

# **Michigan Biology High School Content Expectations**

**Approved by the State Board of Education, October, 2006**

The life sciences are changing in ways that have important implications for high school biology. Many of these changes concern our understanding of the largest and the smallest living systems. Molecular biology continues to produce new insights into how living systems work and how they are connected with one another, as well as new technologies, such as recombinant DNA, that have profound implications for our health, our lifestyles, and our political and economic systems. Equally important are changes in ecology, a traditional biological discipline which plays a key role in the emerging interdisciplinary field of environmental science. Ecologists are working together with oceanographers, atmospheric scientists, and social scientists to study the coupled human and natural systems that support all life on earth, and to understand how those systems are changing in response to growing human populations and our technologies. Our students will need to understand these changing fields in order to be healthy and responsible citizens and productive workers.

An understanding of biology begins with appreciation of the diversity and the structures of living systems. The structure of living systems directly influences how they carry out their life functions. Reasoning about living systems often involves relating different levels of organization, from the molecule to the biosphere, and understanding how living systems are structured at each level. Life processes in a cell are based on molecular interactions which keep the internal environment relatively constant. Cells are composed of highly organized structures called organelles. Cells are the smallest unit of life that can assimilate energy, reproduce, and react to the environment. A collection of cells with a common function forms a tissue and several kinds of tissues form an organ. Together many organs form an organ system such as the digestive system. A multicellular organism is the composite of cells, tissues, and organs. All organisms are interconnected in populations, communities, and ecosystems.

All living systems function in ways that are consistent with basic physical laws, including conservation of matter and energy. Transformations of matter and energy are crucial to the functions of every living system, from the molecular to the global level. The food-making process of photosynthesis generates the energy source, in the form of organic compounds, for all living things. Organic compounds transfer matter and energy through ecosystems via food chains and webs. The energy found in organic chemical bonds is changed to usable cellular energy through the process of cellular respiration. Photosynthesis and cellular respiration are key processes through which living systems exchange matter and energy with the non-living environment, participating in biogeochemical cycles that are being altered in unprecedented ways by human populations and human technologies.

In addition to transforming matter and energy, living systems have a unique ability to maintain their complex organization over time. The information that enables them to do this is stored in the genomes of every living cell. Genetic information is passed from parent to offspring in the form of gametes. Fertilization unites the genetic information from both parents creating a unique individual. Organisms within a species are generally similar because they possess very similar genetic material. However, genetic mixing and occasional mutation result in differences among individuals. Over time, changes in genetic information can affect the size, diversity, and genetic composition of populations, a process called biological evolution.

It is widely accepted that Earth's present day life forms have evolved from common ancestors by processes that include natural selection. In the scientific community, evolution has been a unifying principle that provides a framework for organizing most of biological knowledge into a coherent picture. It has been accepted by the scientific community that evidence for evolution is found in the fossil record and is indicated by anatomical and chemical similarities evident within the diversity of existing organisms.

## STANDARD B1: INQUIRY, REFLECTION, AND SOCIAL IMPLICATIONS

*Students will understand the nature of science and demonstrate an ability to practice scientific reasoning by applying it to the design, execution, and evaluation of scientific investigations. Students will demonstrate their understanding that scientific knowledge is gathered through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. They will be able to distinguish between types of scientific knowledge (e.g., hypotheses, laws, theories) and become aware of areas of active research in contrast to conclusions that are part of established scientific consensus. They will use their scientific knowledge to assess the costs, risks, and benefits of technological systems as they make personal choices and participate in public policy decisions. These insights will help them analyze the role science plays in society, technology, and potential career opportunities.*

Essential	Core and Recommended
<p><b>B1.1 Scientific Inquiry</b></p> <p>Science is a way of understanding nature. Scientific research may begin by generating new scientific questions that can be answered through replicable scientific investigations that are logically developed and conducted systematically. Scientific conclusions and explanations result from careful analysis of empirical evidence and the use of logical reasoning. Some questions in science are addressed through indirect rather than direct observation, evaluating the consistency of new evidence with results predicted by models of natural processes. Results from investigations are communicated in reports that are scrutinized through a peer review process.</p> <p><b>B1.1A</b> Generate new questions that can be investigated in the laboratory or field.</p> <p><b>B1.1B</b> Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.</p> <p><b>B1.1C</b> Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).</p> <p><b>B1.1D</b> Identify patterns in data and relate them to theoretical models.</p> <p><b>B1.1E</b> Describe a reason for a given conclusion using evidence from an investigation.</p>	<p><b>B1.1f</b> Predict what would happen if the variables, methods, or timing of an investigation were changed.</p> <p><b>B1.1g</b> Based on empirical evidence, explain and critique the reasoning used to draw a scientific conclusion or explanation.</p> <p><b>B1.1h</b> Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.</p> <p><b>B1.1i</b> Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.</p>

## **B1.2 Scientific Reflection and Social Implications**

The integrity of the scientific process depends on scientists and citizens understanding and respecting the “Nature of Science.” Openness to new ideas, skepticism, and honesty are attributes required for good scientific practice. Scientists must use logical reasoning during investigation design, analysis, conclusion, and communication. Science can produce critical insights on societal problems from a personal and local scale to a global scale. Science both aids in the development of technology and provides tools for assessing the costs, risks, and benefits of technological systems. Scientific conclusions and arguments play a role in personal choice and public policy decisions. New technology and scientific discoveries have had a major influence in shaping human history. Science and technology continue to offer diverse and significant career opportunities.

**B1.2A** Critique whether or not specific questions can be answered through scientific investigations.

**B1.2B** Identify and critique arguments about personal or societal issues based on scientific evidence.

**B1.2C** Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.

**B1.2D** Evaluate scientific explanations in a peer review process or discussion format.

**B1.2E** Evaluate the future career and occupational prospects of science fields.

**B1.2f** Critique solutions to problems, given criteria and scientific constraints.

**B1.2g** Identify scientific tradeoffs in design decisions and choose among alternative solutions.

**B1.2h** Describe the distinctions between scientific theories, laws, hypotheses, and observations.

**B1.2i** Explain the progression of ideas and explanations that lead to science theories that are part of the current scientific consensus or core knowledge.

**B1.2j** Apply science principles or scientific data to anticipate effects of technological design decisions.

**B1.2k** Analyze how science and society interact from a historical, political, economic, or social perspective.

## STANDARD B2: ORGANIZATION AND DEVELOPMENT OF LIVING SYSTEMS

*Students describe the general structure and function of cells. They can explain that all living systems are composed of cells and that organisms may be unicellular or multicellular. They understand that cells are composed of biological macromolecules and that the complex processes of the cell allow it to maintain a stable internal environment necessary to maintain life. They make predictions based on these understandings.*

Essential	Core and Recommended
<p><b>B2.1 Transformation of Matter and Energy in Cells</b></p> <p>In multicellular organisms, cells are specialized to carry out specific functions such as transport, reproduction, or energy transformation.</p> <p><b>B2.1A</b> Explain how cells transform energy (ultimately obtained from the sun) from one form to another through the processes of photosynthesis and respiration. Identify the reactants and products in the general reaction of photosynthesis.</p> <p><b>B2.1B</b> Compare and contrast the transformation of matter and energy during photosynthesis and respiration.</p> <p><b>B2.1C</b> Explain cell division, growth, and development as a consequence of an increase in cell number, cell size, and/or cell products.</p>	<p><b>B2.1x Cell Differentiation</b></p> <p>Following fertilization, cell division produces a small cluster of cells that then differentiate by appearance and function to form the basic tissues of an embryo.</p> <p><b>B2.1d</b> Describe how, through cell division, cells can become specialized for specific function.</p> <p><b>B2.1e</b> Predict what would happen if the cells from one part of a developing embryo were transplanted to another part of the embryo.</p>
<p><b>B2.2 Organic Molecules</b></p> <p>There are four major categories of organic molecules that make up living systems: carbohydrates, fats, proteins, and nucleic acids.</p> <p><b>B2.2A</b> Explain how carbon can join to other carbon atoms in chains and rings to form large and complex molecules.</p> <p><b>B2.2B</b> Recognize the six most common elements in organic molecules (C, H, N, O, P, S).</p> <p><b>B2.2C</b> Describe the composition of the four major categories of organic molecules (carbohydrates, lipids, proteins, and nucleic acids).</p> <p><b>B2.2D</b> Explain the general structure and primary functions of the major complex organic molecules that compose living organisms.</p> <p><b>B2.2E</b> Describe how dehydration and hydrolysis relate to organic molecules.</p>	<p><b>B2.2x Proteins</b></p> <p>Protein molecules are long, usually folded chains composed mostly of amino acids and are made of C, H, O, and N. Protein molecules assemble fats and carbohydrates; they function as enzymes, structural components, and hormones. The function of each protein molecule depends on its specific sequence of amino acids and the shape of the molecule.</p> <p><b>B2.2f</b> Explain the role of enzymes and other proteins in biochemical functions (e.g., the protein hemoglobin carries oxygen in some organisms, digestive enzymes, and hormones).</p> <p><b>B2.2g</b> Propose how moving an organism to a new environment may influence its ability to survive and predict the possible impact of this type of transfer.</p>
<p><b>B2.3 Maintaining Environmental Stability</b></p> <p>The internal environment of living things must remain relatively constant. Many systems work together to maintain stability. Stability is challenged by changing physical, chemical, and environmental conditions as well as the presence of disease agents.</p> <p><b>B2.3A</b> Describe how cells function in a narrow range of physical conditions, such as temperature and pH (acidity), to perform life functions.</p> <p><b>B2.3B</b> Describe how the maintenance of a relatively stable</p>	<p><b>B2.3x Homeostasis</b></p> <p>The internal environment of living things must remain relatively constant. Many systems work together to maintain homeostasis. When homeostasis is lost, death occurs.</p> <p><b>B2.3d</b> Identify the general functions of the major systems of the human body (digestion, respiration, reproduction, circulation, excretion, protection from disease, and movement, control, and coordination) and describe ways that these systems interact with each other.</p>

<p>internal environment is required for the continuation of life.</p> <p><b>B2.3C</b> Explain how stability is challenged by changing physical, chemical, and environmental conditions as well as the presence of disease agents.</p>	<p><b>B2.3e</b> Describe how human body systems maintain relatively constant internal conditions (temperature, acidity, and blood sugar).</p> <p><b>B2.3f</b> Explain how human organ systems help maintain human health.</p> <p><b>B2.3g</b> Compare the structure and function of a human body system or subsystem to a nonliving system (e.g., human joints to hinges, enzyme and substrate to interlocking puzzle pieces).</p>
<p><b>B2.4 Cell Specialization</b></p> <p>In multicellular organisms, specialized cells perform specialized functions. Organs and organ systems are composed of cells and function to serve the needs of cells for food, air, and waste removal. The way in which cells function is similar in all living organisms.</p> <p><b>B2.4A</b> Explain that living things can be classified based on structural, embryological, and molecular (relatedness of DNA sequence) evidence.</p> <p><b>B2.4B</b> Describe how various organisms have developed different specializations to accomplish a particular function and yet the end result is the same (e.g., excreting nitrogenous wastes in animals, obtaining oxygen for respiration).</p> <p><b>B2.4C</b> Explain how different organisms accomplish the same result using different structural specializations (gills vs. lungs vs. membranes).</p>	<p><b>B2.4d</b> Analyze the relationships among organisms based on their shared physical, biochemical, genetic, and cellular characteristics and functional processes.</p> <p><b>B2.4e</b> Explain how cellular respiration is important for the production of ATP (build on aerobic vs. anaerobic).</p> <p><b>B2.4f</b> Recognize and describe that both living and nonliving things are composed of compounds, which are themselves made up of elements joined by energy-containing bonds, such as those in ATP.</p> <p><b>B2.4g</b> Explain that some structures in the modern eukaryotic cell developed from early prokaryotes, such as mitochondria, and in plants, chloroplasts.</p> <p><b>B2.4h</b> Describe the structures of viruses and bacteria.</p> <p><b>B2.4i</b> Recognize that while viruses lack cellular structure, they have the genetic material to invade living cells.</p>
<p><b>B2.5 Living Organism Composition</b></p> <p>All living or once-living organisms are composed of carbohydrates, lipids, proteins, and nucleic acids. Carbohydrates and lipids contain many carbon-hydrogen bonds that also store energy.</p> <p><b>B2.5A</b> Recognize and explain that macromolecules such as lipids contain high energy bonds.</p> <p><b>B2.5B</b> Explain how major systems and processes work together in animals and plants, including relationships between organelles, cells, tissues, organs, organ systems, and organisms. Relate these to molecular functions.</p> <p><b>B2.5C</b> Describe how energy is transferred and transformed from the Sun to energy-rich molecules during photosynthesis.</p> <p><b>B2.5D</b> Describe how individual cells break down energy-rich molecules to provide energy for cell functions.</p>	<p><b>B2.5x Energy Transfer</b></p> <p>All living or once living organisms are composed of carbohydrates, lipids, proteins, and nucleic acids. Carbohydrates and lipids contain many carbon-hydrogen bonds that also store energy. However, that energy must be transferred to ATP (adenosine triphosphate) to be usable by the cell.</p> <p><b>B2.5e</b> Explain the interrelated nature of photosynthesis and cellular respiration in terms of ATP synthesis and degradation.</p> <p><b>B2.5f</b> Relate plant structures and functions to the process of photosynthesis and respiration.</p> <p><b>B2.5g</b> Compare and contrast plant and animal cells.</p> <p><b>B2.5h</b> Explain the role of cell membranes as a highly selective barrier (diffusion, osmosis, and active transport).</p> <p><b>B2.5i</b> Relate cell parts/organelles to their function.</p>

**B2.6x Internal/External Cell Regulation**

Cellular processes are regulated both internally and externally by environments in which cells exist, including local environments that lead to cell differentiation during the development of multicellular organisms. During the development of complex multicellular organisms, cell differentiation is regulated through the expression of different genes.

**B2.6a** Explain that the regulatory and behavioral responses of an organism to external stimuli occur in order to maintain both short- and long-term equilibrium.

**B2.r6b** Explain that complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Note that cell behavior can also be affected by molecules from other parts of the organism, such as hormones. *(recommended)*

**B2.r6c** Recognize and explain that communication and/or interaction are required between cells to coordinate their diverse activities. *(recommended)*

**B2.r6d** Explain how higher levels of organization result from specific complex interactions of smaller units and that their maintenance requires a constant input of energy as well as new material. *(recommended)*

**B2.r6e** Analyze the body's response to medical interventions such as organ transplants, medicines, and inoculations. *(recommended)*

## STANDARD B3: INTERDEPENDENCE OF LIVING SYSTEMS AND THE ENVIRONMENT

*Students describe the processes of photosynthesis and cellular respiration and how energy is transferred through food webs. They recognize and analyze the consequences of the dependence of organisms on environmental resources and the interdependence of organisms in ecosystems.*

Essential	Core and Recommended
<p><b>B3.1 Photosynthesis and Respiration</b></p> <p>Organisms acquire their energy directly or indirectly from sunlight. Plants capture the Sun’s energy and use it to convert carbon dioxide and water to sugar and oxygen through the process of photosynthesis. Through the process of cellular respiration, animals are able to release the energy stored in the molecules produced by plants and use it for cellular processes, producing carbon dioxide and water.</p> <p><b>B3.1A</b> Describe how organisms acquire energy directly or indirectly from sunlight.</p> <p><b>B3.1B</b> Illustrate and describe the energy conversions that occur during photosynthesis and respiration.</p> <p><b>B3.1C</b> Recognize the equations for photosynthesis and respiration and identify the reactants and products for both.</p> <p><b>B3.1D</b> Explain how living organisms gain and use mass through the processes of photosynthesis and respiration.</p>	<p><b>B3.1e</b> Write the chemical equation for photosynthesis and cellular respiration and explain in words what they mean.</p> <p><b>B3.1f</b> Summarize the process of photosynthesis.</p>
<p><b>B3.2 Ecosystems</b></p> <p>The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in an ecosystem, some energy is stored in newly made structures, but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going.</p> <p><b>B3.2A</b> Identify how energy is stored in an ecosystem.</p> <p><b>B3.2B</b> Describe energy transfer through an ecosystem, accounting for energy lost to the environment as heat.</p> <p><b>B3.2C</b> Draw the flow of energy through an ecosystem. Predict changes in the food web when one or more organisms are removed.</p>	
<p><b>B3.3 Element Recombination</b></p> <p>As matter cycles and energy flows through different levels of organization of living systems—cells, organs, organisms, and communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.</p> <p><b>B3.3A</b> Use a food web to identify and distinguish producers, consumers, and decomposers and explain</p>	<p><b>B3.3b</b> Describe environmental processes (e.g., the carbon and nitrogen cycles) and their role in processing matter</p>

<p>the transfer of energy through trophic levels.</p>	<p>crucial for sustaining life.</p>
<p><b>B3.4 Changes in Ecosystems</b></p> <p>Although the interrelationships and interdependence of organisms may generate biological communities in ecosystems that are stable for hundreds or thousands of years, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution. The impact of the human species has major consequences for other species.</p> <p><b>B3.4A</b> Describe ecosystem stability. Understand that if a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages of succession that eventually result in a system similar to the original one.</p> <p><b>B3.4B</b> Recognize and describe that a great diversity of species increases the chance that at least some living organisms will survive in the face of cataclysmic changes in the environment.</p> <p><b>B3.4C</b> Examine the negative impact of human activities.</p>	<p><b>B3.4x Human Impact</b></p> <p>Humans can have tremendous impact on the environment. Sometimes their impact is beneficial, and sometimes it is detrimental.</p> <p><b>B3.4d</b> Describe the greenhouse effect and list possible causes.</p> <p><b>B3.4e</b> List the possible causes and consequences of global warming.</p>
<p><b>B3.5 Populations</b></p> <p>Populations of living things increase and decrease in size as they interact with other populations and with the environment. The rate of change is dependent upon relative birth and death rates.</p> <p><b>B3.5A</b> Graph changes in population growth, given a data table.</p> <p><b>B3.5B</b> Explain the influences that affect population growth.</p> <p><b>B3.5C</b> Predict the consequences of an invading organism on the survival of other organisms.</p>	<p><b>B3.5x Environmental Factors</b></p> <p>The shape of population growth curves vary with the type of organism and environmental conditions, such as availability of nutrients and space. As the population increases and resources become more scarce, the population usually stabilizes at the carrying capacity of that environment.</p> <p><b>B3.5d</b> Describe different reproductive strategies employed by various organisms and explain their advantages and disadvantages.</p> <p><b>B3.5e</b> Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of population dynamics within ecosystems.</p> <p><b>B3.5f</b> Graph an example of exponential growth. Then show the population leveling off at the carrying capacity of the environment.</p> <p><b>B3.r5g</b> Diagram and describe the stages of the life cycle for a human disease-causing organism. (<i>recommended</i>)</p>

## STANDARD B4: GENETICS

*Students recognize that the specific genetic instructions for any organism are contained within genes composed of DNA molecules located in chromosomes. They explain the mechanism for the direct production of specific proteins based on inherited DNA. Students diagram how occasional modifications in genes and the random distribution of genes from each parent provide genetic variation and become the raw material for evolution.*

Essential	Core and Recommended
<p><b>B4.1 Genetics and Inherited Traits</b></p> <p>Hereditary information is contained in genes, located in the chromosomes of each cell. Cells contain many thousands of different genes. One or many genes can determine an inherited trait of an individual, and a single gene can influence more than one trait. Before a cell divides, this genetic information must be copied and apportioned evenly into the daughter cells.</p> <p><b>B4.1A</b> Draw and label a homologous chromosome pair with heterozygous alleles highlighting a particular gene location.</p> <p><b>B4.1B</b> Explain that the information passed from parents to offspring is transmitted by means of genes that are coded in DNA molecules. These genes contain the information for the production of proteins.</p>	<p><b>B4.1c</b> Differentiate between dominant, recessive, codominant, polygenic, and sex-linked traits.</p> <p><b>B4.1d</b> Explain the genetic basis for Mendel’s laws of segregation and independent assortment.</p> <p><b>B4.1e</b> Determine the genotype and phenotype of monohybrid crosses using a Punnett Square.</p>
<p><b>B4.2 DNA</b></p> <p>The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring’s success in its environment.</p> <p><b>B4.2A</b> Show that when mutations occur in sex cells, they can be passed on to offspring (inherited mutations), but if they occur in other cells, they can be passed on to descendant cells only (noninherited mutations).</p> <p><b>B4.2B</b> Recognize that every species has its own characteristic DNA sequence.</p> <p><b>B4.2C</b> Describe the structure and function of DNA.</p> <p><b>B4.2D</b> Predict the consequences that changes in the DNA composition of particular genes may have on an organism (e.g., sickle cell anemia, other).</p> <p><b>B4.2E</b> Propose possible effects (on the genes) of exposing an organism to radiation and toxic chemicals.</p>	<p><b>B4.2x DNA, RNA, and Protein Synthesis</b></p> <p>Protein synthesis begins with the information in a sequence of DNA bases being copied onto messenger RNA. This molecule moves from the nucleus to the ribosome in the cytoplasm where it is “read.” Transfer RNA brings amino acids to the ribosome, where they are connected in the correct sequence to form a specific protein.</p> <p><b>B4.2f</b> Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules and that this is virtually the same mechanism for all life forms.</p> <p><b>B4.2g</b> Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.</p> <p><b>B4.2h</b> Recognize that genetic engineering techniques provide great potential and responsibilities.</p> <p><b>B4.r2i</b> Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes. <i>(recommended)</i></p>
<p><b>B4.3 Cell Division — Mitosis and Meiosis</b></p> <p>Sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents.</p> <p><b>B4.3A</b> Compare and contrast the processes of cell division</p>	<p><b>B4.3d</b> Explain that the sorting and recombination of genes</p>

<p>(mitosis and meiosis), particularly as those processes relate to production of new cells and to passing on genetic information between generations.</p> <p><b>B4.3B</b> Explain why only mutations occurring in gametes (sex cells) can be passed on to offspring.</p> <p><b>B4.3C</b> Explain how it might be possible to identify genetic defects from just a karyotype of a few cells.</p>	<p>in sexual reproduction result in a great variety of possible gene combinations from the offspring of two parents.</p> <p><b>B4.3e</b> Recognize that genetic variation can occur from such processes as crossing over, jumping genes, and deletion and duplication of genes.</p> <p><b>B4.3f</b> Predict how mutations may be transferred to progeny.</p> <p><b>B4.3g</b> Explain that cellular differentiation results from gene expression and/or environmental influence (e.g., metamorphosis, nutrition).</p>
	<p><b>B4.4x Genetic Variation</b></p> <p>Genetic variation is essential to biodiversity and the stability of a population. Genetic variation is ensured by the formation of gametes and their combination to form a zygote. Opportunities for genetic variation also occur during cell division when chromosomes exchange genetic material causing permanent changes in the DNA sequences of the chromosomes. Random mutations in DNA structure caused by the environment are another source of genetic variation.</p> <p><b>B4.4a</b> Describe how inserting, deleting, or substituting DNA segments can alter a gene. Recognize that an altered gene may be passed on to every cell that develops from it and that the resulting features may help, harm, or have little or no effect on the offspring's success in its environment.</p> <p><b>B4.4b</b> Explain that gene mutation in a cell can result in uncontrolled cell division called cancer. Also know that exposure of cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer.</p> <p><b>B4.4c</b> Explain how mutations in the DNA sequence of a gene may be silent or result in phenotypic change in an organism and in its offspring.</p>
	<p><b>B4.r5x Recombinant DNA</b></p> <p>Recombinant DNA technology allows scientists in the laboratory to combine the genes from different sources, sometimes different species, into a single DNA molecule. This manipulation of genes using bacterial plasmids has been used for many practical purposes including the mass production of chemicals and drugs. <i>(recommended)</i></p> <p><b>B4.r5a</b> Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes. <i>(recommended)</i></p> <p><b>B4.r5b</b> Evaluate the advantages and disadvantages of human manipulation of DNA. <i>(recommended)</i></p>

## STANDARD B5: EVOLUTION AND BIODIVERSITY

*Students recognize that evolution is the result of genetic changes that occur in constantly changing environments. They can explain that modern evolution includes both the concepts of common descent and natural selection. They illustrate how the consequences of natural selection and differential reproduction have led to the great biodiversity on Earth.*

Essential	Core and Recommended
<p><b>B5.1 Theory of Evolution</b></p> <p>The theory of evolution provides a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms.</p> <p><b>B5.1A</b> Summarize the major concepts of natural selection (differential survival and reproduction of chance inherited variants, depending on environmental conditions).</p> <p><b>B5.1B</b> Describe how natural selection provides a mechanism for evolution.</p>	<p><b>B5.1c</b> Summarize the relationships between present-day organisms and those that inhabited the Earth in the past (e.g., use fossil record, embryonic stages, homologous structures, chemical basis).</p> <p><b>B5.1d</b> Explain how a new species or variety may originate through the evolutionary process of natural selection.</p> <p><b>B5.1e</b> Explain how natural selection leads to organisms that are well suited for the environment (differential survival and reproduction of chance inherited variants, depending upon environmental conditions).</p> <p><b>B5.1f</b> Explain, using examples, how the fossil record, comparative anatomy, and other evidence may support the theory of evolution.</p> <p><b>B5.1g</b> Illustrate how genetic variation is preserved or eliminated from a population through natural selection (evolution) resulting in biodiversity.</p>
	<p><b>B5.2x Molecular Evidence</b></p> <p>Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descents branched.</p> <p><b>B5.2a</b> Describe species as reproductively distinct groups of organisms that can be classified based on morphological, behavioral, and molecular similarities.</p> <p><b>B5.2b</b> Explain that the degree of kinship between organisms or species can be estimated from the similarity of their DNA and protein sequences.</p> <p><b>B5.2c</b> Trace the relationship between environmental changes and changes in the gene pool, such as genetic drift and isolation of subpopulations.</p> <p><b>B5.r2d</b> Interpret a cladogram or phylogenetic tree showing evolutionary relationships among organisms. (<i>recommended</i>)</p>
<p><b>B5.3 Natural Selection</b></p> <p>Evolution is the consequence of natural selection, the interactions of (1) the potential for a population to</p>	

increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection from environmental pressure of those organisms better able to survive and leave offspring.

**B5.3A** Explain how natural selection acts on individuals, but it is populations that evolve. Relate genetic mutations and genetic variety produced by sexual reproduction to diversity within a given population.

**B5.3B** Describe the role of geographic isolation in speciation.

**B4.3C** Give examples of ways in which genetic variation and environmental factors are causes of evolution and the diversity of organisms.

**B5.3d** Explain how evolution through natural selection can result in changes in biodiversity.

**B5.3e** Explain how changes at the gene level are the foundation for changes in populations and eventually the formation of new species.

**B5.3f** Demonstrate and explain how biotechnology can improve a population and species.