Science Standards of Learning

Curriculum Framework 2010

Biology

Board of Education
Commonwealth of Virginia

Virginia Department of Education
P.O. Box 2120
Richmond, Virginia 23218-2120
http://www.doe.virginia.gov

Superintendent of Public Instruction
Patricia I. Wright, Ed.D.

Assistant Superintendent for Instruction
Linda M. Wallinger, Ph.D.

Office of Standards, Curriculum, and Instruction
Mark R. Allan, Ph.D., Director
Barbara P. Young, Science Specialist
Paula J. Klonowski, Science Coordinator

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The 2010 *Science Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at http://www.doe.virginia.gov.

Virginia *Science Standards of Learning* Curriculum Framework 2010
Introduction

The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum 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 essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

School divisions should use the *Science Curriculum 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 Standards of Learning should be included as part of quality learning experiences.

The Curriculum Framework serves as a guide for Standards of Learning assessment development. Assessment items may not and should not be a verbatim reflection of the information presented in the Curriculum Framework. Students are expected to continue to apply knowledge and skills from Standards of Learning 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 Standards of Learning 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 Standards of Learning tests, for which students may earn verified units of credit, are administered in a locally determined sequence.

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

Understanding the Standard (K-5)
This section includes background information for the teacher. It contains content that may extend the teachers' knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

Essential Understandings (middle and high school)
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

Essential Knowledge, Skills and Processes (K-12)
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.

Standard BIO.1

BIO.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) observations of living organisms are recorded in the lab and in the field;
b) hypotheses are formulated based on direct observations and information from scientific literature;
c) variables are defined and investigations are designed to test hypotheses;
d) graphing and arithmetic calculations are used as tools in data analysis;
e) conclusions are formed based on recorded quantitative and qualitative data;
f) sources of error inherent in experimental design are identified and discussed;
g) validity of data is determined;
h) chemicals and equipment are used in a safe manner;
i) appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data, communicating results, modeling concepts, and simulating experimental conditions;
j) research utilizes scientific literature;
k) differentiation is made between a scientific hypothesis, theory, and law;
l) alternative scientific explanations and models are recognized and analyzed; and
m) current applications of biological concepts are used.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts a) the natural world is understandable; b) science is based on evidence - both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. • Active participation in scientific investigations is necessary to develop an understanding of biology as an experimental science. • The continual use and development of cognitive and manipulative skills associated with the formulation of scientific explanations is important.	In order to meet this standard, it is expected that students will • conduct investigations in the classroom and field, as appropriate, and critically examine investigations reported in scientific literature and databases. • collect preliminary observations, both qualitative and quantitative. • make clear distinctions among observations, inferences, and predictions. • formulate hypotheses based on cause-and-effect relationships. • justify hypotheses based on both preliminary observations and scientific literature. • identify the independent variable (IV) and the values of the IV that will be used in the experiment. • select dependent variables that allow collection of quantitative data. • identify variables that must be held constant. • establish controls as appropriate.

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Essential Understandings	Essential Knowledge and Skills
• The design of sound scientific experiments relies on systematic preliminary observations and data collected in the laboratory and in the field, as well as on a knowledge base gained from an examination of related scientific literature. Prior establishment of an adequate knowledge base is essential before hypotheses can be developed and tested. • Because of the rigor that scientific inquiry requires, science is a process that involves evaluating the results and conclusions proposed by other scientists. • Scientific tools including microscopes, computers, graphing calculators, and probeware allow for the gathering and analysis of data. • The analysis of evidence and data is essential in order to make sense of the content of science. • Multiple data manipulation and analysis strategies are available to help explain results of quantitative investigations. • Data and evidence should come from a variety of sources, including student investigation, peer investigation, and databases.	• write clear, replicable procedures. • identify and use appropriate technology for data collection and analysis, including probeware (i.e., sensors for temperature, pH and dissolved oxygen). • record quantitative data in clearly labeled tables with units. • include labeled diagrams in the data record. • determine the range, mean, and values for data, using a graphing calculator and/or computer spreadsheet software. • plot data graphically, showing independent and dependent variables. • describe trends from the data where appropriate, using a graphing calculator and/or computer spreadsheet. • recognize and discuss contradictory or unusual data. • determine the extent to which data support/do not support a hypothesis, and propose further hypotheses and directions for continued research.

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Essential Understandings	Essential Knowledge and Skills
• The scientific establishment sometimes rejects new ideas, and new discoveries often spring from unexpected findings. • Scientific knowledge usually grows slowly through contributions from many different investigators from diverse cultures. • Science depends on experimental and observational confirmation and is subject to change as new evidence becomes available. • A hypothesis can be supported, modified, or rejected based on collected data. A hypothesis is a tentative explanation that accounts for a set of facts and that can be tested by further investigation. A theory is an accepted explanation of a large body of information, experimental and inferential, and serves as an overarching framework for numerous concepts. It is subject to change as new evidence becomes available. A law is a statement of fact meant to describe, in concise terms, an action. It is generally accepted to be true and universal.	• discuss the validity of results as related to accuracy, confidence, and sources of experimental error based on number of trials and variance in the data. • use evidence, apply logic, and construct an argument for conclusions based on reported data. • recognize that in order to ensure the validity of scientific investigations, they must be evaluated by other members of the scientific community. • compare and contrast hypotheses, theories and laws. • identify and describe scientific theories that have been changed or modified over time.

Standard BIO.2

BIO.2 The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include
a) water chemistry and its impact on life processes;
b) the structure and function of macromolecules;
c) the nature of enzymes; and
d) the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Water is essential for life on Earth. Water absorbs heat when it evaporates, allowing organisms to release excess heat. The solid form of water, ice, floats, preventing lakes and oceans from freezing solid. Water molecules are both cohesive and adhesive due to the nature of hydrogen bonding. • About two-thirds of the mass of a cell is made up of water, and most of the biochemical processes of life occur in water solutions. Water is able to dissolve many substances (due to polarity); therefore, the water inside and outside of cells is able to carry nutrients into and around cells and wastes away from cells. • The pH scale ranges from 0 to 14. The pH of pure water is 7. Substances added to water can lower or raise the pH. A solution with a pH below 7 is acidic. A solution with a pH above 7 is basic. • Organisms can tolerate only small changes in pH because every cell has a particular pH at which it functions best. For example, changes in pH cause changes in enzyme conformation, resulting in a change in activity. Most cells function best within a narrow range of temperature and pH. At very low temperatures, reaction rates are too slow. High temperatures or extremes of pH can irreversibly change the structure of proteins and alter their function. • In multicellular organisms, the fluid within the cell and the fluids surrounding the cells have a characteristic and nearly constant pH. This pH is maintained in a number of ways, and one of the most important is through buffer systems. • Inside every cell is a concentrated mixture of thousands of different macromolecules forming a variety of specialized structures that carry out cell functions, such as energy production, transport, waste disposal,	In order to meet this standard, it is expected that students will • explain the importance of the chemical and physical properties of water that make it vital to life. • recognize that the main components of a living cell are carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. Carbon atoms can easily bond to several other carbon atoms in chains and rings to form large complex molecules. • explain the role and function of the four major categories of macromolecules (lipids, carbohydrates, proteins and nucleic acids). • identify the functions of different types of proteins and recognize the significance that their conformation play in their functions. • describe the structure of enzymes and explain their role in acting as catalysts to control the rate of metabolic reactions. • explain how light is the initial source of energy for most communities. • recognize the equations for photosynthesis and respiration and identify the reactants and products. • describe the role of ATP in the storage and release of chemical energy in the cell. • explain the interrelatedness of photosynthesis and cell respiration.

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Essential Understandings	Essential Knowledge and Skills
synthesis of new molecules, and storage of genetic material. • Cells can make a variety of macromolecules from a relatively small set of monomers. • The primary functions of carbohydrate macromolecules are to provide and store energy. • The primary functions of lipid macromolecules are to insulate, store energy, and make up cell membranes. • Nucleic acids (DNA and RNA) control cell activities by directing protein synthesis. • Proteins are polymers made by linking together amino acid monomers. Protein molecules that are assembled in cells carry out most of the cells' work. The function of each protein molecule depends on its specific conformation. The sequence of amino acids and the shape of the chain are a consequence of attractions between the chain's parts. Some proteins are structural (hair, nails). Others function in transport (hemoglobin), movement (muscle fibers and cytoskeletal elements), defense (antibodies), and regulation of cell functions (hormones and enzymes). • Most life processes are a series of chemical reactions influenced by environmental and genetic factors. The chemical reactions that occur inside cells are directly controlled by a large set of protein molecules called enzymes, whose functions depend on their specific shapes. Each enzyme has a definite three-dimensional shape that allows it to recognize and bind with its substrate. In living cells, enzymes control the rate of metabolic reaction by acting as catalysts. • The breakdown of nutrient molecules enables all cells to store energy in specific chemicals that are used to carry out the life functions of the cell.	

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Essential Understandings	Essential Knowledge and Skills
• Plant cells and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy-rich organic compounds and release oxygen into the environment. • The process of photosynthesis provides a vital connection between the sun and the energy needs of living systems. During photosynthesis, cells trap energy from sunlight with chlorophyll, found in chloroplasts, and use the energy, carbon dioxide, and water to produce energy-rich organic molecules (glucose) and oxygen. Photosynthesis involves an energy conversion in which light energy is converted to chemical energy in specialized cells. These cells are found in autotrophs such as plants and some protists. • During cell respiration, eukaryotic cells "burn" organic molecules with oxygen in the mitochondria, which releases energy in the form of ATP, carbon dioxide, and water. • Photosynthesis and cell respiration are complementary processes for cycling carbon dioxide and oxygen as well as transferring energy in ecosystems. • Cells release the chemical energy stored in the products of photosynthesis. This energy is transported within the cell in the form of ATP. When cells need energy to do work, certain enzymes release the energy stored in the chemical bonds in ATP.	

Standard BIO.3

BIO.3 The student will investigate and understand relationships between cell structure and function. Key concepts include
a) evidence supporting the cell theory;
b) characteristics of prokaryotic and eukaryotic cells;
c) similarities between the activities of the organelles in a single cell and a whole organism;
d) the cell membrane model; and
e) the impact of surface area to volume ratio on cell division, material transport, and other life processes.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The cell theory is the unifying theme in biology because it emphasizes the similarity of all living things. The traditional cell theory states that 1) living things are composed of one or more cells and that cells come from other cells by the process of cell reproduction; 2) cells are the basic units of structure and function of all living things; and 3) cells contain specialized structures to perform functions necessary for life. • The development of the cell theory was accelerated by the ability to make observations on a microscopic level. The development and refinement of magnifying lenses and light microscopes made the observation and description of microscopic organisms and living cells possible. • Continued advances in microscopy allowed observation of cell organelles and ultrastructure. Current technology allows the observation of cellular processes underlying both cell structure and function. • As a result of additional study and the integration of studies of cell life functions, a modern cell theory has been developed. The modern cell theory, in addition to the tenants of the traditional cell theory, states 1) energy flow (metabolism and biochemistry) occurs within cells; 2) cells contain hereditary information (DNA) that is passed from cell to cell during cell division; and 3) all cells are basically the same in chemical composition in organisms of similar species . • Cell structure is one of the ways in which organisms differ from each other. The diversity that exists ranges from simple prokaryotic cells to complex multicellular organisms. • The simplest life forms exhibiting cellular structure are the prokaryotes.	In order to meet this standard, it is expected that students will • describe the key events leading to the development of the cell theory. • compare and contrast characteristics of prokaryotic and eukaryotic cells. • compare and contrast the activities of an organelle in a single cell and a whole organism. • identify the following essential cell structures and their functions - the nucleus (contains DNA; site where RNA is made) - ribosome (site of protein synthesis) - mitochondrion (site of cell respiration) - chloroplast (site of photosynthesis) - endoplasmic reticulum (transports materials through the cell) - Golgi (site where cell products are packaged for export) - lysosome (contains digestive enzymes) - cell membrane (controls what enters and leaves the cell) - cell wall (provides support) - vacuole (storage of material) - cytoplasm (contains organelles and site of many chemical reactions) - centriole (organizes spindle fibers in animal cells) - cytoskeleton • describe how the selective permeability of the cell membrane affects the life of a cell. • describe processes associated with movement across the membrane for diffusion, facilitated diffusion, osmosis, and active transport.

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Essential Understandings	Essential Knowledge and Skills
Earth's first cells were prokaryotes. Prokaryotic cells exist in two major forms: eubacteria and archaebacteria. Prokaryotes are Earth's most abundant inhabitants. They can survive in a wide range of environments and obtain energy in a variety of ways. • Eukaryotes differ from prokaryotes based on size, genetic material surrounded by a nuclear membrane, and the addition of membrane bound organelles (i.e., mitochondria and chloroplasts). • Eukaryotes arose from prokaryotes and developed into larger, more complex organisms, from single-celled protists to multicellular protists, fungi, plants, and animals. • Some organisms exist as a single cell, while others are composed of many cells, each specialized to perform distinct metabolic functions. The basic processes necessary for living things to survive are the same for a single cell as they are for a more complex organism. A single-celled organism has to conduct all life processes by itself. A multicellular organism has groups of cells that specialize to perform specific functions. • Cellular activities necessary for life include chemical reactions that facilitate acquiring energy, reproduction, and maintaining homeostasis. Relationships between structure and function can be examined at each of the hierarchical levels of organization: molecular, cellular, organism, population, community, and ecosystem. • Cellular differences between plant and animal cells include the presence of a cell wall that gives the plant cell a defined shape, the presence of chloroplast, and the number of vacuoles. • The fluid mosaic model of a membrane emphasizes the arrangement and function of a bilayer of phospholipids, transport proteins, and	• describe the relationship between a cell's external solute concentration and its effect on the cell's internal solute concentration. • compare the efficiency of the ability of a cell to transport material based on surface area to volume ratios.

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Essential Understandings	Essential Knowledge and Skills
cholesterol. • Homeostasis of a cell is maintained by the plasma membrane comprised of a variety of organic molecules. The membrane controls the movement of material in and out of the cell, communication between cells, and the recognition of cells to facilitate multiple metabolic functions. • Diffusion occurs in cells when substances (oxygen, carbon dioxide, salts, sugars, amino acids) that are dissolved in water move from an area of higher concentration to an area of lower concentration. • Facilitated diffusion occurs in cells when larger substances are moved from an area of higher concentration to an area of lower concentration with the assistance of a carrier protein without the use of energy. • Osmosis refers to the movement of water molecules through a semi-permeable membrane from an area of greater water concentration or pressure (lower solute concentration) to an area of lesser water concentration or pressure (higher solute concentration). • Active transport refers to the movement of solid or liquid particles into and out of a cell with an input of energy. • As cells increase in size, surface area to volume ratios decrease, making cells unable to obtain nutrients or remove wastes. To reduce the effects of this, cells divide to stay small or change shape to increase surface area or reduce volume.	

Standard BIO.4

BIO.4 The student will investigate and understand life functions of Archaea, Bacteria and Eukarya. Key concepts include

a) comparison of their metabolic activities;
b) maintenance of homeostasis;
c) how the structures and functions vary among and within the Eukarya kingdoms of protists, fungi, plants, and animals, including humans;
d) human health issues, human anatomy, and body systems;
e) how viruses compare with organisms; and
f) evidence supporting the germ theory of infectious disease.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • The organisms that live on Earth today share many structural and metabolic features, including cellular organization, common molecular mechanisms for energy transformation, utilization and maintenance of homeostasis, common genetic code, and mechanisms for the transmission of traits from one generation to the next. • The diversity that is evident in the natural world can be studied in the local environment in the context of variations on a common theme. • Understanding normal body functioning assists in understanding situations when functioning is impaired. • Like other organisms, human beings are composed of groups of cells (tissues, organs, and organ systems) that are specialized to provide the human organism with the basic requirements for life: obtaining food and deriving energy from it, maintaining homeostasis, coordinating body functions, and reproducing. • Organ systems function and interact to maintain a stable internal environment that can resist disturbance from within or without (homeostasis). • For the body to use food for energy, the food must first be digested into molecules that are absorbed and transported to cells, where the food is used for energy and for repair and growth. To burn food for the release of energy, oxygen must be supplied to cells and carbon dioxide removed. The respiratory system responds to changing demands by increasing or decreasing breathing rate in order to maintain homeostasis.	In order to meet this standard, it is expected that students will • compare and contrast the metabolic activities of all domains of life. • identify the proper response an organism would exhibit in response to changes in the environment to maintain homeostasis. • categorize and compare the Eukarya kingdoms based on cell structure, locomotion, reproduction, response to the environment and metabolism. • identify the main factors that affect human health. • describe the major functions of the human body systems and the role of each in maintaining homeostasis. • compare and contrast a virus and a cell in relation to genetic material and reproduction. • describe how Pasteur's and Koch's experimentation and hypotheses led to an understanding of the presence of microorganisms and their relationship to diseases.

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Essential Understandings	Essential Knowledge and Skills
• The circulatory system, which moves all of these substances to or from cells, responds to changing demands by increasing or decreasing heart rate and blood flow in order to maintain homeostasis. • The urinary system disposes of dissolved waste molecules; the intestinal tract removes solid wastes; and the skin and lungs rid the body of thermal energy. • Specialized cells of the immune system and the molecules they produce are designed to protect against organisms and substances that enter from outside the body and against some cancer cells that arise from within. • Communication between cells is required for coordination of body functions. The nerves communicate with electrochemical signals, hormones circulate through the blood, and some cells secrete substances that spread only to nearby cells. • Environmental factors that impact human health include diet, exercise, sleep, stress, toxic substances that enter the body, viruses, and other living organisms that infect the body. • Genetic predisposition towards diseases impacts human health. Awareness of genetic predisposition allows individuals to make lifestyle changes that can enhance quality of life. • Viruses do not share many of the characteristics of living organisms. Viruses are not cells. Basic viral structure consists of a nucleic acid core surrounded by a protein coat. Viruses can reproduce only inside a living cell, the host cell. • The viral reproductive process includes the following steps: - A virus must insert its genetic material into the host cell.	

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Essential Understandings	Essential Knowledge and Skills
- The viral genetic material takes control of the host cell and uses it to produce viruses. - The newly formed viruses are released from the host cell. • Throughout history, people have created explanations for disease. The introduction of the germ theory led to the understanding that many diseases are caused by microorganisms. Changes in health practices have resulted from the acceptance of the germ theory of disease. • Modern health practices emphasize sanitation, the safe handling of food and water, aseptic techniques to keep germs out of the body, and the development of vaccinations and other chemicals and processes to destroy microorganisms.	

Standard BIO.5

BIO.5 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

a) cell growth and division;
b) gamete formation;
c) cell specialization;
d) prediction of inheritance of traits based on the Mendelian laws of heredity;
e) historical development of the structural model of DNA;
f) genetic variation;
g) the structure, function, and replication of nucleic acids;
h) events involved in the construction of proteins;
i) use, limitations, and misuse of genetic information; and
j) exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • All living cells come from other living cells. A typical cell goes through a process of growth, development, and reproduction called the cell cycle. • Mitosis produces two genetically identical cells. During mitosis, the nucleus of the cell divides, forming two nuclei with identical genetic information. Mitosis is referred to in the following stages: prophase, metaphase, anaphase, and telophase. • Many organisms are capable of combining genetic information from two parents to produce offspring. Sex cells are produced through meiosis. This allows sexually reproducing organisms to produce genetically differing offspring, and maintain their number of chromosomes. Meiosis occurs in sexual reproduction when a diploid germ cell produces four haploid daughter cells that can mature to become gametes (sperm or egg). • Genetically diverse populations are more likely to survive changing environments. Recombination and mutation provide for genetic diversity. Some new gene combinations have little effect, some can produce organisms that are better suited to their environments, and others can be deleterious. • Mitosis and meiosis refer to division of the nuclear material. Cytokinesis is the division of the cytoplasm and organelles.	In order to meet this standard, it is expected that students will • create a diagram to model the stages of mitosis and explain the processes occurring at each stage. • describe the importance of cell specialization in the development of multicellular organisms. • create a diagram to model the stages of meiosis and explain the processes occurring at each stage. • compare and contrast the process of mitosis and meiosis and determine under which conditions each process will occur. • explain how the Mendelian laws of heredity apply to the patterns of inheritance. • identify the traits expressed from a given genotype. • use a Punnett square to show all possible combinations of gametes and the likelihood that particular combinations will occur in monohybrid and dihybrid crosses. • evaluate karyotype charts and make a determination of the gender and genetic health of the individual. • provide examples of reasons for genetic diversity and why it can be an advantage for populations.

Standard BIO.5

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b) gamete formation;
c) cell specialization;
d) prediction of inheritance of traits based on the Mendelian laws of heredity;
e) historical development of the structural model of DNA;
f) genetic variation;
g) the structure, function, and replication of nucleic acids;
h) events involved in the construction of proteins;
i) use, limitations, and misuse of genetic information; and
j) exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
• The many body cells of an organism can be specialized to perform different functions, even though they are all descended from a single cell and contain essentially the same genetic information. • Mendel's laws of heredity are based on his mathematical analysis of observations of patterns of inheritance of traits. Geneticists apply mathematical principles of probability to Mendel's laws of heredity in order to predict the results of simple genetic crosses. The laws of probability govern simple genetic recombinations. • Genotype describes the genetic make-up of an organism and phenotype describes the organism's appearance based on its genes. Homozygous individuals have two identical alleles for a particular trait, while heterozygous individuals have contrasting alleles. When one allele masks the effect of another, that allele is called dominant and the other recessive. When an intermediate phenotype occurs and no allele dominates, incomplete dominance results. Many other patterns of inheritance exist including multiple alleles, polygenic inheritance, and sex-linked inheritance. • Once DNA was shown to be the genetic material, a race among scientists took place to work out its structure. Studies of the amounts of each DNA base in different organisms led to the concept of complementary base-paring. Interpretations of X-ray photographs of DNA were used to describe the shape and dimensions of the molecule. An analysis of this and other available data led to a structural model for the DNA double helix.	• provide examples of mutations that are lethal, harmful, and beneficial. • describe the basic structure of DNA and its function in inheritance. • describe the key events leading to the development of the structural model of DNA. • given a DNA sequence, write a complementary mRNA strand (A-U, T-A, C-G and G-C). • explain the process of DNA replication. • explain the process of protein synthesis, including DNA transcription and translation. • evaluate examples of genetic engineering and the potential for controversy. • describe the uses, limitations, and potential for misuse of genetic information.

Standard BIO.5

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j) exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
• DNA is a polymer consisting of nucleotides. A DNA nucleotide is identified by the base it contains: adenine (A), guanine (G), cytosine (C) or thymine (T). DNA is a double-stranded molecule. The strands are composed of covalently bonded sugar and phosphate molecules and are connected by complementary nucleotide pairs (A-T and C-G) like rungs on a ladder. The ladder twists to form a double helix. • The double helix model explained how heredity information is transmitted and provided the basis for an explosion of scientific research in molecular genetics. The sorting and recombination of genes in sexual reproduction results in a great variety of gene combinations in the offspring of any two parents. • The genetic code is a sequence of DNA nucleotides in the nucleus of eukaryotic cells. Before a cell divides, the instructions are duplicated so that each of the two new cells gets all the necessary information for carrying on life functions. Cells pass on their genetic code by replicating their DNA. • DNA stores the information for directing the construction of proteins within a cell. These proteins determine the phenotype of an organism. The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. The code is virtually the same for all life forms. • During DNA replication, enzymes unwind and unzip the double helix and each strand serves as a template for building a new DNA molecule.	

Standard BIO.5

BIO.5	The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include a) cell growth and division; b) gamete formation; c) cell specialization; d) prediction of inheritance of traits based on the Mendelian laws of heredity; e) historical development of the structural model of DNA; f) genetic variation; g) the structure, function, and replication of nucleic acids; h) events involved in the construction of proteins; i) use, limitations, and misuse of genetic information; and j) exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
Free nucleotides bond to the template (A-T and C-G) forming a complementary strand. The final product of replication is two identical DNA molecules. • Inserting, deleting, or substituting DNA bases can alter genes. An altered gene may be passed on to every cell that develops from it, causing an altered phenotype. An altered phenotype may be neutral, beneficial or detrimental. Sometimes entire chromosomes can be added or deleted, resulting in a genetic disorder. These abnormalities may be diagnosed using a Karyotype. • In order for cells to make proteins, the DNA code must be transcribed (copied) to messenger RNA (mRNA). The mRNA carries the code from the nucleus to the ribosomes in the cytoplasm. RNA is a single-stranded polymer of four nucleotide monomers. A RNA nucleotide is identified by the base it contains: adenine (A), guanine (G), and cytosine (C) or uracil (U). • At the ribosome, amino acids are linked together to form specific proteins. The amino acid sequence is determined by the mRNA molecule. • DNA technologies allow scientists to identify, study, and modify genes. Forensic identification is an example of the application of DNA technology. • Genetic engineering techniques are used in a variety of industries, in agriculture, in basic research, and in medicine. There is great benefit in	

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Essential Understandings	Essential Knowledge and Skills
terms of useful products derived through genetic engineering (e.g., human growth hormone, insulin, and pest- and disease-resistant fruits and vegetables). • Eugenics, a pseudo-science of selective procreation, was a movement throughout the twentieth century, worldwide as well as in Virginia, that demonstrated a misuse of the principles of heredity. • The Human Genome Project is a collaborative effort to map the entire gene sequence of organisms. This information may be useful in detection, prevention, and treatment of many genetic diseases. The potential for identifying and altering genomes raises practical and ethical questions. • Cloning is the production of genetically identical cells and/or organisms.	

Standard BIO.6

BIO.6 The student will investigate and understand bases for modern classification systems. Key concepts include
a) structural similarities among organisms;
b) fossil record interpretation;
c) comparison of developmental stages in different organisms;
d) examination of biochemical similarities and differences among organisms; and
e) systems of classification that are adaptable to new scientific discoveries.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities that reflect their relationships over a period of time. • Binomial nomenclature is a standard way of identifying a species with a scientific two-word name. The first word is the genus name and the second the species name. Species is the basic unit of classification. A species is defined as a group of organisms that has the ability to interbreed and produce fertile offspring in nature. • A dichotomous key is a classification tool used to identify and organize organisms using defining characteristics. • Information about relationships among living organisms and those that inhabited Earth in the past is gained by comparing biochemistry and developmental stages of organisms and by examining and interpreting the fossil record. This information is continually being gathered and used to modify and clarify existing classification systems. • Evolutionary relationships can be represented using a branching diagram called a cladogram or phylogenetic tree which are organized by shared, derived characteristics. • Similarities among organisms on the structural and metabolic levels are reflected in the large degree of similarity in proteins and nucleic acids of different organisms. Diversity is the product of variations in these molecules.	In order to meet this standard, it is expected that students will • construct and utilize dichotomous keys to classify groups of objects and organisms. • describe relationships based on homologous structures. • compare structural characteristics of an extinct organism, as evidenced by its fossil record, with present, familiar organisms. • recognize similarities in embryonic stages in diverse organisms in the animal kingdom, from zygote through embryo and infer relationships. • compare biochemical evidence (DNA sequences, amino acid sequences) and describe relationships. • interpret a cladogram or phylogenic tree showing evolutionary relationships among organisms. • investigate flora and fauna in field investigations and apply classification systems.

Standard BIO.7

BIO.7	The student will investigate and understand how populations change through time. Key concepts include a) evidence found in fossil records; b) how genetic variation, reproductive strategies, and environmental pressures impact the survival of populations; c) how natural selection leads to adaptations; d) emergence of new species; and e) scientific evidence and explanations for biological evolution.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • A fossil is any evidence of an organism that lived long ago. Scientists have used the fossil record to construct a history of life on Earth. Although there is not a complete record of ancient life for the past 3.5 billion years, a great deal of modern knowledge about the history of life comes from the fossil record. • Populations are groups of interbreeding individuals that live in the same place at the same time and compete with each other for food, water, shelter, and mates. Populations produce more offspring than the environment can support. Organisms with certain genetic variations will be favored to survive and pass their variations on to the next generation. The unequal ability of individuals to survive and reproduce leads to the gradual change in a population, generation after generation over many generations. Depending on the selective pressure, these changes can be rapid over few generations (i.e., antibiotic resistance). • Genetic mutations and variety produced by sexual reproduction allow for diversity within a given population. Many factors can cause a change in a gene over time. Mutations are important in how populations change over time because they result in changes to the gene pool. • Through his observations, including those made in the Galapagos Islands, Charles Darwin formulated a theory of how species change over time, called natural selection. Natural selection is a process by which organisms with traits well suited to an environment survive and reproduce at a greater rate than organisms less suited to that environment, and is governed by the principles of genetics. The change in frequency of a gene in a given population leads to a change favoring maintenance of that gene within a population and if so, may result in the	In order to meet this standard, it is expected that students will • determine the relative age of a fossil given information about its position in the rock and absolute dating by radioactive decay. • differentiate between relative and absolute dating based on fossils in biological evolution. • recognize that adaptations may occur in populations of organisms over a period of time. • describe the impact of reproductive strategies and rates on a population's survival. • describe how genetic variation can lead to gradual changes in populations and the emergence of new species over time. • predict the impact of environmental pressures on populations. • explain how natural selection leads to changes in gene frequency in a population over time. • compare and contrast punctuated equilibrium with gradual change over time.

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Essential Understandings	Essential Knowledge and Skills
emergence of a new species. Natural selection operates on populations over many generations. • Depending on the rate of adaptation, the rate of reproduction, and the environmental factors present, structural adaptations may take millions of years to develop. • Adaptations sometimes arise abruptly in response to strong environmental selective pressures, for example, the development of antibiotic resistance in bacterial populations, morphological changes in the peppered moth population, and the development of pesticide resistance in insect populations. • Stephen Jay Gould's idea of punctuated equilibrium proposes that organisms may undergo rapid (in geologic time) bursts of speciation followed by long periods of time unchanged. This view is in contrast to the traditional evolutionary view of gradual and continuous change.	

Standard BIO.8

BIO.8 The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include
a) interactions within and among populations including carrying capacities, limiting factors, and growth curves;
b) nutrient cycling with energy flow through ecosystems;
c) succession patterns in ecosystems;
d) the effects of natural events and human activities on ecosystems; and
e) analysis of the flora, fauna, and microorganisms of Virginia ecosystems.

Essential Understandings	Essential Knowledge and Skills
The concepts developed in this standard include the following: • As any population of organisms grows, it is held in check by interactions among a variety of biotic and abiotic factors. • Abiotic factors are the nonliving elements in an ecosystem, such as temperature, moisture, air, salinity, and pH. Biotic factors are all the living organisms that inhabit the environment, including predators, food sources, and competitors. • Population growth curves exhibit many characteristics, such as initial growth stage, exponential growth, steady state, decline, and extinction. Limiting factors are the components of the environment that restrict the growth of populations. Carrying capacity is the number of organisms that can be supported by the resources in an ecosystem. • A community is a collection of interacting populations. • Symbiosis is a close and permanent relationship between organisms of two different species. Examples include mutualism, commensalism, and parasitism. • Ecosystems demonstrate an exchange of energy and nutrients among inhabiting organisms. • An ecosystem consists of all the interacting species and the abiotic environment in a given geographic area. All matter including essential nutrients cycle through an ecosystem. The most common examples of such matter and nutrients include carbon, nitrogen, and water. • Energy flows in an ecosystem from producers to various levels of consumers and decomposers. This flow of energy can be diagramed using a food chain or food web. The efficiency of this flow of energy is	In order to meet this standard, it is expected that students will • graph and interpret a population growth curve and identify the carrying capacity of the populations. • make predictions about changes that could occur in population numbers as the result of population interactions. • illustrate and/or model the key processes in the water, carbon, and nitrogen cycle and explain the role of living things in each of the cycles. • given an illustration of a food chain and a food web, identify each organism as a producer (autotroph), consumer (primary/second order), or decomposer and describe their role in the ecosystem. • interpret how the flow of energy occurs between trophic levels in all ecosystems in each of the following: - food chain - food web - pyramid of energy - pyramid of biomass - pyramid of numbers. • identify and describe an ecosystem in terms of the following: - effects of biotic and abiotic components - examples of interdependence - evidence of human influences - energy flow and nutrient cycling - diversity analysis • describe the patterns of succession found in aquatic and terrestrial

Standard BIO.8

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Essential Understandings	Essential Knowledge and Skills
represented by an energy pyramid. • Ecological succession is a predictable change in the sequence of species that establish in a particular area over time. • A climax community occurs when succession slows down and a stable community is established. The climax community in most of Virginia is a deciduous oak-hickory (hardwood) forest. • As the human population increases, so does human impact on the environment. Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the environment, and intensive farming, have changed Earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms.	ecosystems of Virginia. • identify the similarities and differences between primary and secondary succession. • describe the characteristics of a climax community. • use local ecosystems to apply ecological principles in the classroom and in the field where appropriate, using field guides and dichotomous keys for identifying and describing flora and fauna that characterize the local ecosystem. • evaluate examples of human activities that have negative and positive impacts on Virginia's ecosystems. • recognize that the Chesapeake Bay watershed includes the majority of Virginia and human activities play an important role in its health.