2018 Virginia Science Standards of Learning

Curriculum Framework

Board of Education

Commonwealth of Virginia

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The *2018 Virginia Science Standards of Learning Curriculum Framework* can be found on the Virginia Department of Education's website at http://www.doe.virginia.gov/testing/sol/standards_docs/science/index.shtml.

Introduction

The *2018 Virginia Science Standards of Learning Curriculum Framework* amplifies the *Science Standards of Learning for Virginia Public Schools* (SOL) and defines the content knowledge, skills, and understandings that provide a foundation in science concepts and practices. The framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying enduring understandings and defining the essential science and engineering practices students need to master. This framework delineates in greater specificity the minimum content requirements that all teachers should teach and all students should learn.

School divisions should use the framework as a resource for developing sound curricular and instructional programs. This framework should not limit the scope of instructional programs. Additional knowledge and skills that can enrich instruction and enhance students' understanding of the content identified in the SOL should be included in quality learning experiences.

The framework serves as a guide for SOL assessment development. Assessment items may not and should not be a verbatim reflection of the information presented in the framework. Students are expected to continue to apply knowledge and skills from the SOL presented in previous grades as they build scientific expertise.

The Board of Education recognizes that school divisions will adopt a K–12 instructional sequence that best serves their students. The design of the SOL assessment program, however, requires that all Virginia school divisions prepare students to demonstrate achievement of the standards for elementary and middle school by the time they complete the grade levels tested. The high school end-of-course SOL tests, for which students may earn verified units of credit, are administered in a locally determined sequence.

Each topic in the framework is developed around the SOL. The format of the framework facilitates teacher planning by identifying the enduring understandings and the scientific and engineering practices that should be the focus of instruction for each standard. The categories of scientific and engineering practices appear across all grade levels and content areas. Those categories are: asking questions and defining problems; planning and carrying out investigations; interpreting, analyzing, and evaluating data; constructing and critiquing conclusions and explanations; developing and using models; and obtaining, evaluating, and communicating information. These science and engineering practices are embedded in instruction to support the development and application of science content.

Science and Engineering Practices

Science utilizes observation and experimentation along with existing scientific knowledge, mathematics, and engineering technologies to answer questions about the natural world. Engineering employs existing scientific knowledge, mathematics, and technology to create, design, and develop new devices, objects, or technology to meet the needs of society. By utilizing both scientific and engineering practices in the science classroom, students develop a deeper understanding and competence with techniques at the heart of each discipline.

Engineering Design Practices

Engineering design practices are similar to those used in an inquiry cycle; both use a system of problem solving and testing to come to a conclusion. However, unlike the inquiry cycle in which students ask a question and use the scientific method to answer it, in the engineering and design process, students use existing scientific knowledge to solve a problem. Both include research and experimentation; however, the engineering design process has a goal of a solving a societal problem and may have multiple solutions. More information on the engineering and design process can be found at https://www.eie.org/overview/engineering-design-process.

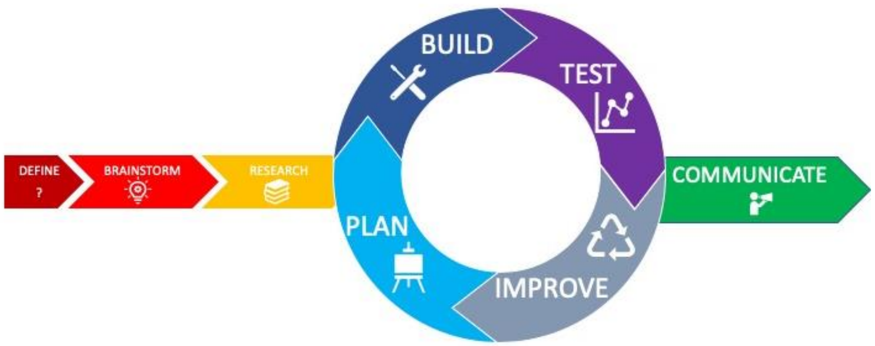

Figure 1: Engineering Design Process image based on the National Aeronautics and Space Administration (NASA) engineering design model.

The Engineering Design Process:

- Define: Define the problem, ask a question
- Imagine: Brainstorm possible solutions
- Research: Research the problem to determine the feasibility of possible solutions
- Plan: Plan a device/model to address the problem or answer the question
- Build: Build a device/model to address the problem or answer the question
- Test: Test the device/model in a series of trials
    - Does the design meet the criteria and constraints defined in the problem?
        - Yes? Go to Share (#8)
        - No? Go to Improve (#7)
- Improve: Using the results of the test, brainstorm improvements to the device/model; return to #3
- Share: Communicate your results to stakeholders and the public

Computational Thinking

The term *computational thinking* is used throughout this framework. Computational thinking is a way of solving problems that involves logically organizing and classifying data and using a series of steps (algorithms). Computational thinking is an integral part of Virginia's computer science standards and is explained as such in the *Computer Science Standards of Learning*:

> *Computational thinking is an approach to solving problems that can be implemented with a computer. It involves the use of concepts, such as abstraction, recursion, and iteration, to process and analyze data, and to create real and virtual artifacts. Computational thinking practices such as abstraction, modeling, and decomposition connect with computer science concepts such as algorithms, automation, and data visualization. [Computer Science Teachers Association & Association for Computing Machinery]*

Students engage in computational thinking in the science classroom when using both inquiry and the engineering design process. Computational thinking is used in laboratory experiences as students develop and follow procedures to conduct an investigation.

Structure of the *2018 Virginia Science Standards of Learning Curriculum Framework*

The framework is divided into two columns: Enduring Understandings and Essential Knowledge and Practices. The purpose of each column is explained below.

Enduring Understandings
The Enduring Understandings highlight the key concepts and the big ideas of science that are applicable to the standard. These key concepts and big ideas build as students advance in their scientific and engineering understanding. The bullets provide the context of those big ideas at that grade or content level.

Essential Knowledge and Practices
Each standard is expanded in the Essential Knowledge and Practices column. What each student should know and be able to do as evidence of understanding of the standard is identified here. This is not meant to be an exhaustive list nor is a list that limits what is taught in the classroom. It is meant to be the key knowledge and practices that define the standard. Science and engineering practices are highlighted with a leaf bullet (see footer).

The *2018 Virginia Science Standards of Learning Curriculum Framework* is informed by the Next Generation Science Standards (https://www.nextgenscience.org/).

Life Science

The Life Science standards emphasize a more complex understanding of change, cycles, patterns, and relationships in the living world. Students build on basic principles related to these concepts by exploring the cellular organization and the classification of organisms; the dynamic relationships among organisms, populations, communities, and ecosystems; and change as a result of the transmission of genetic information from generation to generation. Students build on scientific investigation skills by independently identifying questions and planning investigations. Students evaluate the usefulness and limits of models and support their conclusions using evidence. Mathematics, computational thinking, and experience in the engineering design process gain importance as students advance in their scientific thinking.

Scientific and Engineering Practices

Engaging in the practices of science and engineering helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the many ways to investigate, model, and explain the world. These scientific and engineering practices include the use of scientific skills and processes to explore the content of science as outlined in the *Science Standards of Learning*. The engineering design practices are the application of science content to solve a problem or design an object, tool, process, or system. These scientific and engineering practices are critical to science instruction and are to be embedded throughout the year.

LS.1 The student will demonstrate an understanding of scientific and engineering practices by

- **a) asking questions and defining problems**
  - **ask questions and develop hypotheses to determine relationships between independent and dependent variables**
  - **offer simple solutions to design problems**
- **b) planning and carrying out investigations**
  - **independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate and include the safe use of chemicals and equipment**
  - **evaluate the accuracy of various methods for collecting data**
  - **take metric measurements using appropriate tools and technologies including the use of microscopes**
- **c) interpreting, analyzing, and evaluating data**
  - **identify, interpret, and evaluate patterns in data**
  - **construct, analyze, and interpret graphical displays of data**
  - **compare and contrast data collected by different groups and discuss similarities and differences in their findings**

- **consider limitations of data analysis and/or seek to improve precision and accuracy of data**
- **use data to evaluate and refine design solutions**

d) constructing and critiquing conclusions and explanations

- **construct explanations that include qualitative or quantitative relationships between variables**
- **construct scientific explanations based on valid and reliable evidence obtained from sources (including the students' own investigations)**
- **differentiate between a scientific hypothesis and theory**

e) developing and using models

- **construct and use models and simulations to illustrate, predict, and/or explain observable and unobservable phenomena, life processes, or mechanisms**
- **evaluate limitations of models**

f) obtaining, evaluating, and communicating information

- **read scientific texts, including those adapted for classroom use, to obtain scientific and/or technical information**
- **gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication**
- **construct, use, and/or present an argument supported by empirical evidence and scientific reasoning**

Life Science Content

LS.2 The student will investigate and understand that all living things are composed of one or more cells that support life processes, as described by the cell theory. Key ideas include

a) the development of the cell theory demonstrates the nature of science;
b) cell structure and organelles support life processes;
c) similarities and differences between plant and animal cells determine how they support life processes;
d) cell division is the mechanism for growth and reproduction; and
e) cellular transport (osmosis and diffusion) is important for life processes.

Central Idea: All living things are composed of cells; these cells have different structures and organelles that support life processes. Cell theory describes the current understanding of cells. Theories and laws in science are used by scientists to describe natural phenomena. Theories and law are equal in terms of scientific validity.

Vertical Alignment: In fourth grade, students learn that plants and animals have structures that distinguish them from one another and play a vital role in their ability to survive (4.2). In Biology, students build on the concept of cell theory and focus on the relationships and interactions of organelles in biochemical processes (BIO.2, BIO.3).

Enduring Understandings	**Essential Knowledge and Practices**
The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science continually tests and refines our understanding of the natural world. The nature of science includes the concept that o the natural world is understandable o science is based on evidence—both observational and experimental o science is a blend of logic and innovation o scientific ideas are durable yet subject to change as new data are collected o science is a complex social endeavor o scientists try to remain objective and engage in peer review to help avoid bias. Theories and laws are two different types of knowledge used by scientists to describe natural phenomena. They are equal in terms of scientific validity. Theories are generally used to explain complex natural processes not easily quantifiable (e.g., cells, evolution). Laws often use mathematical formulas to show relationships and make predictions about the natural world (e.g., heredity). • The cell theory is a shared understanding that encapsulates our current understanding of the cell. The development of this theory illustrates the nature of science (LS.2 a). *Students are not responsible for identifying the contributions of specific scientists.*	In order to meet this standard, it is expected that students will • make connections among the components of the nature of science, their investigations, and the greater body of scientific knowledge and research (LS.2 a) • differentiate among a scientific hypothesis, theory, and law (LS.2 a) • identify the three components of the original cell theory (LS.2 a) • provide examples to illustrate how the development of cell theory illustrates the nature of science (LS.2 a) • explain how advances in microscope technology have improved our understanding of cells and their parts (LS.2 a) • conduct an investigation to provide evidence that living things are made of cells, either one cell or many different numbers and types of cells (LS.2 a) • identify and relate cellular organelles (cell membrane, cytoplasm, nucleus, cell wall, vacuole, mitochondrion, endoplasmic reticulum and chloroplast) with the life processes they perform within a living cell (LS.2 b) • develop and use a model to demonstrate how organelles function as a system to carry out life processes within the cell (LS.2 b)

Enduring Understandings	Essential Knowledge and Practices
Scientists and engineers use two-dimensional (2-D), three-dimensional (3-D), mathematical, and virtual models to represent, predict, and elaborate upon objects and systems and their interactions. Scientists use models when the object of investigation is too large, too small, or too complex to be studied directly. • Science and technology are tightly linked. Science seeks to understand the natural world through observation and experimentation. Technologies are developed to aid in gathering data. New data bring fresh insights, raise new questions, and prompt further investigation. In this way, scientific knowledge evolves slowly over time (LS.2 a). • A good example of the link between science and technology is how advances in microscopes have helped us investigate cells—the smallest part of living things—and how they work to sustain life processes (LS.2 a). Sustaining life requires substantial energy and matter inputs. The complex structural organization of organisms accommodates the capture, transformation, and elimination of the matter and energy needed to sustain them. • Living cells are full of highly organized organelles that function as a system to carry out life processes within the cell. Life processes include growth and repair, reproduction, gas exchange, metabolism, and response (LS.2 b). • Metabolism refers to all interactions among molecules within the well-ordered environment of the cell. Photosynthesis and cellular respiration are two important metabolic activities within living cells (LS.2 b). *Students are not responsible for*	• evaluate limitations of models to accurately represent the cell and its organelles (LS.2 b) • compare plant and animal cells and their parts, using microscopes and microscopic images (LS.2 c) • explore differences in the structure and function of animal and plant cells (LS.2 c) • relate the parts of a cell to the life functions they perform within the cell (LS.2 c) • explain how the parts of a cell work as a system to carry out life processes in the cell and the organism (LS.2 c) • sequence the steps and recognize images of each stage in the cell cycle, including mitosis (LS.2 d) • identify and explain the role of each stage of mitosis to ultimately support successful cell division (LS.2 d) • explain why cell division is essential to the growth and reproduction of all living things (LS.2 d) • differentiate between the purpose of mitosis and meiosis (LS.2 d) • model how materials move into and out of cells in the processes of osmosis, diffusion, and selective permeability (LS.2 e) • predict and provide an explanation to account for the net movement of materials across a selectively-permeable membrane during osmosis and diffusion (LS.2 e).

Enduring Understandings	Essential Knowledge and Practices
explaining specific endothermic and exothermic metabolic pathways. The structure of an object or living thing determines many of its properties and functions. • Animal and plant cells may differ in shape, size, and the organelles they contain. Most often these differences in structure are related to the function of the cell (LS.2 c). • Similarities and differences between plants and animals are evident at the cellular level (LS.2 c). • Plant cells differ from animal cells in that plant cells contain cell walls, chloroplasts, and large, central vacuoles to aid in photosynthesis that help them convert matter and energy to usable forms (LS.2 c). Reproduction is a life process (system) by which living things transfer genetic information to their offspring. • All living things grow and reproduce. As an organism grows and repairs itself, the number of its cells increase. For this to happen, existing cells divide through the process of mitosis so that new cells can be made. The cells which divide go through the cell cycle. The cell cycle has two main components—interphase and mitosis (LS.2 d). • During mitosis, a body cell first duplicates its chromosomes and then divides into two identical daughter cells, each one with a complete set of chromosomes identical to the original parent cell (LS.2 d). • The purpose of mitosis is to produce new cells for growth and repair that are identical to the parent cell. The purpose	

Enduring Understandings	Essential Knowledge and Practices
of meiosis is to produce reproductive (sex) cells that carry half the genetic material of the parent (LS.2 d). Living things must move materials into, out of, and within the cell. • Two passive processes that allow for this exchange of materials are diffusion and osmosis. These processes require no energy on the part of the cell. Substances merely move toward equilibrium (from an area of high concentration to an area of low concentration) (LS.2 e). • *Osmosis* is the movement of water molecules across a cell membrane. *Diffusion* is the movement of substances other than water across a cell membrane. Cell membranes are selectively permeable to various substances (LS.2 e). *Students are not responsible for describing facilitated diffusion, tonicity, and active transport.*	

LS.3 The student will investigate and understand that there are levels of structural organization in living things. Key ideas include

a) patterns of cellular organization support life processes;
b) unicellular and multicellular organisms have comparative structures; and
c) similar characteristics determine the classification of organisms.

Central Idea: Among organisms, there is a universality of the functions that maintain life.

Vertical Alignment: Students use classification to identify organisms in fourth grade (4.3). In Biology, students investigate how cell specialization leads to differentiation, comparative structures, and how the modern classification system can be used as an organizational tool in the study of organisms in their respective domains, kingdoms, and phyla (BIO.3, BIO.4, BIO.6**).**

Enduring Understandings	**Essential Knowledge and Practices**
Organisms are complex, organized, and built on a hierarchical structure, with each level providing the foundation for the next, from the chemical foundation of elements and atoms, to the cells and systems of individual organisms, to species and populations living and interacting in complex ecosystems. • Organisms range in composition from unicellular microorganisms to multicellular organisms (LS.3 a). • In multicellular organisms, large groups of cells work together to form systems of tissues and organs that are specialized and aid the organism in carrying out its life processes of growth, reproduction, gas exchange, metabolism, and response (LS.3 a). • Multicellular organisms exhibit a hierarchy of cellular organization allowing for a division of labor when carrying out life processes (LS.3 b). • A key concept in science is that *form fits function*. In multicellular organisms, cells have specialized shapes that enable them to perform specific roles within the organism (LS.3 b). Classification is useful in explaining relationships and organizing objects or processes into groups. Classification relies on careful observation of patterns of similarities and differences. • Biological classification (taxonomy) uses a systematic method to name, organize, and show relationships among species (LS.3 c). • Any grouping of organisms into domains or kingdoms is based on several factors, including the presence or absence of cellular structures, such as the nucleus, mitochondria, or a cell wall; whether the organisms exist as single cells or	In order to meet this standard, it is expected that students will • explain the relationship among cells, tissue, organs, and organ systems (LS.3 a) • differentiate among common examples of unicellular and multicellular organisms (LS.3 b) • compare how unicellular and multicellular organisms perform various life functions, including the application of knowledge about systems in organisms and division of labor (LS.3 b) • provide evidence to support the idea that a cell's form fits its function within a multicellular organism (LS.3 b) • classify organisms based on a comparison of key physical features and activities (LS.3 c) • arrange organisms in a hierarchy according to similarities and differences in features (LS.3 c) • apply classification criteria to categorize examples of organisms as representatives of the three domains: Archaea, Bacteria, and Eukarya (LS.3 c) • apply classification criteria to categorize examples of four kingdoms of Eukarya: protists, fungi, plants, and animals (LS.3 c) • apply classification criteria to categorize examples of organisms as representative of major animal phyla and plant divisions (LS.3 c) • recognize scientific names as part of a binomial nomenclature (LS.3 c).

Enduring Understandings	Essential Knowledge and Practices
are multicellular; and how the organisms get their food (LS.3 c). • As living things are investigated, new attributes (physical and chemical) are revealed that affect the relationships and taxonomic group into which an organism is placed (LS.3 c). • Information about the physical features and activities of living things are organized into a hierarchy of increasing specificity. The levels in this hierarchy include *domain*, *kingdom*, *phylum*, *class*, *order*, *family*, *genus*, and *species* (LS.3 c). • Classifications at one scale may not be valid at a different scale. For example, classification of organisms based on physical traits may not be the same as those based on DNA sequences (LS.3 c). • The current biological classification system groups organisms into three domains: Archaea, Bacteria, and Eukarya (LS.3 c). • A group of similar-looking organisms that can interbreed under natural conditions and produce offspring that are capable of reproduction defines a species which are differentiated using binomial nomenclature (LS.3 c).	

LS.4 The student will investigate and understand that there are chemical processes of energy transfer which are important for life. Key ideas include
a) photosynthesis is the foundation of virtually all food webs; and
b) photosynthesis and cellular respiration support life processes.

Central Idea: Energy from the sun enters the food web through photosynthesis which produces sugar (glucose) and then is transferred through the food web. Animal and plant cells use glucose for energy through the process of cellular respiration.

Vertical Alignment: Students learn that plants have structures that enable them to use photosynthesis to obtain energy and survive in fourth grade (4.2). In Biology, the processes of photosynthesis and cellular respiration are investigated as essential processes for the flow of energy (BIO.2).

Enduring Understandings	Essential Knowledge and Practices
Energy is continually transferred from one object to another and transformed between various forms. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined to form different products. The result of these chemical reactions is that energy is transferred from one system of interacting molecules to another. • Some organisms obtain energy for life processes by storing energy from the sun in chemical bonds. This process is called *photosynthesis* (LS.4 a, b). *Students are not responsible for explaining the biochemical mechanisms of photosynthesis.* • Photosynthesizing organisms, including green plants, algae, and phytoplankton, produce their own food (sugar), and are called *producers* (LS.4 a). • No process is more important for life on Earth than photosynthesis. Producers are the foundation of virtually all food webs (LS.4 a). Sustaining life processes requires substantial energy and matter inputs. The complex structural organization of organisms accommodates the capture, transformation, and elimination of the matter and energy needed to sustain them. • Two organelles—chloroplasts and mitochondria—act as change agents within the cells of living things to make energy available for life processes (LS.4 b).	In order to meet this standard, it is expected that students will 🍃 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 (LS.4 a) • relate the importance of photosynthesis to the role of producers as the foundation of food webs (LS.4 a) 🍃 plan and conduct an investigation related to photosynthesis (LS.4 a) • explain how organisms use energy stored from the products of photosynthesis (LS.4 b) • demonstrate an understanding of the interaction of reactants, products, plant parts, and cellular organelles in the process of photosynthesis (LS.4 a, b) • explain how the processes of photosynthesis and cellular respiration serve to make energy available for life processes within living systems (LS.4 b) 🍃 provide evidence to demonstrate the interdependence of photosynthesis and cellular respiration (LS.4 b) 🍃 develop a model of cellular respiration 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 (LS.4 b) • discuss how matter and energy are conserved in chemical changes within biological systems (individual cells to ecosystems) (LS.4 b)

Enduring Understandings	Essential Knowledge and Practices
• The organelles, cells, tissues, organs, and organ systems of plants work as a system to obtain the raw materials (sunlight, water, and carbon dioxide) and produce the products (sugars and oxygen) in photosynthesis (LS.4 b). • Chloroplasts, organelles found in some plant cells, convert radiant energy from sunlight into chemical energy. Chloroplasts do this with the help of the pigment chlorophyll. Chlorophyll aids in the energy transformation of sunlight (radiant energy) to chemical energy in sugar (LS.4 b). • The sugar molecules produced from photosynthesis can be used immediately by plants and animals for energy, stored for later use, or rearranged into other compounds to carry out life processes (LS.4 b). *Students are not responsible for identifying the details of the complex chemical reactions for photosynthesis.* • Cellular respiration occurs in the mitochondria of all cells (including plant cells). In this process, sugar molecules combine with oxygen to release energy in a form that cells can more easily use (LS.4 b). *Students are not responsible for identifying the details of the complex chemical reactions for respiration.* • Although they occur in different organelles, photosynthesis and cellular respiration are interdependent processes. The products of one process are the reactants for the other process and vice versa (LS.4 b). • Matter and energy are conserved in chemical processes. This is true of all biological systems, from individual cells to ecosystems (LS.4 b).	• create plausible hypotheses about the effects of changes in available materials on the rate of photosynthesis or cellular respiration; evaluate whether the hypotheses are testable in your laboratory, and test the hypotheses if possible (LS.4 a, b).

Enduring Understandings	Essential Knowledge and Practices
Living things are composed of systems which are dynamic and change in response to inputs and outflows of energy and matter. • The availability of raw materials and other factors can affect the life processes of living things, including the rate of photosynthesis and cellular respiration (LS.4 b). • Factors affecting the rate of photosynthesis are light intensity, carbon dioxide concentration, and temperature (LS.4 b). • Cellular respiration also releases the energy needed to maintain body temperature, despite ongoing energy loss to the surrounding environment (LS.4 b).	

LS.5 The student will investigate and understand that biotic and abiotic factors affect an ecosystem. Key ideas include
a) matter moves through ecosystems via the carbon, water, and nitrogen cycles;
b) energy flow is represented by food webs and energy pyramids; and
c) relationships exist among producers, consumers, and decomposers.

Central Idea: Both biotic and abiotic factors affect the movement of matter and energy within an ecosystem.

Vertical Alignment: Students investigate the flow of energy in food webs and within an ecosystem in fourth grade (4.3). In Biology, students expand their understanding of the nutrient cycle and energy flow and apply it to interactions of populations (BIO.8).

Enduring Understandings	Essential Knowledge and Practices
As matter and energy flow through different organizational levels of living systems, many important elements and compounds cycle through the living (biotic) and nonliving (abiotic) components of the environment. This chain of events continuously repeats. The cycling of matter ensures its availability for life processes.	In order to meet this standard, it is expected that students will • differentiate among key processes in the water, carbon, and nitrogen cycles and provide examples to illustrate how they support life (LS.5 a)

Enduring Understandings	Essential Knowledge and Practices
• Biotic factors are all the living, or once living, things that directly or indirectly affect an organism and its environment. Biotic factors also include the presence of organisms, their parts, and wastes. In addition, parasites and diseases are classified as biotic factors (LS.5). • Abiotic factors are nonliving components that determine the types and numbers of organisms that exist in an environment. Some examples include annual rainfall, the pH level in lakes and ponds, levels of minerals in the soil, and the amount of light at different depths of the ocean (LS.5). • The carbon, nitrogen, and water cycles serve to transfer matter through all levels of the ecosystem to support life processes (LS.5 a). • The processes of the nitrogen cycle include nitrogen fixation, nitrification, assimilation, ammonification, and de-nitrification (LS.5 a). *Students are not responsible for identifying the names of these processes.* • The main processes of the carbon cycle include photosynthesis, respiration, combustion, and decomposition (LS.5 a). • The main processes of the water cycle include precipitation, evaporation, condensation, and transpiration (LS.5 a). Within natural and designed systems, it is possible to track the flow, cycles, and conservation of matter and energy. • Food chains and webs illustrate how energy is transferred from producers to different levels of consumers in an ecosystem (LS.5 b). • The amount of energy available decreases from producer to first-order, second-order, and third-order consumers. This	🍃 develop and/or use a model to illustrate the cycling of matter and flow of energy among living and nonliving parts of an ecosystem (LS.5 a) 🍃 analyze local aquatic and terrestrial ecosystems, identify biotic and abiotic components, and describe their roles in the cycling of matter and flow of energy (LS.5 a) • explain and provide examples to illustrate the cause-and-effect relationship of human activity on the cycling of matter and flow of energy in an ecosystem (LS.5 a) • explain matter and energy transfer as modeled through food webs and energy pyramids (LS.5 b) • determine the relationship between a population's position in a food web and its size (LS.5 b) 🍃 interpret energy pyramids to determine the relative amount of energy available at each trophic level (LS.5 b) 🍃 develop and/or interpret a model of a food web using organisms found in a local ecosystem and classify organisms as producers or first-, second-, or third-order consumers (LS.5 b, c) • recognize examples of common producers, consumers, and decomposers and explain the role of each in the flow of energy and cycling of matter through an ecosystem (LS.5 c) • provide examples to illustrate the effects of human activity on the activity of producers, consumers, and decomposers in an ecosystem (LS.5 c).

Enduring Understandings	Essential Knowledge and Practices
concept can be modeled through an energy pyramid (LS.5 b). • No energy conversion is perfectly efficient. Each level of the energy pyramid has less energy to pass on to the next with roughly one-tenth of the energy in one level available for the next. Energy is given off to the environment as thermal energy through metabolism (LS.5 b). The life processes of plants and animals are interdependent and contribute to the flow of energy and cycles of matter within an ecosystem. The need to obtain matter and resources drives the behavior and interactions among living things within an ecosystem. • Producers are consumed (eaten) by consumers. When either producers or consumers die, they are broken down and consumed by decomposers. Decomposers return nutrients to the environment where they can be used by producers (LS.5 c). • Human actions can positively and negatively affect the populations of producers, consumers, and decomposers in an ecosystem (LS.5 c).	

LS.6 The student will investigate and understand that populations in a biological community interact and are interdependent. Key ideas include

a) relationships exist between predators and prey and these relationships are modeled in food webs;
b) the availability and use of resources may lead to competition and cooperation;
c) symbiotic relationships support the survival of different species; and
d) the niche of each organism supports survival.

Central Idea: Each organism exists as a member of a population and interacts with other members in a population in a variety of ways. Members of different populations interact in a variety of ways within communities.

Vertical Alignment: Students investigate the relationships among organisms in an ecosystem in third grade (3.5). In fourth grade, students study the interrelationships in populations, communities, and ecosystems, as well an organism's niche (4.3). These concepts are expanded in Biology to include limiting factors and carrying capacities (BIO.8).

Enduring Understandings	Essential Knowledge and Practices
The life processes of plants and animals are interdependent and contribute to the flow of energy and cycles of matter within an ecosystem. • The interaction between a consumer that captures and consumes another consumer is the predator-prey relationship (LS.6 a). • Many animals exhibit social behaviors that help them obtain resources. Herbivores often exhibit herding behaviors, which can protect the group from predators. Predators often work together to hunt, capture, and share their prey as well as to raise offspring (LS.6 a). • Organisms may exist as members of a population; populations interact and are interdependent with other populations in a community (LS.6 a). Members of a population interact with other populations in a community. They compete to obtain the matter and energy they need for basic resources, mates, and territory, and cooperate to meet basic needs and carry out life processes. • Organisms or populations that rely on each other for basic needs form interdependent communities, where a change in the population of one organism will affect the survival of others (LS.6 b). • Environmental factors (biotic and abiotic), which determine the types and number of organisms of a species in an	In order to meet this standard, it is expected that students will • explain how the interactions of populations form communities within an ecosystem (LS.6 a) • formulate inferences based on graphs and other data about predator-prey populations (LS.6 a) • argue based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors help them to obtain resources (LS.6 a) • analyze and interpret data to predict and explain the effects of resource availability on organisms and populations in an ecosystem (LS.6 b) • predict the effect of limiting factors on organisms, populations, and/or communities in a food web/ecosystem (LS.6 b) • provide examples to illustrate how organisms cooperate and/or compete with one another for resources (LS.6 b) • analyze and interpret data about the effects of resource availability on organisms and populations of organisms in an ecosystem (LS.6 a) • differentiate among the types of symbiosis and recognize and/or provide examples of each (LS.6 c) • infer the niche of organisms from their physical characteristics (LS.6 d).

Enduring Understandings	Essential Knowledge and Practices
ecosystem, are called *limiting factors*. Many limiting factors affect the growth of populations in nature (LS.6 b). • Symbiosis is a close relationship between individuals of two different species living together. Symbiotic relationships include *mutualism* (whereby both organisms benefit), *commensalism* (whereby one organism benefits and the other is unaffected), and *parasitism* (whereby one organism benefits and the other is harmed) (LS.6 c). • The physical location where organisms live is called their *habitat*. Each living thing fills a specific role, or *niche*, in its habitat. A niche helps an organism meet basic needs for life processes (LS.6 d).	

LS.7 The student will investigate and understand that adaptations support an organism's survival in an ecosystem. Key ideas include

a) biotic and abiotic factors define land, marine, and freshwater ecosystems; and

b) physical and behavioral characteristics enable organisms to survive within a specific ecosystem.

Central Idea: Populations adapt to survive within an ecosystem.

Vertical Alignment: Students begin to explore physical and behavioral adaptations as well as the living and nonliving components of the environment in third grade (3.5). In fourth grade, students are introduced to the ocean environment and the interactions of organisms in the oceans. These concepts are extended in Biology, to include changes in populations through time. Evidence of these changes, to include fossil records and DNA analysis, is provided as support to the theory of evolution (BIO.7).

Enduring Understandings	Essential Knowledge and Practices
Ecosystems and their characteristics are the result of complex interactions among Earth's systems (biosphere, geosphere, atmosphere, and hydrosphere).	In order to meet this standard, it is expected that students will • compare the biotic and abiotic factors that distinguish land, marine, and freshwater ecosystems (LS.7 a)

Enduring Understandings	Essential Knowledge and Practices
• Earth's tilt on its axis, combined with its revolution around the sun, plays a major role in determining the climate of a given location. Other factors, such as latitude, temperature, precipitation, topography, elevation, and human actions can also influence climate (LS.7 a). • Ecosystems can be large or small, terrestrial or aquatic (LS.7 a). • Ecosystems are dynamic, experiencing shifts in population composition and abundance and changes in the physical environment over time, which ultimately affects the stability and resilience of the entire system (LS.7 a). Organisms possess physical characteristics and behaviors that enable them to survive in their environment and obtain resources to meet basic needs and carry out life processes, increasing their chances of survival (LS.7 b).	• analyze and describe how physical characteristics and behaviors enable organisms to survive in an ecosystem (LS.7 a, b) • investigate how structural adaptations among populations allow organisms to survive with ecosystems (LS.7 b).

LS.8 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time. Key ideas include

a) organisms respond to daily, seasonal, and long-term changes;

b) changes in the environment may increase or decrease population size; and

c) large-scale changes such as eutrophication, climate changes, and catastrophic disturbances affect ecosystems.

Central Idea: As conditions change, organisms, populations, communities, and ecosystems respond to those changes to survive.

Vertical Alignment: Students learn how organisms respond to changes in temperature, light, and precipitation in first and second grade (1.7, 2.7). Students investigate the effect of large-scale changes on plants and animals in sixth grade and at a more complex level in Biology (6.9, BIO.8).

Enduring Understandings	Essential Knowledge and Practices
Living things have a range of conditions that are optimal for survival. Living things respond to daily, seasonal, and long-term changes in their environment to survive. • To survive, plants require light and water for photosynthesis. Plants have developed responses, called *tropisms*, to help ensure they grow toward adequate sources of light and water (i.e., *phototropism* and *geotropism*) (LS.8 a). • Some plants and animals can better survive adverse environmental conditions through periods of dormancy. Dormancy occurs when normal physical functions are slowed down or suspended (LS.8 a). *Students are not responsible for defining the terms* torpor, *and* estivation. • A *circadian rhythm* is a roughly 24-hour cycle in the physiological processes of living things, including plants, animals, fungi, and cyanobacteria. This cycle aids life processes (LS.8 a). Systems are dynamic and change in response to inputs and outflows of energy and matter. • Factors can positively and negatively affect the cycles of matter and the life processes of living things within an ecosystem. Disruptions to any component of an ecosystem can lead to shifts in the size and/or distribution of its populations (LS.8 b). • Changes in the living and nonliving components of an ecosystem can accelerate or decelerate natural processes (LS.8 b). • Many factors such as pollution, habitat destruction, disease, and over-harvesting can increase or decrease population size (LS.8 b).	In order to meet this standard, it is expected that students will • categorize responses as daily, seasonal, or long-term (LS.8 a) • construct a scientific explanation based on evidence to explain the benefit(s) of daily, seasonal, and/or long-term responses of organisms to their enhanced survival (LS.8 a) • classify as long-term, short-term, or seasonal the various types of changes that occur over time in ecosystems, communities, populations, and organisms (LS.8 b) • predict the effect of changes to living and/or nonliving factors on the size and distribution of populations in an ecosystem (LS.8 b) • compare the factors that increase or decrease population size (LS.8 b) • argue, citing evidence, that changes to physical or biological components of an ecosystem affect populations (LS.8 b) • predict the effect of large-scale changes on ecosystems and communities (LS.8 c) • analyze data to determine the effect of a catastrophic event on a community (LS.8 c) • predict the environmental effects of large-scale changes, such as climate change, ocean acidification, and sea-level rise (LS.8 c).

Enduring Understandings	Essential Knowledge and Practices
Systems are comprised of a group of interacting and interdependent elements forming a complex whole. Systems change in response to inputs and outflows of energy and matter. A change in one part of the system affects other parts of the system. • Long-term changes may affect entire communities and ecosystems (LS.8 c). • When excess nutrients flow into an aquatic ecosystem, a chain of events may take place which leads to a low dissolved-oxygen level in the water. This is called *eutrophication* (LS.8 c). • Natural disasters, such as forest fires, floods, and tornados are disruptive factors that shift the balance with in an ecosystem and initiate a process of gradual change from one community of organisms to another (LS.8 c).	

LS.9 The student will investigate and understand that relationships exist between ecosystem dynamics and human activity. Key ideas include

a) changes in habitat can disturb populations;
b) disruptions in ecosystems can change species competition; and
c) variations in biotic and abiotic factors can change ecosystems.

Central Idea: Human interactions affect ecosystem dynamics.

Vertical Alignment: Students study the impact of human activity on air, water, and habitats in both third and sixth grades (3.8, 6.8, 6.9). In Biology, students investigate competition among species and the natural events and human activities that impact ecosystems and their flora and fauna, specifically in Virginia (BIO.8).

Enduring Understandings	Essential Knowledge and Practices
An ecosystem can be viewed as many components that interact together to form a complex whole. A change in one part of the system affects other parts of the system. • Changes in the interactions among the living and nonliving components of an ecosystem cause change in the system (LS.9 a). • Factors (natural and human-caused) can positively and negatively affect the cycles of matter and the life processes of living things within an ecosystem (LS.8 a, b). • Humans are a natural part of the ecosystem. Humans use the ecosystem to meet their basic needs, such as to obtain food (LS.8 a). • Human input can disturb the balance of populations in a habitat. These disturbances may lead to a decrease or increase in a population’s size. Since populations in an ecosystem are interdependent, these disturbances can have a ripple effect throughout the larger ecosystem (LS.8 a, b). • The interaction of humans with the dynamic ecosystem may lead to changes in climate, water supply, air quality, energy production, ocean acidification, and waste management (LS.8 c).	In order to meet this standard, it is expected that students will • describe ways that human interaction has altered habitats positively and negatively (LS.9 a) • describe the relationship between human food harvest and habitat stability (LS.9 a) • debate the pros and cons of human land use vs. ecosystem stability (LS.9 a) • compare population disturbances that affect competition among species and species survival (LS.9 b) • use evidence to describe the impact of human activity on the biotic and abiotic factors within an ecosystem (LS.9 c) • interpret data obtained through observations and electronic and print resources to determine the effects of human interaction on local ecosystems (LS.9 a, b, c) • plan an investigation examining relationships between ecosystem dynamics and human activity (it may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis) (LS.9 a, b, c) • analyze and critique the experimental design of basic investigations related to the relationships between ecosystem dynamics and human activity (LS.9 a, b, c).

LS.10 The student will investigate and understand that organisms reproduce and transmit genetic information to new generations. Key ideas include

a) DNA has a role in making proteins that determine organism traits;
b) the role of meiosis is to transfer traits to the next generation; and
c) Punnett squares are mathematical models used to predict the probability of traits in offspring.

Central Idea: DNA is key in the production and transfer of traits from one generation to another.

Vertical Alignment: Students learn that plants and animals have different structures and processes for creating offspring in fourth grade (4.7). In Biology, inheritance, DNA as the structure and foundation for protein synthesis, the stages of meiosis, and synthetic biology are investigated (BIO.5).

Enduring Understandings	**Essential Knowledge and Practices**
The structure and function of DNA are intimately linked. DNA is a double helix molecule containing a specific sequence of nitrogenous bases which create a code for making proteins. Proteins are used to build cells, tissues, organs, and to perform life processes. • Chromosomes are strands of tightly wound DNA. Genes are sections of a chromosome that carry the code for a particular protein (LS.10 a). • Each gene controls the production of specific proteins, which in turn affects the traits of the organism. Proteins carry out most of the work of cells to perform life functions (LS.10 a). • DNA provides the code that tells the cell exactly which proteins to make. The sequence of the bases A, T, C, and G along a section of DNA forms a code to make each protein (LS.10 a). • The sugar and phosphate molecules on the sides of the DNA molecule are always the same for all living things, so when scientists write out the DNA code, they write only the sequence of the pairs of nitrogenous bases in the center (i.e., on the rungs) of the ladder-like DNA molecule (LS.10 a). • A series of contributions and discoveries has led to our current understanding of DNA, genes, chromosomes, and traits. This process illustrates the nature of science (LS.10 a).	In order to meet this standard, it is expected that students will • use a variety of models to investigate the structure of DNA (LS.10 a) • describe the structure and function of DNA (LS.10 a) • discuss how the contributions and discoveries leading to our current understanding of DNA, genes, chromosomes, and traits illustrate the nature of science (LS.10 a) • explain the relationship among genes, chromosomes, and alleles (LS.10 a) • explain that DNA contains coded instructions that store and pass on genetic information from one generation to the next (LS.10 a) 🍃 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 (LS.10 b) • compare genetic variation of offspring produced from sexual and asexual reproduction (LS.10 b) • explain the significance of gametes contributing half of their genetic material through sexual reproduction (LS.10 b) • differentiate between characteristics that can be inherited and those that cannot be inherited (LS.10 c)

Students are not responsible for identifying the contributions of specific scientists. A complex system functions to pass characteristics (traits) from one generation to the next. The interaction of heredity mechanisms and the environment creates both stability from one generation to the next and drives the changes that produce the diversity of life on our planet. • Living organisms must reproduce to continue the existence of their species. Through reproduction, new individuals that resemble their parents are formed. All the organisms alive today arose from preexisting organisms (LS.10 b). • Reproduction is a life process (system) by which living things transfer genetic information to their offspring (LS.10 b). • Sexual reproduction involves the production of sex cells through meiosis. Sex cells each carry half the parent's genetic material, resulting in variation between parent and offspring (LS.10 b). • During meiosis, chromosome pairs independently become distributed so that each sex cell contains one-half of the chromosomes of the original cell. The probability of a sex cell containing either allele from the pair is 50 percent (LS.10 b). *Students are not responsible for describing the stages of meiosis.* The Punnett square is one mathematical model that predicts the probability of the genotype (genetic makeup) and phenotype of the offspring of a cross between parents. • A Punnett square predicts the probability of the ratios of genotypes and phenotypes among offspring (LS.10 c). *Students are not responsible for identifying multi-trait*	• distinguish between dominant and recessive traits (LS.10 c) • use Punnett squares to predict the possible genetic combinations and phenotype expressions from single trait crosses using dominant and recessive traits (LS.10 c).

Enduring Understandings	Essential Knowledge and Practices
crosses, multiple alleles, incomplete dominance, and sex-linked crosses. • Traits that are expressed through genes can be inherited. Characteristics that are acquired through environmental influences, such as injuries or practiced skills, cannot be inherited (LS.10 c). • The basic laws of Mendelian genetics explain the transmission of most traits that can be inherited (LS.10 c). • Genotype refers to the specific combination of genes. Phenotype refers to the physical expression of traits. Dominant traits mask the expression (phenotype) of recessive traits (LS.10 c).	

LS.11 The student will investigate and understand that populations of organisms can change over time. Key ideas include
- **a) mutation, adaptation, natural selection, and extinction change populations;**
- **b) the fossil record, genetic information, and anatomical comparisons provide evidence for evolution; and**
- **c) environmental factors and genetic variation, influence survivability and diversity of organisms.**

Central Idea: Species respond to changes in their environment through adaptation, which is a gradual process that occurs over a long period of time. The progression of these long-term changes is well documented in the fossil record.

Vertical Alignment: Students investigate and understand how adaptations enable organisms to satisfy life needs and respond to the environment, which includes behavioral and physical adaptations and the use of fossils as evidence about life in the past, in third grade (3.4). Students investigate fossil records, genetic variation, natural selection, and evolution in Biology (BIO.7).

Enduring Understandings	Essential Knowledge and Practices
The genetic variation in a population will remain stable from one generation to the next in the absence of disturbing factors (changes) such as mutations and natural selection.	In order to meet this standard, it is expected that students will • interpret data from simulations that demonstrate natural selection (LS.11 a)

Enduring Understandings	**Essential Knowledge and Practices**
• As habitats change, some organisms survive and reproduce, some move out of or into the transformed habitat, and some die (LS.11 a). • A change in the sequence of DNA (and thus the protein produced) can have a positive, negative, or no effect on an organism (LS.11 a). *Students are not responsible for identifying types of genetic mutations.* • Mutations can be caused by random errors during DNA replication, exposure to radiation, or chemicals (LS.11 a). • Whereas mutations in the body cells of an organism won't be passed on to its offspring, mutations in the sex cells of an organism will be passed on to its offspring (LS.11 a). • The interaction of heredity mechanisms and the environment creates both stability from one generation to the next and drives change that produces the diversity of life on our planet (LS.11 b). • *Natural selection* describes the survival and reproduction of individuals within a population exhibiting variations for traits that best enable them to survive in their environment (LS.11 a). • The frequency of certain traits in a species can shift over time in response to natural and artificial selection. This process acts over generations, producing traits that support successful survival and reproduction in the new environment (LS.11 a). • Adaptation is any alteration to the structure, function, or behavior of an organism resulting from natural selection.	• explain the relationship among mutations, variations in traits in a population, and natural selection (LS.11 a) • compare natural selection and extinction (LS.11 a) • explain how mutations differ from adaptations (LS.11 a) • construct an evidence-based explanation about how genetic variations in traits in a population increase some individuals' probability of surviving and reproducing in a specific environment (LS.11 a) • describe the role of fossils in determining events in Earth's history (LS.11 b) • explain the evidence for evolution from a variety of sources of scientific data (LS.11 b) • apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships (LS.11 b) • explain how genetic variations in offspring, which leads to variations in successive generations, can result from the same two parents (LS.11 c) • construct an evidence-based explanation about how environmental factors and genetic variation can influence a species' survival, reproduction, and diversity (LS.11 c) • explain what is meant by the phrase, "survival of the fittest" (LS.11 a, c).

Enduring Understandings	Essential Knowledge and Practices
Adaptation makes the organism better suited to survive and reproduce in its environment (LS.11 a). • If a species does not possess traits that enable survival in its environment or adaptation to changes in the environment, then the species may become extinct (LS.11 a). The fossil record documents the existence, diversity, extinction, and change of many life forms and their environments through Earth's history. The fossil record and comparisons of anatomical similarities among organisms enables the inference of lines of evolutionary descent. • The theory of evolution is a shared understanding that encapsulates our current understanding of how biological systems change over time (LS.11 b). • Mechanisms which drive evolution include mutation, adaptation, natural selection, and extinction (LS.11 b). • Evidence for evolution is drawn from a variety of data sources, including the fossil record, genetic information, and anatomical similarities across species (LS.11 b). Organisms can be described by their physical features, such as color, shape, body covering, and height. Although individuals within a population have the same basic physical characteristics, close examination will reveal slight variations for a given trait. • Genetic variations occur randomly among individuals of any population and may or may not help the individual organism survive and reproduce in its environment (LS.11 c).	

Enduring Understandings	Essential Knowledge and Practices
• The expression of many traits involves both inheritance and the environment (LS.11 c). • Individuals of a population each exhibit a range of variations in a trait as a result of the variations in their genetic codes. Genetic variations create diversity within a species (LS.11 c). • Changes in environmental factors such as habitat loss, increased pollution, climate change, and invasive species can challenge the survival of members of a population. Organisms that survive pass their traits on to offspring (LS.11 c).	