtures and Solutions</td>
<td>Earth and Sun</td>
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<td>4</td>
<td>Energy</td>
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<td>3</td>
<td>Motion and Matter</td>
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<td>2</td>
<td>Solids and Liquids</td>
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<tr>
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<td>Sound and Light</td>
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<td>K</td>
<td>Materials and Motion</td>
<td>Trees and Weather</td>
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*Diversity of Life Course—FOSS Next Generation*
DIVERSITY OF LIFE — Framework and NGSS

BACKGROUND FOR THE CONCEPTUAL FRAMEWORK in Diversity of Life

Life on Earth

Life scientists generally agree that life has been on Earth for about 3.5 billion years. The conditions on this planet are perhaps unique: the presence of water, the right distance from the Sun, molecules that formed the precursors to organic life, all the things that make it possible for life (as we know it) to exist.

What did the first life on Earth look like? Well, probably not much more than a membrane filled with seawater and chemicals. A single cell that could survive and replicate in the as yet extreme conditions that constituted Earth’s environment, something on the order of a bacterium or archaea. Or as some current theories posit, perhaps the first replicating life-forms were more akin to what we recognize today as viruses. Regardless, the first 3 billion years or so of life was microbial, single-celled, and evolving until some of those cells worked together and the first multicellular life appeared.

The history of life from that time forth, however, does not appear to be a simple straight line with a few branches. Rather, it is characterized by stops and starts, extinctions and new organisms. Scientists like to think of the history of life as a kind of tree of life, but one that looks more like a bush of life, or a “mangrove of life,” with a tangle of roots at its base leading to three trunks: bacteria, archaea, and eukaryotes.

To untangle those roots, we have to have some common understanding. And this is where our studies begin: What characteristics do all organisms share? The Diversity of Life Course takes us along the path to understanding that key concept, a concept that opens doors to the fascinating array of life on Earth.

Middle school students know that life is a wonderful thing, so now is a good time to find out where it resides. Life happens in cells. The cell is the chalice that holds the treasured spark. Cells are alive. Everything that is alive is a cell or is made of cells. Cell biology is the study of life at its fundamental level.

Students will get to know the lifestyle of a few cells—protists such as paramecia. These single-celled organisms live simple lives, but they do pretty much the same things we do when it comes to basic life functions. They require water and a source of energy. They eliminate waste and engage in gas exchange. They reproduce and grow and respond to stimuli. There you have it—humans and paramecia, and...
every other organism for that matter, march to the same drummer when it comes to the essential activities required for survival.

The flip side of all this uniformity in life is the diversity in forms. Organisms can be aquatic, terrestrial, marine, or aerial. Life occupies every conceivable place on this planet, speaking volumes about the versatility and plasticity of life. Even more impressive is the diversity of life you don’t see. More than half the biomass on Earth is microscopic. You just don’t see the billions of organisms living on, in, and all around you at all times. This concept may be difficult for students to grasp fully, but it is another fact of life that they will be exposed to.

Students study flowers. These pinnacles of adaptation convey the story of sexual reproduction, leading to the variation of traits in offspring. Embedded in the study of pollination is the story of natural selection and adaptation.

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.

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CONCEPTUAL FRAMEWORKS
Life Science, Focus on Structure and Function and Complex Systems: Diversity of Life

**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.
  - The cell is the basic unit of life. All organisms are one or more cells.
  - 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.
  - In multicellular organisms, cells form tissues, tissues form organs, and organs form organ systems (subsystems), which interact to serve the needs of the organism.

- **Concept B** Reproduction is essential to the continued existence of every kind of organism. Organisms have diverse life cycles.
  - Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.
  - Genetic factors as well as local conditions affect the growth of organisms.

**Complex Systems**

- **Concept A** Organisms and populations of organisms depend on their environmental interactions with other living things and with nonliving factors.
  - An ecosystem is the interactions of organisms with one another and the abiotic environment.
  - Photosynthesis is a chemical reaction by which plants use an energy input (sunlight) and carbon dioxide and water to combine to form carbon-based organic molecules and release oxygen.

- **Concept C** Heredity involves passing information from one generation to the next and introducing variation in traits 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. (Sex cells have single sets.)
  - In sexually reproducing organisms, each parent contributes half the offspring’s genes (alleles), resulting in variation in traits in the offspring.

- **Concept D** Biological evolution, the process by which all living things have evolved over many generations from common ancestors, explains both the unity and the diversity of species.
  - Organisms have structures and behaviors (adaptations) that allow them to survive and reproduce in certain environments.
  - Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems; it is a measure of the health of the system.
Life Science Content Sequence

This table shows most of the modules and courses for grades 1–8 in the FOSS content sequence for life science with an emphasis on the modules/courses that inform the structure and function and complex systems strands. The supporting elements in these modules (somewhat abbreviated) are listed. The elements for the Diversity of Life Course are expanded to show how they fit into the sequence.

<table>
<thead>
<tr>
<th>LIFE SCIENCE</th>
<th>Structure and Function</th>
<th>Complex Systems</th>
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</table>
| **Human Systems Interactions** (middle school) | • Aerobic cellular respiration is the process of producing usable energy for cells.  
• In multicellular organisms, such as humans, cells form tissues, tissues form organs, and organs form organ systems, which interact to serve the organism.  
• The human body is a system of interacting subsystems.  
• The nervous system is a human subsystem that functions to gather and synthesize information from the environment. Sensory receptors are structures that respond to stimuli by sending messages to the brain for processing and response. | • 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. |
| **Diversity of Life** (middle school) |  |  |
| **Living Systems** (grade 5) | • Food is digested to provide animals with the materials they need for body repair and growth and to release the energy they need to maintain body warmth and for motion.  
• Reproduction is essential to the continued existence of every kind of organism.  
• Humans and other animals have systems made up of organs that are specialized for particular body functions.  
• Animals detect, process, and use information about their environment to survive. | • Organisms obtain gases, water, and minerals from the environment and release waste matter back into the environment.  
• Matter cycles between air and soil, and among plants, animals, and microbes as these organisms live and die.  
• Organisms are related in food webs.  
• Some organisms, such as fungi and bacteria, break down dead organisms, operating as decomposers. |
| **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. |
| **Plants and Animals** (grade 1) | • Plants and animals have structures, and animals have behaviors that help the organisms grow and survive in their habitat.  
• Seeds and bulbs are alive.  
• Plants need water, light, air, and space.  
• Plants don’t live forever. New plants can grow from seeds, bulbs, roots, and stems. | • Plants make their own food.  
• Animals eat plants and other animals.  
• A habitat is a place where plants and animals live. There are many different kinds of habitats.
## Diversity of Life

### Structure and Function

- All living things are made of cells (unicellular or multicellular). Special structures within cells are responsible for various functions.
- All organisms exhibit common characteristics and have certain requirements: they grow, need energy (food) and water, exchange gases, respond to the environment, reproduce, eliminate waste, and need a suitable environment in which to live.
- Cells have the same needs and perform the same functions as more complex organisms.
- In multicellular organisms, cells form tissues, tissues form organs, and organs form organ system, which interact to serve the needs of the organism.
- Plants reproduce in a variety of ways, sometimes depending on animal behaviors and specialized features for reproduction.

### Complex Systems

- Genes on DNA encode proteins that are responsible for an organism’s traits.
- Asexual reproduction is a method of reproduction that results in offspring with identical genetic information.
- Sexual reproduction results in offspring with genetic variation, similar to parents but not identical. Alleles are different versions of the same gene, one of each pair, inherited from each parent.
- Organisms have structures and behaviors (adaptations) that enhance their chances of surviving and reproducing 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.

### The NGSS Performance Expectations addressed in this course include:

**Life Sciences**
- MS-LS1-1
- MS-LS1-2
- MS-LS1-3
- MS-LS1-4
- MS-LS1-5
- MS-LS1-6 (foundational)
- MS-LS1-7 (foundational)
- MS-LS3-2

See pages 38–41 in this chapter for more details on the grades 6–8 NGSS performance expectations.
## CONNECTIONS TO NGSS BY INVESTIGATION

### Science and Engineering Practices

<table>
<thead>
<tr>
<th>Inv. 1: What Is Life?</th>
<th>Inv. 2: The Microscope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions</td>
<td>Planning and carrying out investigations</td>
</tr>
<tr>
<td>Planning and carrying out investigations</td>
<td>Using mathematics and computational thinking</td>
</tr>
<tr>
<td>Analyzing and interpreting data</td>
<td>Engaging in argument from evidence</td>
</tr>
<tr>
<td>Constructing explanations</td>
<td>Obtaining, evaluating, and communicating information</td>
</tr>
</tbody>
</table>

### Connections to Common Core State Standards—ELA

#### 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.
3. Analyze the structure an author uses to organize a text.
4. 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
1. Write arguments.
2. Determine the central ideas or conclusions of a text; provide an accurate summary.
3. Engage in collaborative discussions.
4. Present claims and findings, emphasizing salient points in a focused sound valid reasoning, and well-chosen details; use appropriate pronunciation.

#### Speaking and Listening
1. Engage in collaborative discussions.
2. Delineate and evaluate a speaker’s argument.
3. Present claims and findings, emphasizing salient points in a focused sound valid reasoning, and well-chosen details; use appropriate pronunciation.

#### Language
4. Determine or clarify the meaning of unknown words or phrases.

---

### LS1.A: Structure and function

- **All living things are made up of cells**, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). *(MS-LS1-1, foundational)*

- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. *(MS-LS1-2)*

### Patterns

- **Cause and effect**
- **Scale, proportion, and quantity**

---

---
**Disciplinary Core Ideas**

<table>
<thead>
<tr>
<th>LS1.A: Structure and function</th>
</tr>
</thead>
<tbody>
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<td>• All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). <em>(MS-LS1-1, foundational)</em></td>
</tr>
<tr>
<td>• In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. <em>(MS-LS1-3)</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crosscutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterns</td>
</tr>
<tr>
<td>Cause and effect</td>
</tr>
<tr>
<td>Scale, proportion, and quantity</td>
</tr>
</tbody>
</table>

**LS1.A: Structure and function**

| • All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). *(MS-LS1-1, foundational)* |
| • Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. *(MS-LS1-2)* |

| Scale, proportion, and quantity |
| Structure and function |

---

**Connections to NGSS by Investigation**

**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.
5. Analyze the structure an author uses to organize a text.
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**

1. Write arguments.
8. Gather relevant information from multiple print and digital sources, using search terms effectively.

**Speaking and Listening**

1. Engage in collaborative discussions.
3. Delineate and evaluate a speaker’s argument.
4. Present claims and findings, emphasizing salient points in a focused way, valid reasoning, and well-chosen details; use appropriate pronunciation.

**Language**

6. Acquire and use academic and domain-specific words and phrases.
Science and Engineering Practices

- 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

Connections to Common Core State Standards—ELA

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.
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.
9. Compare and contrast information from experiments, simulations, video, or multimedia sources with that 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.
5. Develop and strengthen writing.
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.
3. Delineate and evaluate a speaker’s argument.
4. Present claims and findings.
6. Adapt speech to a variety of contexts and tasks.

Language
4. Determine or clarify meaning of unknown words and phrases.
4b. Use Greek or Latin affixes and roots as clues to the meaning of a word.

Inv. 3: The Cell

LS1.A: Structure and function
- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-1)
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-2)

LS1.B: Growth and development of organisms
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (MS-LS3-2)
### Disciplinary Core Ideas

**LS1.A: Structure and function**
- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). ([MS-LS1-1](#))
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. ([MS-LS1-2](#))

**LS1.B: Growth and development of organisms**
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. ([MS-LS3-2](#))

### Crosscutting Concepts

- Scale, proportion, and quantity
- Systems and system models
- Structure and function
### Science and Engineering Practices

- 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

### Connections to Common Core State Standards—ELA

#### 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.
3. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.
4. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
5. Read and comprehend science/technical texts independently and proficiently.

#### Writing—Literacy in Science and Technical Subjects
6. Gather relevant information from multiple print and digital sources.
7. Draw evidence from informational texts to support analysis, reflection, and research.

#### Speaking and Listening
1. Engage in collaborative discussions.

#### Language
4. Determine or clarify meaning of unknown words and phrases.
5. Demonstrate understanding of word relationships and nuances in word meanings.
6. Acquire and use academic and domain-specific words and phrases.

### Inv. 4: Domains

**LS1.A: Structure and function**
- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-1)
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-2)

**LS1.B: Growth and development of organisms**
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (MS-LS3-2)
LS1.A: Structure and function
- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-1)
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LS1.B: Growth and development of organisms
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (MS-LS3-2)
### Science and Engineering Practices

- Asking questions
- 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

### Inv. 5: Plants: The Vascular System

### Connections to Common Core State Standards—ELA

#### 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.
3. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.
4. Compare and contrast information from experiments, simulations, video, or multimedia sources with that from reading a text on the same topic.
5. Read and comprehend science texts independently and proficiently.

#### Writing—Literacy in Science and Technical Subjects
1. Write informative/explanatory texts.
2. Draw evidence from informational texts to support analysis, reflection, and research.
3. Engage in collaborative discussions.
4. Present claims and findings.
5. Include multimedia components and visual displays in presentations.

#### Speaking and Listening
1. Engage in collaborative discussions.
2. Present claims and findings.
3. Include multimedia components and visual displays in presentations.

#### Language
4. Determine or clarify meaning of unknown words and phrases.
5. Demonstrate understanding of word relationships and nuances in word meanings.
6. Acquire and use academic and domain-specific words and phrases.

---

**LS1.A: Structure and function**

- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-1)
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-2)
- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues or organs that are specialized for particular body functions. (MS-LS1-3)

**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)
## Disciplinary Core Ideas

**LS1.A: Structure and function**
- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). *(MS-LS1-1)*
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. *(MS-LS1-2)*
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- 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)*

## Crosscutting Concepts

- Cause and effect
- Systems and system models
- Energy and matter
- Structure and function
### Inv. 7: Variation of Traits

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Connections to Common Core State Standards—ELA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions</td>
<td><strong>Reading</strong>—Literacy in Science and Technical Subjects</td>
</tr>
<tr>
<td>Planning and carrying out investigations</td>
<td>1. Cite evidence to support analysis of science texts</td>
</tr>
<tr>
<td>Analyzing and interpreting data</td>
<td>2. Determine the central ideas or conclusions of a text; provide an accurate summary.</td>
</tr>
<tr>
<td>Constructing explanations</td>
<td>3. Follow precisely multistep procedures when carrying out experiments, taking measurements, or performing technical tasks.</td>
</tr>
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<td>Engaging in argument from evidence</td>
<td>7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.</td>
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</tbody>
</table>

### Inv. 6: Plant Reproduction and Growth

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Connections to Common Core State Standards—ELA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing and using models</td>
<td><strong>Reading</strong>—Literacy in Science and Technical Subjects</td>
</tr>
<tr>
<td>Analyzing and interpreting data</td>
<td>2. Determine the central ideas or conclusions of a text; provide an accurate summary.</td>
</tr>
<tr>
<td>Using mathematics and computational thinking</td>
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</tr>
<tr>
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</tr>
<tr>
<td>Obtaining, evaluating, and communicating information</td>
<td>9. Compare and contrast information from experiments, simulations, video, or multimedia sources with that from reading a text on the same topic.</td>
</tr>
</tbody>
</table>

### LS1.B: Growth and development of organisms

- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4)
- Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5)
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (MS-LS3-2)

### LS3.A: Inheritance of traits

- 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)
### Disciplinary Core Ideas

**LS1.B: Growth and development of organisms**
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4)
- Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5)
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (MS-LS3-2)

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- 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)

### Crosscutting Concepts

**Patterns**
- Cause and effect

**Systems and system models**

**Structure and function**

### NOTE
Investigation 7 addresses NGSS Performance Expectation MS–LS3-2 (LS1.B, LS3.A, and LS3.B). If your grade-level standards do not include this performance expectation, you could omit this investigation. MS–LS3-2 is addressed again in the FOSS Heredity and Adaptation course.
Science and Engineering Practices

Inv. 8: Insects
- Asking questions
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Inv. 9: Diversity of Life
- Asking questions
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Connections to Common Core State Standards—ELA

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.
3. Analyze the structure an author uses to organize a text.
4. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.
5. Read and comprehend science texts independently and proficiently.

Writing—Literacy in Science and Technical Subjects
8. Gather relevant information from multiple print and digital sources.

Speaking and Listening
6. Adapt speech to a variety of contexts and tasks.

Language
4. Determine or clarify meaning of unknown words and phrases.
### Disciplinary Core Ideas

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</tr>
<tr>
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<td></td>
</tr>
</tbody>
</table>

| LS2.C: Ecosystem dynamics, functioning, and resilience             |                                            |
| • 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)                               |                                            |

### Crosscutting Concepts

- Cause and effect
- Systems and system models
- Structure and function

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Structure and function
- Stability and change
## Recommended FOSS Next Generation K–8 Scope and Sequence

<table>
<thead>
<tr>
<th>Grade</th>
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</tr>
</thead>
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<td></td>
<td>Chemical Interactions</td>
</tr>
<tr>
<td></td>
<td>Weather and Water</td>
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</table>

*Half-length courses

<table>
<thead>
<tr>
<th>Grade</th>
<th>Physical Science</th>
<th>Earth Science</th>
<th>Life Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Mixtures and Solutions</td>
<td>Earth and Sun</td>
<td>Living Systems</td>
</tr>
<tr>
<td>4</td>
<td>Energy</td>
<td>Soils, Rocks, and Landforms</td>
<td>Environments</td>
</tr>
<tr>
<td>3</td>
<td>Motion and Matter</td>
<td>Water and Climate</td>
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</tr>
<tr>
<td>2</td>
<td>Solids and Liquids</td>
<td>Pebbles, Sand, and Silt</td>
<td>Insects and Plants</td>
</tr>
<tr>
<td>1</td>
<td>Sound and Light</td>
<td>Air and Weather</td>
<td>Plants and Animals</td>
</tr>
<tr>
<td>K</td>
<td>Materials and Motion</td>
<td>Trees and Weather</td>
<td>Animals Two by Two</td>
</tr>
</tbody>
</table>