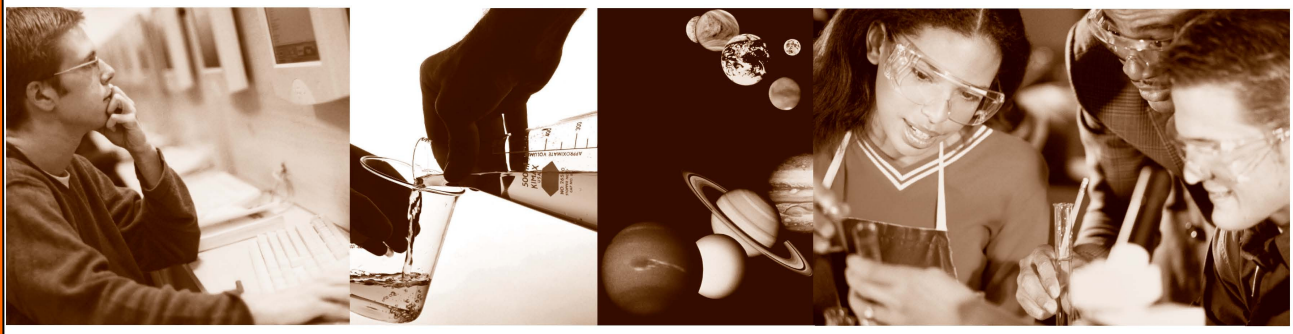
High School Content Expectations

Companion Document



SCIENCE

- **Biology**
- **Chemistry**
- **Earth Science**
- **Physics**

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HSSCE Companion Document

OVERVIEW

The Michigan High School Science Content Expectations establish what every student is expected to know and be able to do by the end of high school and outline the parameters for receiving high school credit as recently mandated by the Merit Curriculum legislation in the state of Michigan. The Science Content Expectations Documents and the Michigan Merit Curriculum Document have raised the bar for our students, teachers and educational systems.

In an effort to support these standards and help our science teachers develop rigorous and relevant curricula to assist students in mastery, the Michigan Science Leadership Academy, in collaboration with the Michigan Mathematics and Science Center Network and the Michigan Science Teachers Association, worked in partnership with Michigan Department of Education to develop this companion document. Our goal is for each student to master the science content expectations as outlined in the merit curriculum.

This companion document is an effort to clarify and support the High School Science Content Expectations and the Michigan Merit Curriculum. The Merit Curriculum has been organized into twelve teachable units – organized around the big ideas and conceptual themes in each of the four discipline areas. The document is similar in format to the Science Assessment and Item Specifications for the 2009 National Assessment for Educational Progress (NAEP). The companion document is intended to provide boundaries to the content expectations. These boundaries are presented as "notes to teachers", not comprehensive descriptions of the full range of science content; they do not stand alone, but rather, work in conjunction with the content expectations. The boundaries use five categories of parameters:

a. **Real World Context** refers to breadth and depth of topic coverage and includes those ideas that are "common" or "familiar" to students and appear frequently in curriculum materials and in most students' experiences outside of school. This section is not intended to guide assessment, but rather, may be used as a context for assessment.

a. **Instruments, measurements, and representations** refer to instruments students are expected to use and the level of precision expected to measure, classify, and interpret phenomena or measurement. This section contains assessable information.

b. **Technical vocabulary** refers to the vocabulary for use and application of the science topics and principles that appear in the content statements and expectations. The words in this section along with those presented within the standard, content statement and content expectation comprise the assessable vocabulary.

c. **Clarification** refers to the restatement of a "key idea" or specific intent or elaboration of the content statements. It is not intended to denote a sense of content priority. The clarifications guide assessment.

d. **Instructional Examples** are included as exemplars of five different modes of instruction appropriate to the unit in which they are listed. These examples include inquiry, reflection, general instruction, enrichment and intervention strategies. These examples are intended for instructional guidance only and are not assessable.

BIOLOGY
Table of Contents

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Standard B1	**INQUIRY, REFLECTION, AND SOCIAL IMPLICATIONS**		
Statement B1.1	**Scientific Inquiry**		
B1.1A	Generate new questions that can be investigated in the laboratory or field.		Lesson 1i, Lesson 2i, Lesson 2iv, Lesson 3i, Lesson 3iii, Lesson 7i, Lesson 7iv, Lesson 8i, Lesson 8iii, Lesson 9i, Lesson 10i, Lesson 11i, Lesson 12i
B1.1B	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.		Lesson 1i, Lesson 2i, Lesson 2iv, Lesson 5i, Lesson 7i, Lesson 8i, Lesson 8iii, Lesson 10i, Lesson 10ii, Lesson 11i, Lesson 12i
B1.1C	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).		Lesson 1i, Lesson 1iii, Lesson 1iv, Lesson 1v, Lesson 2i, Lesson 2iv, Lesson 2v, Lesson 3i, Lesson 3iii, Lesson 3iv, Lesson 5i, Lesson 5iii, Lesson 5iv, Lesson 5v, Lesson 7i, Lesson 8iv, Lesson 10i, Lesson 11i, Lesson 11iii, Lesson 12i
B1.1D	Identify patterns in data and relate them to theoretical models.		Lesson 1i, Lesson 1iii, Lesson 2v, Lesson 3i, Lesson 5i, Lesson 5iv, Lesson 5v, Lesson 6i, Lesson 7i, Lesson 7iii, Lesson 7iv, Lesson 9i, Lesson 10i, Lesson 11i, Lesson 11iii, Lesson 11iv, Lesson 11v
B1.1E	Describe a reason for a given conclusion using evidence from an investigation.		Lesson 2i, Lesson 2v, Lesson 3i, Lesson 3iii, Lesson 5i, Lesson 5iv, Lesson 5v, Lesson 7i, Lesson 7iii, Lesson 7iv, Lesson 8iv, Lesson 10i, Lesson 11iv, Lesson 11v, Lesson 12i

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example	
B1.1f	Predict what would happen if the variables, methods, or timing of an investigation were changed.		Lesson 1i Lesson 2i Lesson 2iv Lesson 3i Lesson 3iii	Lesson 5i Lesson 5iv Lesson 6i Lesson 7i Lesson 11i
B1.1g	Use empirical evidence to explain and critique the reasoning used to draw a scientific conclusion or explanation.		Lesson 2i Lesson 3i Lesson 3iii Lesson 3iv Lesson 4i Lesson 4ii Lesson 4iii Lesson 4iv Lesson 4v Lesson 5i Lesson 5v	Lesson 7i Lesson 7ii Lesson 7iii Lesson 7iv Lesson 8i Lesson 10i Lesson 11i Lesson 11iii Lesson 11iv Lesson 12i
B1.1h	Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.		Lesson 1i Lesson 2i Lesson 3i Lesson 3iii Lesson 3iv Lesson 5i	Lesson 7i Lesson 7iii Lesson 8i Lesson 8iv Lesson 10i Lesson 12i
B1.1i	Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.		Lesson 8i Lesson 9i Lesson 9ii Lesson 9iii	
Statement B1.2	**Scientific Reflection and Social Implications**			
B1.2A	Critique whether or not specific questions can be answered through scientific investigations.		Lesson 7ii Lesson 10ii Lesson 11ii	
B1.2B	Identify and critique arguments about personal or societal issues based on scientific evidence.		Lesson 3ii Lesson 5ii Lesson 7ii Lesson 8ii	Lesson 9ii Lesson 10ii Lesson 11ii
B1.2C	Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.		Lesson 1ii Lesson 2ii Lesson 2iii Lesson 3ii Lesson 4i Lesson 4ii Lesson 4iii Lesson 4iv Lesson 4v Lesson 5ii	Lesson 6ii Lesson 7ii Lesson 7iv Lesson 8ii Lesson 9i Lesson 9ii Lesson 9iii Lesson 10ii Lesson 11ii Lesson 12ii

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
B1.2D	Evaluate scientific explanations in a peer review process or discussion format.		Lesson 1ii Lesson 8ii Lesson 2ii Lesson 10ii Lesson 6ii Lesson 11ii Lesson 7ii Lesson 12ii
B1.2E	Evaluate the future career and occupational prospects of science fields.		
B1.2f	Critique solutions to problems, given criteria and scientific constraints.		Lesson 3ii Lesson 9ii Lesson 7ii Lesson 10ii Lesson 8ii Lesson 12ii
B1.2g	Identify scientific tradeoffs in design decisions and choose among alternative solutions.		Lesson 3ii Lesson 8i Lesson 3iii Lesson 10ii Lesson 7ii
B1.2h	Describe the distinctions between scientific theories, laws, hypotheses, and observations.		
B1.2i	Explain the progression of ideas and explanations that leads to science theories that are part of the current scientific consensus or core knowledge.		Lesson 3ii
B1.2j	Apply science principles or scientific data to anticipate effects of technological design decisions.		Lesson 5iii Lesson 6ii Lesson 7ii Lesson 10ii
B1.2k	Analyze how science and society interact from a historical, political, economic, or social perspective.		Lesson 3ii Lesson 9ii Lesson 7ii Lesson 10ii Lesson 8ii Lesson 11ii
Standard B2	**ORGANIZATION AND DEVELOPMENT OF LIVING SYSTEMS**		
Statement B2.1	Transformation of Matter and Energy in Cells		
B2.1A	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.	Unit 7	Lesson 3i
B2.1B	Compare and contrast the transformation of matter and energy during photosynthesis and respiration.	Unit 7	

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Statement B2.1x	**Cell Differentiation**		
B2.1d	Describe how, through cell division, cells can become specialized for specific function.	Unit 9	
B2.1e	Predict what would happen if the cells from one part of a developing embryo were transplanted to another part of the embryo.	Unit 5 Unit 11	
Statement B2.2	**Organic Molecules**		
B2.2A	Explain how carbon can join to other carbon atoms in chains and rings to form large and complex molecules.	Unit 1	
B2.2B	Recognize the six most common elements in organic molecules (C, H, N, O, P, S).	Unit 1	
B2.2C	Describe the composition of the four major categories of organic molecules (carbohydrates, lipids, proteins, and nucleic acids).	Unit 1	Lesson 1ii Lesson 1iii Lesson 1iv Lesson 1v
B2.2D	Explain the general structure and primary functions of the major complex organic molecules that compose living organisms.	Unit 1	Lesson 1ii Lesson 1iii Lesson 1iv Lesson 1v
B2.2E	Describe how dehydration and hydrolysis relate to organic molecules.	Unit 1	
Statement B2.2x	**Proteins**		
B2.2f	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).	Unit 1	
B2.2g	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.	Unit 8	
Statement B2.3	**Maintaining Environmental Stability**		
B2.3A	Describe how cells function in a narrow range of physical conditions, such as temperature and pH (acidity), to perform life functions.	Unit 6	Lesson 6iv
B2.3B	Describe how the maintenance of a relatively stable internal environment is required for the continuation of life.	Unit 6	Lesson 6iii Lesson 6iv Lesson 6v

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
B2.3C	Explain how stability is challenged by changing physical, chemical, and environmental conditions as well as the presence of disease agents.	Unit 6	Lesson 6iii Lesson 6iv Lesson 6v
Statement B2.3x	**Homeostasis**		
B2.3d	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.	Unit 5	Lesson 5i Lesson 5ii Lesson 5iii Lesson 5iv Lesson 5v
B2.3e	Describe how human body systems maintain relatively constant internal conditions (temperature, acidity, and blood sugar).	Unit 6	Lesson 6iv
B2.3f	Explain how human organ systems help maintain human health.	Unit 6	Lesson 6iv Lesson 6v
B2.3g	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).	Unit 5	Lesson 5iii
Statement B2.4	**Cell Specialization**		
B2.4A	Explain that living things can be classified based on structural, embryological, and molecular (relatedness of DNA sequence) evidence.	Unit 12	
B2.4B	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).	Unit 4	Lesson 4i Lesson 4ii Lesson 4iii Lesson 4iv Lesson 4v
B2.4C	Explain how different organisms accomplish the same result using different structural specializations (gills vs. lungs vs. membranes).	Unit 4	Lesson 4i Lesson 4ii Lesson 4iii Lesson 4iv Lesson 4v
B2.4d	Analyze the relationships among organisms based on their shared physical, biochemical, genetic, and cellular characteristics and functional processes.	Unit 12	
B2.4e	Explain how cellular respiration is important for the production of ATP (build on aerobic vs. anaerobic).	Unit 3	

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
B2.4f	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.	Unit 1	Lesson 1i
B2.4g	Explain that some structures in the modern eukaryotic cell developed from early prokaryotes, such as mitochondria, and in plants, chloroplasts.	Unit 2	
B2.4h	Describe the structures of viruses and bacteria.	Unit 2	
B2.4i	Recognize that while viruses lack cellular structure, they have the genetic material to invade living cells.	Unit 2	
Statement B2.5	**Living Organism Composition**		
B2.5A	Recognize and explain that macromolecules such as lipids contain high energy bonds.	Unit 1	Lesson 1i
B2.5B	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.	Unit 4	Lesson 4i Lesson 4ii Lesson 4iii Lesson 4v
B2.5C	Describe how energy is transferred and transformed from the Sun to energy-rich molecules during photosynthesis.	Unit 7	
B2.5D	Describe how individual cells break down energy-rich molecules to provide energy for cell functions.	Unit 3	
Statement B2.5x	**Energy Transfer**		
B2.5e	Explain the interrelated nature of photosynthesis and cellular respiration in terms of ATP synthesis and degradation.	Unit 3	
B2.5f	Relate plant structures and functions to the process of photosynthesis and respiration.	Unit 3	Lesson 3iii
B2.5g	Compare and contrast plant and animal cells.	Unit 2	
B2.5h	Explain the role of cell membranes as a highly selective barrier (diffusion, osmosis, and active transport).	Unit 2	Lesson 2i Lesson 2ii Lesson 2iii Lesson 2iv Lesson 2v
B2.5i	Relate cell parts/organelles to their function.	Unit 2	

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Statement B2.6x	**Internal/External Cell Regulation**		
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.	Unit 6	
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)*	R	
B2.r6c	Recognize and explain that communication and/or interaction are required between cells to coordinate their diverse activities. *(recommended)*	R	
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)*	R	
B2.r6e	Analyze the body's response to medical interventions such as organ transplants, medicines, and inoculations. *(recommended)*	R	
Standard B3	**INTERDEPENDENCE OF LIVING SYSTEMS AND THE ENVIRONMENT**		
Statement B3.1	**Photosynthesis and Respiration**		
B3.1A	Describe how organisms acquire energy directly or indirectly from sunlight.	Unit 7	
B3.1B	Illustrate and describe the energy conversions that occur during photosynthesis and respiration.	Unit 3 Unit 7	Lesson 3v
B3.1C	Recognize the equations for photosynthesis and respiration and identify the reactants and products for both.	Unit 3 Unit 7	Lesson 3iv
B3.1D	Explain how living organisms gain and use mass through the processes of photosynthesis and respiration.	Unit 7	
B3.1e	Write the chemical equation for photosynthesis and cellular respiration and explain in words what they mean.	Unit 7	
B3.1f	Summarize the process of photosynthesis.	Unit 3	

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
Statement B3.2	**Ecosystems**		
B3.2A	Identify how energy is stored in an ecosystem.	Unit 7	Lesson 7iv
B3.2B	Describe energy transfer through an ecosystem, accounting for energy lost to the environment as heat.	Unit 7	Lesson 7iv
B3.2C	Draw the flow of energy through an ecosystem. Predict changes in the food web when one or more organisms are removed.	Unit 7	Lesson 7iv
Statement B3.3	**Element Recombination**		
B3.3A	Use a food web to identify and distinguish producers, consumers, and decomposers and explain the transfer of energy through trophic levels.	Unit 7	Lesson 7iv Lesson 7v
B3.3b	Describe environmental processes (e.g., the carbon and nitrogen cycles) and their role in processing matter crucial for sustaining life.	Unit 7	Lesson 7iii
Statement B3.4	**Changes in Ecosystems**		
B3.4A	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.	Unit 8	Lesson 8ii Lesson 8v
B3.4B	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.	Unit 12	
B3.4C	Examine the negative impact of human activities.	Unit 8	Lesson 8i Lesson 8iii Lesson 8v
Statement B3.4x	**Human Impact**		
B3.4d	Describe the greenhouse effect and list possible causes.	Unit 8	
B3.4e	List the possible causes and consequences of global warming.	Unit 8	
Statement B3.5	**Populations**		
B3.5A	Graph changes in population growth, given a data table.	Unit 8	Lesson 8iv

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
B3.5B	Explain the influences that affect population growth.	Unit 8	Lesson 8ii Lesson 8iv
B3.5C	Predict the consequences of an invading organism on the survival of other organisms.	Unit 8	Lesson 8iii Lesson 8v
Statement B3.5x	**Environmental Factors**		
B3.5d	Describe different reproductive strategies employed by various organisms and explain their advantages and disadvantages.	Unit 9	
B3.5e	Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of population dynamics within ecosystems.	Unit 8	Lesson 8iv
B3.5f	Graph an example of exponential growth. Then show the population leveling off at the carrying capacity of the environment.	Unit 8	
B3.r5g	Diagram and describe the stages of the life cycle for a human disease-causing organism. *(recommended)*	R	
Standard B4	**GENETICS**		
Statement B4.1	**Genetics and Inherited Traits**		
B4.1A	Draw and label a homologous chromosome pair with heterozygous alleles highlighting a particular gene location.	Unit 11	
B4.1B	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.	Unit 10	
B4.1c	Differentiate between dominant, recessive, codominant, polygenic, and sex-linked traits.	Unit 11	Lesson 11v
B4.1d	Explain the genetic basis for Mendel's laws of segregation and independent assortment.	Unit 11	
B4.1e	Determine the genotype and phenotype of monohybrid crosses using a Punnett Square.	Unit 11	Lesson 10i Lesson 11v
Statement B4.2	**DNA**		
B4.2A	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).	Unit 9	

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
B4.2B	Recognize that every species has its own characteristic DNA sequence.	Unit 10	
B4.2C	Describe the structure and function of DNA.	Unit 10	
B4.2D	Predict the consequences that changes in the DNA composition of particular genes may have on an organism (e.g., sickle cell anemia, other).	Unit 10	
B4.2E	Propose possible effects (on the genes) of exposing an organism to radiation and toxic chemicals.	Unit 10	Lesson 10i
Statement B4.2x	**DNA, RNA, and Protein Synthesis**		
B4.2f	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.	Unit 10	Lesson 10iii Lesson 10iv Lesson 10v Lesson 11iii
B4.2g	Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.	Unit 10	Lesson 10iii Lesson 10iv Lesson 10v
B4.2h	Recognize that genetic engineering techniques provide great potential and responsibilities.	Unit 11	
B4.2i	Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes. *(recommended)*	R	
Statement B4.3	**Cell Division — Mitosis and Meiosis**		
B4.3A	Compare and contrast the processes of cell division (mitosis and meiosis), particularly as those processes relate to production of new cells and to passing on genetic information between generations.	Unit 9	Lesson 9v
B4.3B	Explain why only mutations occurring in gametes (sex cells) can be passed on to offspring.	Unit 9	
B4.3C	Explain how it might be possible to identify genetic defects from just a karyotype of a few cells.	Unit 9	Lesson 9iv
B4.3d	Explain that the sorting and recombination of genes in sexual reproduction result in a great variety of possible gene combinations from the offspring of two parents.	Unit 9	
B4.3e	Recognize that genetic variation can occur from such processes as crossing over, jumping genes, and deletion and duplication of genes.	Unit 9	

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
B4.3f	Predict how mutations may be transferred to progeny.	Unit 9	Lesson 91
B4.3g	Explain that cellular differentiation results from gene expression and/or environmental influence (e.g., metamorphosis, nutrition).	Unit 5 Unit 11	
Statement B4.4x	**Genetic Variation**		
B4.4a	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.	Unit 11	Lesson 11iii
B4.4b	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.	Unit 9	Lesson 9iii
B4.4c	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.	Unit 10	
Statement B4.r5x	**Recombinant DNA**		
B4.r5a	Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes. *(recommended)*	R	
B4.r5b	Evaluate the advantages and disadvantages of human manipulation of DNA. *(recommended)*	R	
Standard B5	**EVOLUTION AND BIODIVERSITY**		
Statement B5.1	**Theory of Evolution**		
B5.1A	Summarize the major concepts of natural selection (differential survival and reproduction of chance inherited variants, depending on environmental conditions).	Unit 12	Lesson 12i Lesson 12iv Lesson 12v
B5.1B	Describe how natural selection provides a mechanism for evolution.	Unit 12	Lesson 12v
B5.1c	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).	Unit 12	Lesson 12iii

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
B5.1d	Explain how a new species or variety originates through he evolutionary process of natural selection.	Unit 12	Lesson 12v
B5.1e	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).	Unit 12	Lesson 12i Lesson 12iv Lesson 12v
B5.1f	Explain, using examples, how the fossil record, comparative anatomy, and other evidence supports the theory of evolution.	Unit 12	Lesson 12ii Lesson 12iii
B5.1g	Illustrate how genetic variation is preserved or eliminated from a population through natural selection (evolution) resulting in biodiversity.	Unit 12	
Statement B5.2x	**Molecular Evidence**		
B5.2a	Describe species as reproductively distinct groups of organisms that can be classified based on morphological, behavioral, and molecular similarities.	Unit 12	Lesson 12ii Lesson 12iii
B5.2b	Explain that the degree of kinship between organisms or species can be estimated from the similarity of their DNA and protein sequences.	Unit 12	Lesson 12ii Lesson 12iii
B5.2c	Trace the relationship between environmental changes and changes in the gene pool, such as genetic drift and isolation of subpopulations.	Unit 12	
B5.r2d	Interpret a cladogram or phylogenetic tree showing evolutionary relationships among organisms. *(recommended)*	R	
Statement B5.3	**Natural Selection**		
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.	Unit 12	
B5.3B	Describe the role of geographic isolation in speciation.	Unit 12	
B5.3C	Give examples of ways in which genetic variation and environmental factors are causes of evolution and the diversity of organisms.	Unit 12	

Biology Cross Reference Guide

HSCE Code	Expectation	Clarification Unit	Instructional Example
B5.3d	Explain how evolution through natural selection can result in changes in biodiversity.	Unit 12	
B5.3e	Explain how changes at the gene level are the foundation for changes in populations and eventually the formation of new species.	Unit 12	
B5.3f	Demonstrate and explain how biotechnology can improve a population and species.	Unit 12	

Units by Content Expectation

BIOLOGY

Unit 1: Chemistry and Biochemistry

Code	Content Expectation
B2.2	*Organic Molecules* There are four major categories of organic molecules that make up living systems: carbohydrates, fats, proteins, and nucleic acids.
B2.2A	Explain how carbon can join to other carbon atoms in chains and rings to form large and complex molecules.
B2.2B	Recognize the six most common elements in organic molecules.
B2.2C	Describe the composition of the four major categories of organic molecules (carbohydrates, lipids, proteins, and nucleic acids).
B2.2D	Explain the general structure and primary functions of the major complex organic molecules that compose living organisms.
B2.2E	Describe how dehydration and hydrolysis relate to organic molecules.
B2.2x	*Proteins* 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.
B2.2f	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).
B2.4	*Cell Specialization* 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.
B2.4f	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.
B2.5	*Living Organism Composition* 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
B2.5A	Recognize and explain that macromolecules such as lipids contain high energy bonds.

BIOLOGY

Unit 1: Chemistry and Biochemistry

Big Ideas (Core Concepts)
Living systems are made up of four major types of organic molecules: carbohydrates, lipids, proteins and nucleic acids.

Organisms are made up of different arrangements of these molecules, giving all life a biochemical framework.

Selected cells in multicellular organisms are specialized to carry out particular life functions.

Standard(s):
B2: Organization And Development Of Living Systems

Content Statements:
B2.2: Organic Molecules
B2.2x: Proteins
B2.4: Cell Specialization
B2.5: Living Organism Composition

Content Expectations: (Content Statement Clarification)
B2.2A: Explain how carbon can join to other carbon atoms in chains and rings to form large and complex molecules.

Clarification: Carbon molecules are limited to those possessing single and double covalent bonds.

B2.2B: Recognize the six most common elements in organic molecules (C, H, N, O, P, S).

Clarification: None

B2.2C: Describe the composition of the four major categories of organic molecules (carbohydrates, lipids, proteins, and nucleic acids).

Clarification: None (see next clarification)

B2.2D: Explain the general structure and primary functions of the major complex organic molecules that compose living organisms.

Clarification: Carbohydrates are limited to general structural formulas of simple sugars and polymers of those sugars and their functions as short- and long-term energy storage molecules as well as structural components of cell walls.

Lipids are limited to general structural formulas of fats and cell membrane structures and their functions.

Proteins are specified to be polymers of amino acids with a variety of functions. These functions are limited to include proteins that relate to structure, such as those found in parts of the cell membrane, muscle and connective tissue. A large number of proteins also exist as enzymes, controlling the biochemical activities of an organism.

Nucleic acids, DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) are limited to their structure as polymers of nucleotide subunits which provide information storage for the biochemical identity of an organism.

B2.2E: Describe how dehydration and hydrolysis relate to organic molecules.

Clarification: Dehydration and hydrolysis reactions are limited to the understanding that dehydration links subunits together to make larger molecules, at the same time releasing water. Hydrolysis reactions are essentially the reverse of dehydration reactions, with water reacting with a large molecule to break it down into smaller subunits.

B2.2f: 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).

Clarification: Proteins serve a variety of purposes in cells and are limited to general understanding of enzymes as substrate-specific catalysts that speed up the rate of biochemical reactions and facilitate the breakdown of complex molecules. Also permissible are important functions that include transport of chemical messages and essential materials for the cell.

B2.4f: 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.

Clarification: None

B2.5A: Recognize and explain that macromolecules such as lipids contain high energy bonds.

Clarification: High energy bonds are limited to those found commonly in biological molecules, such as carbon-hydrogen and those found in ATP.

Vocabulary
ATP
carbohydrate
catalyst
chemical bond

covalent bonds
DNA (deoxyribonucleic acid)
dehydration
element
enzyme
hemoglobin
high energy bonds
hormone
hydrolysis
lipid
molecular energy
nucleic acid
protein
protein structure
polymers
RNA (ribonucleic acid)
substrate

Real World Context

Living things are made up of complex molecules (carbohydrates, lipids, proteins and nucleic acids) and their subunits. These subunits include simple sugars in carbohydrates, fatty acids in lipids, amino acids in proteins and nucleotides in nucleic acids.

Carbohydrates are a biochemical class made up of simple sugars which consist of a general atomic ratio of carbon (C) to hydrogen (H) to oxygen (O) of 1:2:1 ($C_nH_{2n}O_n$). They also include polymers of simple sugars. Carbohydrates function as short-term energy storage in the form of simple sugars and as intermediate-term energy storage as polysaccharides, specifically as starches in plants and glycogen in animals. Polysaccharides are also structural components in cells as cellulose in the cell walls of plants and many protists and as chitin in the exoskeleton of insects and other arthropods.

Lipids are involved mainly with long-term energy storage. Lipids make up such molecules as fats, oils and waxes and also contain carbon, hydrogen and oxygen. They are generally insoluble in polar substances such as water. Other functions of lipids are functional, as in the case of phospholipids as the major building block in cell membranes and some kinds of hormone messengers that have a role in communications within and between cells.

Proteins are very important in biological systems as control and structural elements. Control functions of proteins are carried out by enzymes and some kinds of hormones. Enzymes are biochemicals that act as organic catalysts to speed up the rate of a chemical reaction. These proteins are folded in intricate ways that produce shapes that "fit" corresponding features of specific substrates. This enzyme-substrate specificity is very important for students to understand. Structural proteins function in the cell as parts of the cell membrane, muscle tissue, and connective tissue types. Proteins are polymers of amino acids and contain, in addition to carbon, hydrogen and oxygen, also

nitrogen and sometimes sulfur.

Nucleic acids are composed of very long chains of subunits called nucleotides, which contain carbon, hydrogen, oxygen, nitrogen and phosphorus. The two chief types of nucleic acids are DNA (deoxyribonucleic acid) which contains the hereditary information in all living organisms and RNA (ribonucleic acid) which delivers the instructions coded in a cell's DNA to its protein manufacturing sites.

Organisms make the molecules they need or obtain them from their diet. Specific proteins, for example, are required for specific cellular processes. Without these proteins, or with non-functioning proteins, certain processes may not be carried out at all.

Dehydration links smaller subunits into larger units by removing water and forming covalent bonds. Hydrolysis is a chemical reaction in which a compound reacts with water. This type of reaction is used to break down larger organic molecules into smaller subunits. Dehydration and hydrolysis are essentially the reverse of each other.

Energy is involved in the formation of chemical bonds. The breaking and reforming of new bonds by living things often involves a transformation of energy from higher energy bonds to lower energy bonds, allowing usable energy to be released for use by the organism. An example of high energy bonds are the phosphate bonds in ATP. When the third phosphate group of ATP is removed by hydrolysis, a substantial amount of free energy is released. For this reason, this bond is known as a "high-energy" bond.

Instruments, Measurement and Representations

Representations of large biological molecules as polymers of simpler subunits

Exclusions: Primary, secondary, tertiary structure of proteins

Names, functional groups, and structural formulas of amino acids

Differentiation among types of amino acids:
hydrophobic, hydrophilic

The term "nucleotide" if used in items should be followed by "(a subunit of DNA)"

Structural formulas of monomers of fats, proteins, carbohydrates (fatty acids, amino acids, simple sugars)

Specific names of enzymes and substrates

Instructional Examples

i. Inquiry
CE: B1.1A, B1.1B, B1.1C, B1.1D, B1.1f, B1.1h, B2.4f, B2.5A

Predict from a variety of foods (e.g., gumdrops, peanuts, raisins or bread) which will have the most energy released when it is burned. Design and perform an activity that involves burning the foods to measure the energy released in a calorimeter.

ii. Reflection
CE: B1.2C, B1.2D, B2.2C, B2.2D

Teams will select a nutrient group (fats, simple sugars, proteins, starches). Investigate how these nutrients are obtained and then used in the human body. Prepare a presentation that shares the group information with the rest of the class and shows what a healthy portion of each of the nutrient groups looks like.

iii. Enrichment
CE: B1.1C, B1.1D, B2.2C, B2.2D

Use qualitative tests for food nutrients (Benedict's solution for the presence of simple sugars, Lugol's Iodine solution to identify the presence of starch, Biuret solution for the presence of protein and Sudan III stain to identify the presence of lipids), to evaluate the nutrient content of a fast food meal of student choice that has been blended and filtered. Compare this with the nutrient information posted by the restaurant chain in its stores or website. Report results to classmates.

iv. General
CE: B1.1C, B2.2C, B2.2D

Perform the qualitative tests listed above to identify the presence of nutrients in food. Using foods known to contain the nutrients as standards, test unknown food compounds to determine their composition.

v. Intervention
CE: B1.1C, B2.2C, B2.2D

Perform an Internet search on teacher-chosen foods, possibly foods already tested or a fast food item, discovering the content of carbohydrates (simple and complex), fats and proteins (in calories) that these foods contain. Compare these values to those recommended as nutritional guidelines for these biochemical classes.

Units by Content Expectation

BIOLOGY

Unit 2: Cells – Structure and Function

Code	Content Expectation
B2.4	*Cell Specialization* 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.
B2.4g	Explain that some structures in the modern eukaryotic cell developed from early prokaryotes, such as mitochondria, and in plants, chloroplasts.
B2.4h	Describe the structures of viruses and bacteria.
B2.4i	Recognize that while viruses lack cellular structure, they have the genetic material to invade living cells.
B2.5	*Living Organism Composition* 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.
B2.5g	Compare and contrast plant and animal cells.
B2.5h	Explain the role of cell membranes as a highly selective barrier (diffusion, osmosis, and active transport).
B2.5i	Relate cell parts/organelles to their functions.

BIOLOGY

Unit 2: Cells – Structure and Function

Big Ideas (Core Concepts):
Cells are the basic units of life.

Cells combine to form more complex structures

Standard:
B2: Organization and Development of Living Systems

Content Statements(s):
B2.4: Cell Specialization
B2.5: Living Organism Composition

Content Expectations: (Content Statement Clarification)
B2.4g: Explain that some structures in the modern eukaryotic cell developed from early prokaryotes, such as mitochondria, and in plants, chloroplasts.

Clarification: None

B2.4h: Describe the structures of viruses and bacteria.

Clarification: Structures are limited to bacterial cell walls, cell membranes, DNA and cytoplasm. Viral structures are limited to genetic material (either DNA or RNA) and protein coat covering of the virus.

B2.4i: Recognize that while viruses lack cellular structure, they have the genetic material to invade living cells.

Clarification: None

B2.5g: Compare and contrast plant and animal cells.

Clarification: Cellular structures are limited to cell membranes, cell walls, chloroplasts, cytoplasm, Golgi apparatus, mitochondria, nucleus, ribosomes, vacuoles.

B2.5h: Explain the role of cell membranes as a highly selective barrier (diffusion, osmosis, and active transport).

Clarification: Transport processes are limited to those listed in the content expectation.

B2.5i: Relate cell parts/organelles to their function.

Clarification: Cellular structures are limited to cell membranes, cell walls, chloroplasts, cytoplasm, Golgi apparatus, mitochondria, nucleus, ribosomes, vacuoles.

Vocabulary

active transport
bacteria
biological evolution
cell function
cell membrane
cell nucleus
cell organelle
cell wall
cellular differentiation
chloroplast
chromosome
cytoplasm
diffusion
DNA (deoxyribonucleic acid)
eukaryote
Golgi apparatus
mitochondrion
nucleus
nucleated cell
organelle
osmosis
photosynthesizing organism
prokaryote
protein
ribosome
storage of genetic information
transport of cell materials
vacuole
virus

Real World Context

Cells are the basic unit of all life and represent a vast array of types, yet they share many similarities. All living things are made up of cells whose work is carried out by many different types of molecules. Cellular and molecular biology has the power to explain a wide variety of phenomena related to the organization and development of living systems.

Modern cell theory states that:

- All organisms are made up of cells.
- New cells are derived from pre-existing cells.
- The cell is the structural and functional unit of all living things.
- Cells contain hereditary information that is passed from cell to cell during cell division.
- All cells are basically the same in chemical composition and metabolic activities.

Endosymbiotic theory, which proposes the chloroplasts and mitochondria were once free-living prokaryotes that developed such close relationships with early cells and that they were eventually taken in as substructures, represents a major step in the evolution of eukaryotes, since it couples energetic processes to cell function. Evidence for the theory is striking:

- chloroplasts and mitochondria both contain circular DNA, similar to prokaryotes
- their cell membrane structures are similar to prokaryotes
- they reproduce by binary fission, as do prokaryotes
- their ribosomes are similar in structure to prokaryotes

Differences between types of cells: prokaryotic and eukaryotic, plant and animal, highlight features of form and function that relate to the specific role of a given cell to its organism type.

Instruments, Measurement, and Representations

Microscopes to see cells in plant and animal tissues and cell division

Relative scale of organs, tissues, cells (not directly measured)

Drawings of plant and animal cells

Drawings of viruses and bacteria

Drawings showing movement of food, water, oxygen, carbon dioxide, and digestive waste through land plants and vertebrates

Exclusions: Specific examples of molecular transport across the cell membrane (e.g., oxygen and carbon dioxide by diffusion, glucose by facilitated diffusion)

Instructional Examples:

i. Inquiry
CE: B1.1A, B1.1B, B1.1C, B1.1E, B1.1f, B1.1g, B1.1h, B2.5h

Investigate the effects of placing potato wedges in varying salt water solutions to show changes in mass related to diffusion of water into and out off the plant cells. Predict the concentration at which the plant cell mass will not change. Design and perform the experiment to test the prediction.

ii. Reflection
CE: B1.2C, B1.2D, B2.5h

Research the harmful effects on plants or animals that result from changes in membrane permeability. Such topics may include: herbicides that disrupt cell membranes, allowing the contents of the cell to leak out, swelling and the inflammatory process, or diseases that affect membrane permeability.

iii. Enrichment
CE: B1.2C, B2.5h

Participate in an Internet computer simulation using active transport to illustrate the mechanics of maintaining a concentration gradient for the benefit of the cell.

iv. General
CE: B1.1A, B1.1B, B1.1C, B1.1f, B2.5h

Investigate the effect of placing a plant cell (red onion, or similar plant) in solutions of differing salt or sugar concentrations to produce differential diffusion of the cell's vacuole. Predict the concentration at which osmosis would equalize the concentrations on either side of the membrane and perform an experiment to test that hypothesis.

v. Intervention
CE: B1.1C, B1.1D, B1.1E, B2.5h

Using agar-phenolphthalein blocks, investigate the rate of diffusion of sodium hydroxide to show the effects of surface area to volume ratio on limits to the size of cells and their ability to transport nutrients and wastes efficiently.

Units by Content Expectation

BIOLOGY

Unit 3: Cell Energetics

Code	Content Expectation
B2.4	*Cell Specialization* 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.
B2.4e	Explain how cellular respiration is important for the production of ATP (build on aerobic vs. anaerobic).
B2.5	*Living Organism Composition* 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.
B2.5D	Describe how individual cells break down energy-rich molecules to provide energy for cell functions.
B2.5x	*Energy Transfer* 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.
B2.5e	Explain the interrelated nature of photosynthesis and cellular respiration in terms of ATP synthesis and degradation.
B2.5f	Relate plant structures and functions to the process of photosynthesis and respiration.
B3.1	*Photosynthesis and Respiration* 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.
B3.1B	Illustrate and describe the energy conversions that occur during photosynthesis and respiration. (also repeated in Ecology)
B3.1C	Recognize the equations for photosynthesis and respiration and identify the reactants and products for both. (also repeated in Ecology)
B3.1f	Summarize the process of photosynthesis.

BIOLOGY

Unit 3 – Cell Energetics

Big Ideas (Core Concepts):
Organisms need energy to do cell work.

Photosynthesis converts the sun's energy into the chemical potential energy of food.

Cell respiration converts the chemical potential energy stored in food to the chemical potential energy stored in ATP.

ATP supplies the energy to do cell work.

Standard:
B2: Organization and Development of Living Systems
B3: Interdependence of Living Systems and the Environment

Content Statements:
B2.4: Cell Specialization
B2.5: Living Organism Composition
B2.5x: Energy Transfer
B3.1: Photosynthesis and Respiration

Content Expectations: (Content Statement Clarification)
B2.4e: Explain how cellular respiration is important for the production of ATP (build on aerobic vs. anaerobic).

Clarification: Explanation is limited to a comparison of energy production from the breakdown of food with oxygen (aerobic) or without oxygen (anaerobic). The explanation can include that the food molecule is more completely broken down when oxygen is present-a more complete "burning" of the food occurs-leading to more ATP production. Numbers of ATP, specific reactions of cellular respiration are not required.

B2.5D: Describe how individual cells break down energy-rich molecules to provide energy for cell functions.

Clarification: Mitochondria in cells have enzyme pathways that can break the chemical bonds in energy rich molecules (food) and the energy released is stored as chemical potential energy in ATP. The ATP then is the "energy currency" used to "pay" for doing cell work such as muscle contraction, neuron function, synthesis of other molecules, etc.

B2.5e: Explain the interrelated nature of photosynthesis and cellular respiration in terms of ATP synthesis and degradation.

Clarification: None

B2.5f: Relate plant structures and functions to the process of photosynthesis and respiration.

Clarification: Explanation limited to plant cells containing both chloroplasts and mitochondria to function in the processes of photosynthesis and respiration.

B3.1B: Illustrate and describe the energy conversions that occur during photosynthesis and respiration. (Also repeated in Ecology)

Clarification: None

B3.1C: Recognize the equations for photosynthesis and respiration and identify the reactants and products for both. (Also repeated in Ecology)

Clarification: The equations may be either words or formulas.
$C_6H_{12}O_6$ (glucose/sugar) + 6 O_2 (oxygen) $\longrightarrow$ 6 CO_2 (carbon dioxide) + 6 H_2O (water)

B3.1f: Summarize the process of photosynthesis.

Clarification: Explanation limited to plants capturing the energy of sunlight to put together carbon and oxygen (from carbon dioxide) and hydrogen (from water) to make high potential energy organic molecules (glucose) and releasing oxygen (from water) as a by-product.

Vocabulary:
aerobic
anaerobic
ATP
breakdown of food molecules
cellular respiration
cellular energy conversion
chloroplast
enzyme
mitochondrion
molecular energy
photosynthesis
potential energy
product
reactant
transforming matter and/or energy

Vocabulary Exclusions: Light reactions, Calvin Cycle (light-independent reactions), Krebs Cycle, glycolysis or intermediate products in respiration and photosynthesis

Real World Context:
Matter and energy transformations are involved in all life processes, such as photosynthesis, growth and repair, cellular respiration, and the need of living systems for continual input of energy. All single-celled and multicellular organisms have the same basic needs: water, air, a source of energy and materials for growth and repair, waste disposal, and conditions for growth and reproduction. In terms of matter and energy transformations, the source of food is the distinguishing difference between plants and animals.

Both plants and animals require a source of energy and materials for growth and repair, and both plants and animals use high-energy compounds as a source of fuel and building material. Plants, and some bacteria, are distinguished from animals by the fact that plants have the capability (through photosynthesis) to take energy from light and form higher energy molecules containing carbon, hydrogen and oxygen (carbohydrates) from lower energy molecules.

Plants are similar to animals in that, to make other molecules for their growth and reproduction, they use the energy that is released as carbohydrates react with oxygen. In making these other molecules, plants use breakdown products of carbohydrates, along with minerals from the soil and fertilizers (known colloquially as "plant foods"), as building blocks. Plants also synthesize substances (carbohydrates, fats, proteins, vitamins) that are components of foods eaten by animals.

So, while synthesis and breakdown are common to both plants and animals, photosynthesis (the conversion of light energy into stored chemical energy) is unique to plants, making them the primary source of energy for all animals.

Basic needs are connected with the processes of growth and metabolism. Organisms are made up of carbon-containing molecules; these molecules originate in molecules that plants assemble from carbon dioxide and water. In converting carbon-containing molecules back to water and carbon dioxide, organisms release energy, making some of it available to support life functions. Matter and energy transformations in cells, organisms, and ecosystems have a chemical basis.

Instruments, Measurements, and Representations
Representations of large biological molecules as polymers of simpler subunits

Labeled structural formulas of monomers of fats, proteins, carbohydrates (amino acids, fatty acids, simple sugars)

Chemical equations for overall process of cellular respiration and photosynthesis

General representations of synthesis and breakdown of large biomolecules
Diagrams of matter cycling and energy flow in ecosystems

Exclusions: Representations of specific detailed steps of synthesis and decomposition (e.g., intermediate steps and molecules, details of dehydration synthesis)

Instructional Examples:

i. Inquiry
CE: B1.1A, B1.1B, B1.1C, B1.1D, B1.1E, B1.1f, B1.1g, B1.1h, B2.1A

Study photosynthesis using a floating leaf disk assay or fast plants, allowing students to investigate variables of their own choosing. Make predictions about how these variables will affect the rate of photosynthesis or growth rate.

ii. Reflection
CE: B1.2B, B1.2C, B1.2f, B1.2g, B1.2k

Research the impacts on energy requirements to produce meat for American diets as opposed to vegetarian food sources. Comment on the economic impacts of these decisions. Is meat-eating cost effective?

iii. Enrichment
CE: B1.1A, B1.1C, B1.1E, B1.1f, B1.1g, B1.1h, B1.2g, B1.2j, B2.5f

Design and perform an activity that utilizes wild-type and atrazine-resistant Wisconsin fast-plants© to investigate the biological costs (e.g.,number of seeds, plant vigor) to the plants of that resistance. (Note: atrazine is an herbicide that inhibits photosynthesis.)

iv. General
CE: B1.1C, B1.1g, B1.1h, B3.1C

Use carbon dioxide and/or oxygen gas probes and software to measure changes in those gasses as seeds germinate. Compare these changes to those produced when insects (crickets) undergo cellular respiration.

v. Intervention
CE: B3.1B

As part of classroom discussion, develop a flowchart of the changes in energy forms that occur in cellular respiration and photosynthesis.

Units by Content Expectation

BIOLOGY

Unit 4: Comparative Structure and Function of Living Things

Code	Content Expectation
B2.4	*Cell Specialization* 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.
B2.4B	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).
B2.4C	Explain how different organisms accomplish the same result using different structural specializations (gills vs. lungs vs. membranes).
B2.5	*Living Organism Composition* 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.
B2.5B	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.

BIOLOGY

Unit 4: Comparative Structure and Function of Living Things

Big Ideas (Core Concepts)
Different structures in different organisms accomplish the same or similar function.

Systems work together physiologically to support the needs of the entire organism and the cells of which it is composed.

Standard:
B2: Organization And Development Of Living Systems

Content Statements:
B2.4: Cell Specialization
B2.5: Living Organism Composition

Content Expectations: (Content Statement Clarification)
B2.4B: 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.

Clarification: Descriptions are limited to discussion of how the process of evolution through natural selection gave rise to different strategies for accomplishing the same result in widely varying species.

B2.4C: Explain how different organisms accomplish the same result using different structural specializations (gills vs. lungs vs. membranes).

Clarification: Structural designs that serve the same purpose in varying species are limited to the organs and organ systems that follow: digestion, skeletal, respiration, reproduction and excretion. Organisms should include plant as well as animal structures (e.g., flowers, seeds and fruits as reproductive structures)

B2.5B: 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.

Clarification: Explanations are limited to the following systems and processes in plants and animals: how organisms use food/fuel, obtain gasses for metabolism, support themselves structurally, reproduce and excrete waste materials.

Vocabulary

anatomical characteristic
cell function
cell organelle
cellular differentiation
cellular waste disposal
gills
lungs
membranes
natural selection
nitrogenous waste
structural specialization

Real World Context

At the cellular level we find biological molecules associated with one another to form complex, organized and highly specialized structures within the cell called organelles. These sub-cellular organelles are each designed to perform specific processes within the cell. The cell is the basic structural and functional unit of life. It is the smallest and simplest part of living matter that can carry on all the activities necessary for life. In most multicellular organisms, cells associate to form tissues, such as muscle tissue or nervous tissue. Tissues are arranged into functional structures called organs, such as the heart or stomach. Each major group of biological functions is performed by a coordinated group of tissues and organs called an organ system. Functioning together with great precision, organ systems (e.g., nervous, circulatory, digestive, respiratory) make up the complex multicellular organism.

Living things share common needs for food, cellular waste disposal, exchange of gasses, and means of reproduction. Different organisms have evolved different physical and biochemical mechanisms for accomplishing the same function. For example, single and multi-celled organisms display diverse structural variations that allow them to accomplish necessary tasks. Examples of these structural adaptations may include: gills versus lungs versus trachea (insects) to exchange gasses or body design that includes internal or external skeletons. For example, the malpighian tubule system in an earthworm and the kidneys in a mammal both remove nitrogenous waste but are not structurally similar. Plants often do not get their share of attention in such discussions, but they also have organs and tissue types that serve their own needs and should be included in the discussion of comparative structure and function. Analogous structures, the result of convergent evolution, have provided many different, but perfectly functional, solutions to needs shared by all organisms.

Cellular processes (e.g., transport of materials, energy capture and release, protein building, waste disposal) are similar in plants and animals. The structures that accomplish these processes, including organs and organ systems as well as tissue types may be similar or different in various life forms.

Instruments, Measurement and Representations
Representations of various structural adaptations in plants and animals

Relative scale of organs, tissues, cells, biomolecules (not directly measured)

Exclusions: Names of cellular organelles except as follows: cell membranes, cell walls, chloroplasts, cytoplasm, Golgi apparatus, mitochondria, nucleus, ribosomes, vacuoles.

Instructional Examples
i. Inquiry
CE: B1.1g, B1.2C, B2.4B, B2.4C, B2.5B

Choose a life process (e.g. oxygen uptake, nitrogenous waste removal) and then describe how three organisms from different phyla perform this process. Propose an explanation for why these structures might have evolved in this form for this particular organism.

ii. Reflection
CE: B1.1g, B1.2C, B2.4B, B2.4C, B2.5B

Compare the fins of a whale and fins of a shark. How are they similar and how are they different?

iii. Enrichment
CE: B1.1g, B1.2C, B2.4B, B2.4C, B2.5B

Choose one life process and design two animals that accomplish the same life process with different anatomical structures. Be sure to detail the similarities and differences between the structures.

iv. General
CE: B1.1g, B1.2C, B2.4B, B2.4C

Dissect flowers and fruits and investigate the similarities and differences between plant and human reproductive structures. Discuss why different reproductive strategies are successful for each in terms of reproductive success.

v. Intervention
CE: B1.1g, B1.2C, B2.4B, B2.4C, B2.5B

Give examples of structures that perform similar functions in an insect and a mammal.

Units by Content Expectation

BIOLOGY

Unit 5: Human Systems

Code	Content Expectation
B2.1x	*Cell Differentiation* 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
B2.1e	Predict what would happen if the cells from one part of a developing embryo were transplanted to another part of the embryo.
B2.3x	*Homeostasis* The internal environment of living things must remain relatively constant. Many systems work together to maintain homeostasis. When homeostasis is lost, death occurs
B2.3d	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 one another.
B2.3g	Compare the structure and function of a human body system or subsystem to a nonliving system (e.g., human joints to hinges, enzymes and substrate to interlocking puzzle pieces).
B4.3	*Cell Division- Mitosis and Meiosis* Sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents.
B4.3g	Explain that cellular differentiation results from gene expression and/ or environmental influence (e.g., metamorphosis, nutrition).

BIOLOGY

Unit 5 – Human Systems

Big Idea (Core Concepts):
Cell differentiation occurs early in embryonic development and gives rise to all tissue types by a series of complex environmental and biochemical interactions.

Human systems work together to maintain the short and long term health of the organism.

Standard:
B2: Organization and Development of Living Systems
B4: Genetics

Content Statements(s):
B2.1x: Cell Differentiation
B2.3x: Homeostasis
B4.3: Cell Division – Mitosis and Meiosis

Content Expectations: (Content Statement Clarification)
B2.1e: Predict what would happen if the cells from one part of a developing embryo were transplanted to another part of the embryo.

Clarification: Predictions are limited to understanding that the organism undergoes specific changes early in embryonic development that differentiate certain cells to become certain cell types. Before those events, cells can become any tissue type, after that, they are fated and no longer have that ability.

B2.3d: 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 one another.

Clarification: Systems will be limited to those stated in the content expectation. General functions will not include detailed descriptions of organ tissue types, muscle and skeletal names, or the biochemistry of physiologic functions.

B2.3g: Compare the structure and function of a human body system or subsystem to a nonliving system (e.g., human joints to hinges, enzymes and substrate to interlocking puzzle pieces).

Clarification: None

B4.3g: Explain that cellular differentiation results from gene expression and/or environmental influence (e.g., metamorphosis, nutrition).

Clarification: Explanation is limited to general understanding that cell differentiation is the result of signals from inside the cell via genetic control and from external, environmental influences.

Vocabulary

breakdown of food molecules
cell division
cell function
cell organelle
cellular communication
cellular differentiation
cellular energy conversion
cellular regulation
cellular response
cellular waste disposal
differentiation
embryo formation
environmental influence
enzyme
gene combinations
gene expression
homeostasis
metamorphosis
neuron
neurotransmitter
recombination of genes
sexual reproduction
substrate
transplantation

Real World Context

The specialization process by which cells acquire an identity as cell type is called differentiation and occurs very early in the development of an embryo. Gastrulation, the division of embryonic cells into germ cell layers, occurs in humans during the second week after fertilization. Prior to these events, very early embryo cells are considered totipotent, capable of becoming any cell type. Embryonic stem cells, the subject of much controversy, are derived from these very early cells. Following gastrulation, the cells are destined to become only certain cell types. In embryos that have not undergone cellular differentiation, the transplantation of tissue from one region of the embryo to another has no effect. After embryonic cells have begun to specialize, however, transplanted cells lose this flexibility.

Specialization after germ cell formation is a complex process that involves the turning on and off of specific genes, input from neighboring cells and cues from the environment.

Much later in development and beyond, organs, made up of various tissue types, and organ systems work together physiologically to support the needs of the entire organism to support the major processes required for life.

Instruments, Measurement, and Representations

Microscopes to see cells in human tissues and cell division

Drawings and photographs of organs and cells of human origin

Drawings and photographs of developing human embryos

Drawings of organ systems and interactions between them (e.g., muscles and skeleton)

Representations of non-living systems (e.g., hinges, puzzle pieces, waves)

Measurements of organ functions (e.g., heart /pulse rate, respiration rate, blood pressure)

Instructional Examples:

i. Inquiry

CE: B1.1A, B1.1B, B1.1C, B1.1D, B1.1E, B1.1f, B1.1g, B1.1h, B2.3d

Students will monitor a partner's pulse or heart rate in a sitting position, at rest. The pair will propose possible ways to change the rate and test their hypotheses. Possible variables may include: change of position (prone, supine, standing, feet up or down). They will finally describe the physiological reasons for changes that are documented.

ii. Reflection

CE: B1.2B, B1.2C, B2.3d

Student groups will investigate the causes and effects of prevalent diseases, such as cardiovascular disease, pulmonary disease, and diabetes. They will include such factors as lifestyle choice and age as contributors to the disease process.

iii. Enrichment
CE: B1.1C, B1.2j, B2.3d, B2.3g

Students will construct a model of the human knee joint using cardboard tubes, plastic straws, rubber bands, tape, and other common materials. They can then hypothesize and test how the arrangement of different muscles and tendons will allow movement of the knee and leg via contraction and expansion of the muscle tissue. They can also see where cartilage cushions the impact points within the knee joint. (AAAS, 1987)

iv. General
CE: B1.1C, B1.1D, B1.1E, B1.1f, B2.3d

Students will study the effects of exercise on carbon dioxide production by using bromothymol blue indicator to show changes in the acidity of air exhaled into an aqueous solution.

v. Intervention
CE: B1.1C, B1.1D, B1.1E, B1.1g, B2.3d

Students will investigate the differences between reflexes (e.g., patellar, Kaminski) and reactions (e.g., drop/catch rulers, dealing cards) by observing the reflexes and timing reactions. They will then draw their neurological pathways on a diagram of the human body.

Units by Content Expectation

BIOLOGY

Unit 6: Homeostasis and Health

Code	Content Expectation
B2.3	*Maintaining Environmental Stability* 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.
B2.3A	Describe how cells function in a narrow range of physical conditions, such as temperature and pH (acidity) to perform life functions.
B2.3B	Describe how the maintenance of a relatively stable internal environment is required for the continuation of life.
B2.3C	Explain how stability is challenged by changing physical, chemical, and environmental conditions as well as the presence of disease agents.
B2.3x	*Homeostasis* The internal environment of living things must remain relatively constant. Many systems work together to maintain homeostasis. When homeostasis is lost, death occurs.
B2.3e	Describe how human body systems maintain relatively constant internal conditions (temperature, acidity, and blood sugar).
B2.3f	Explain how human organ systems help maintain human health.
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.

BIOLOGY

Unit 6 - Homeostasis and Health

Big Idea (Core Concepts):
Body systems function together to maintain homeostasis as conditions inside and outside the body change.

Regulatory mechanisms are responsible for many of the homeostatic controls systems in living organisms.

Standard:
B2: Organization and Development of Living Systems

Content Statement(s):
B2.3: Maintaining Environmental Stability
B2.3x: Homeostasis
B2.6x: Internal/External Cell Regulation

Content Expectations: (Content Expectation Clarification)
B2.3A: Describe how cells function in a narrow range of physical conditions, such as temperature and pH (acidity) to perform life functions.

Clarification: Descriptions will be limited to those listed in the content expectation (temperature and pH).

B2.3B: Describe how the maintenance of a relatively stable internal environment is required for the continuation of life.

Clarification: Systems involved in homeostasis will be limited to the nervous, digestive, immune, circulatory, respiratory and excretory systems of organisms.

B2.3C: Explain how stability is challenged by changing physical, chemical, and environmental conditions as well as the presence of disease agents.

Clarification: See clarification above.

B2.3e: Describe how human body systems maintain relatively constant internal conditions (temperature, acidity, and blood sugar).

Clarification: Mechanisms involved are limited to those pertaining to the examples listed in the content expectation.

B2.3f: Explain how human organ systems help maintain human health.

Clarification: Systems described are limited to those involved in nutrition, cardiovascular and respiratory health.

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.

Clarification: The expectation is limited to explanation involving the nervous and immune systems and hormone control as governing response to external stimuli.

Vocabulary:
behavioral response
disease agents
equilibrium
homeostasis
hormone
neuron
pH
physiological change
regulatory response

Real World Context:
Life processes are based on the maintenance of a relatively constant internal environment. Regulating this environment depends on the continual vigilance of many systems that monitor conditions both inside and outside an organism and work together to correct any significant deviations. The mechanisms involved in maintaining homeostasis require both communication in alerting the organism that changes have occurred as well as means to re-establish stable conditions. Some examples of life processes that require constant monitoring include many regulated by the nervous system (e.g., reactions, reflexes, reproduction, basic "housekeeping" functions) working in concert with the endocrine system and all other organ systems. These mechanisms are similar in all animals, although the specific conditions that are homeostatically regulated may be different.

Many of the regulatory responses to changes in an organism's environment involve negative feedback. These mechanisms work by signaling changes in the body that allow it to reverse the direction of change. For example, if blood sugar gets too high, the hormone insulin is secreted by the pancreas and it acts on the liver to remove glucose from the blood and store it as glycogen. This restores the level to a normal range. Blood is buffered biochemically to maintain a certain pH. If the acidity level is significantly altered, the body responds by adjusting the equilibrium position of the formation of carbonic acid-bicarbonate buffer system to allow the pH to be restored to a normal level. This change in equilibrium is assisted by the respiratory system, as breathing is adjusted to regulate the amount of carbon dioxide in the bloodstream. Many other examples may be used to illustrate these kinds of homeostatic mechanisms. An organism can receive and act on signals received from external stimuli through the nervous system and through these signals can find food, shelter, reproduce, and escape from predators. Many chronic diseases are the result of the inability of the body to respond efficiently to changes.

Instruments, Measurements, and Representations

Representations of organ systems: how a human body uses the excretory, circulatory, nervous and immune systems to maintain homeostasis.

Representations of homeostatic mechanisms: how the body controls temperature, acidity and blood sugar levels as examples of negative feedback.

Representations of how the body responds to pathogens/disease.

Instructional Examples:

i. Inquiry
CE: B1.1D, B1.1f

Play the online interactive video simulation game, "Creature Control: The Quest for Homeostasis":
www.creaturecontrolscience.com/homeostasis/play.php?site=kids

ii. Reflection
CE: B1.2C, B1.2D, B1.2j

Research methods of how medicine/technology intervenes when homeostatic mechanisms fail.

iii. Enrichment
CE: B2.3C, B2.3B, B2.6a

A Kangaroo rat lives in the desert without drinking water. How does it survive?

iv. General
CE: B2.3A, B2.3B, B2.3C, B2.3e, B2.3f, B2.6a

Discuss disease/healthy condition to show how homeostasis should work and what occurs when it doesn't. Example: diabetes and blood sugar levels.

v. Intervention
CE: B2.3f, B2.3C, B2.3B

Draw a cartoon of how the immune system cells fight a specific invader.

Units by Content Expectation

BIOLOGY

Unit 7: Matter and Energy in Ecosystems

Code	Content Expectation
B2.1	*Transformation of Matter and Energy in Cells* In multicellular organisms, cells are specialized to carry out specific functions such as transport, reproduction, or energy transformation.
B2.1A	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.
B2.1B	Compare and contrast the transformation of matter and energy during photosynthesis and respiration.
B2.5	*Living Organism Composition* 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.
B2.5C	Describe how energy is transferred and transformed from the Sun to energy-rich molecules during photosynthesis.
B3.1	*Photosynthesis and Respiration* 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.
B3.1A	Describe how organisms acquire energy directly or indirectly from sunlight.
B3.1B	Illustrate and describe the energy conversions that occur during photosynthesis and respiration.
B3.1C	Recognize the equations for photosynthesis and respiration and identify the reactants and products for both.
B3.1D	Explain how living organisms gain and use mass through the processes of photosynthesis and respiration.
B3.1e	Write the chemical equation for photosynthesis and cellular respiration and explain in words what they mean.
B3.2	*Ecosystems* 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.

B3.2A	Identify how energy is stored in an ecosystem.
B3.2B	Describe energy transfer through an ecosystem, accounting for energy lost to the environment as heat.
B3.2C	Draw the flow of energy through an ecosystem. Predict changes in the food web when one or more organisms are removed.
B3.3	*Element Recombination* 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.
B3.3A	Use a food web to identify and distinguish producers, consumers, and decomposers and explain the transfer of energy through trophic levels.
B3.3b	Describe environmental processes (e.g., the carbon and nitrogen cycles) and their role in processing matter crucial for sustaining life.

BIOLOGY

Unit 7: Matter and Energy in Ecosystems

Big Idea (Core Concepts)
Energy transformations from the Sun to organisms provide energy for all life forms to exist.

Matter transfer in ecosystems between living and non-living organisms provides the materials necessary for all life.

Matter and energy are conserved in ecosystems, although their transformations are not efficient.

Standard:
B2: Organization and Development of Living Systems
B3: Interdependence of Living Systems and the Environment

Content Statement(s):
B2.1: Transformation of Matter and Energy in Cells
B2.5: Living Organism Composition
B3.1: Photosynthesis and Respiration
B3.2: Ecosystems
B3.3: Element Recombination

Content Expectations: (Content Statement Clarification)
B2.1A: 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.

Clarification: Explanation is limited to one way flow of energy from the Sun to organisms and energy transformations that occur in the processes of photosynthesis and respiration. Reactants and products may be identified either by chemical formula or name.

B2.1B: Compare and contrast the transformations of matter and energy during photosynthesis and respiration.

Clarification: None

B2.5C: Describe how energy is transferred and transformed from the Sun to energy-rich molecules during photosynthesis.

Clarification: Energy-rich molecules are limited to simple carbohydrates produced during photosynthesis.

B3.1A: Describe how organisms acquire energy directly or indirectly from sunlight.

Clarification: None

B3.1B: Illustrate and describe the energy conversions that occur during photosynthesis and respiration.

Clarification: Illustrations may include flowcharts, graphic displays or pictures.

B3.1C: Recognize the equations for photosynthesis and respiration and identify the reactants and products for both.

Clarification: The equations may be either words or formulas.
$C_6H_{12}O_6$ (glucose/sugar) + 6 O_2 (oxygen) $\longrightarrow$ 6 CO_2 (carbon dioxide) + 6 H_2O (water).
Also located in Unit 3- Cell Energetics

B3.1D: Explain how living organisms gain and use mass through the processes of photosynthesis and respiration.

Clarification: None

B3.1e: Write the chemical equation for photosynthesis and cellular respiration and explain in words what they mean.

Clarification: The general form of the equations will be organized with the reactants on the left side of the equation and the products on the right, but they may consist of names of the participants and their chemical formulas. See also Clarification for B3.1C above.

B3.2A: Identify how energy is stored in an ecosystem.

Clarification: Identification is limited to discussion of chemical bonds as stored energy structures.

B3.2B: Describe energy transfer through an ecosystem, accounting for energy lost to the environment as heat.

Clarification: Descriptions are limited to non-numerical accounting of inefficiencies of energy transformations.

B3.2C: Draw the flow of energy through an ecosystem. Predict changes in the food web when one or more organisms are removed.

Clarification: Drawings will not include numerical data, but will emphasize inefficient conversions as energy moves through the trophic levels. Predictions may include changes in populations of organisms at various trophic levels as energy available to them changes.

B3.3A: Use a food web to identify and distinguish producers, consumers, and decomposers and explain the transfer of energy through trophic levels.

Clarification: None

B3.3b: Describe environmental processes (e.g., the carbon and nitrogen cycles) and their role in processing matter crucial for sustaining life.

Clarification: Descriptions are limited to names of participants in the carbon and nitrogen cycles and how they are used by and cycled through organisms.

Vocabulary

abiotic components of ecosystems
biological molecule
breakdown of food molecules
carbon
carbon cycle
carbon dioxide
cellular energy conversion
cellular respiration
chemical bond
chemical organization of organisms
consumer
energy requirements of living systems
flow of energy
flow of matter
nitrogen cycle
organic compound
organic compound synthesis
organic matter
photosynthesizing organism
producer
product
reactant
recombination of chemical elements
release of energy
transforming matter and/or energy
transporting matter and/or energy
trophic level

Real World Context:

Life is comprised of many complex cellular processes that occur in all organisms, including plants and animals. These processes include: the transport of materials, energy capture and release, protein building and waste disposal.

The flow of energy into ecosystems is from the Sun to producers through the process of photosynthesis. Producers are able to use this energy to convert carbon dioxide, a gas, and water into energy-rich, highly-condensed carbon compounds, usually carbohydrates. Plants may then use these materials for their own cellular energy needs by the process of cellular respiration. Consumers also obtain usable energy from the biochemical breakdown of carbohydrates and molecules derived from them during respiration. In this way, derived directly or indirectly from a plant source, carbohydrates are foods that, when converted into waste materials, yield usable energy for the organism in the process of cellular respiration. Ultimately, nearly all organisms will be subjected to breakdown by decomposers, who themselves convert mass into waste materials, using the derived energy.

When consumers eat plants or other consumers, they are transferring matter, in the form of flesh, through an ecosystem. Energy is also being transferred as it is stored in the chemical bonds that bind the food molecules together. As this energy is transferred through ecosystems, liberated for organismal use by cellular respiration, conversions are not entirely efficient and heat is lost as a by-product at each step, dissipated into the environment, leaving less *usable* energy available to each successive trophic level.

Organisms may be classified as producers, consumers and decomposers, based on their feeding relationships within their particular food web. These food webs may be from ecosystems that are widely represented in textbooks and of importance to all students, even if they do not live near them.

Changes in relationships and populations of producers and consumers may occur as the result of the loss of one or more types of organisms in the ecosystem. The loss of any group of organisms from an ecosystem changes the flow of energy within that system.

The overall cycling of matter, specifically carbon and nitrogen, through ecosystems as it passes between living systems to abiotic components of ecosystems is very important because it shows the interdependence of organisms with their physical environment, and vice versa.

Human created disturbances in ecosystems or environments, including local and global climate change, uses of tilling and pesticides to favor human crops, human land use, harvesting of fish stocks, pollution, invasive species, and others are common to many ecosystems and represent problems that cause imbalances in the cycling of matter and the transformation of energy through ecosystems.

Instruments, Measurement, and Representations

Chemical equations for overall processes of cellular respiration and photosynthesis

General representations of synthesis and breakdown of large bio-molecules

Diagrams of matter cycling and energy flow in ecosystems

Qualitative descriptions of biodiversity in various ecosystems

Qualitative descriptions of fluctuations in populations due to natural and human generated disturbances

Graphic or geographic representations of size, diversity, key species in ecosystems

Analysis of quantitative data on biodiversity

Exclusions:

Representations of specific detailed steps of synthesis and decomposition (e.g., intermediate steps and molecules, details of dehydration synthesis)

Light Reactions, Calvin cycle, Krebs cycle, glycolysis, or intermediate products in respiration and photosynthesis

Tracking particular atoms or elements (especially carbon) through the processes of photosynthesis, growth, food webs, and cellular respiration at multiple levels: cellular, organismal, and ecological

Instructional Examples:

i. Inquiry

CE: B1.1A, B1.1B, B1.1C, B1.1D, B1.1E, B1.1f, B1.1g, B1.1h, B2.1A

Study photosynthesis using a floating leaf disk assay or fast plants, allowing students to investigate variables of their own choosing. Make predictions about how these variables will affect the rate of photosynthesis or growth rate.

ii. Reflection
CE: B1.1g, B1.2A, B1.2B, B1.2C, B1.2D, B1.2f, B1.2g, B1.2j, B1.2k

Evaluate the claims of products that promise to increase energy efficiency or promote the use of alternative fuels. Students should work in groups to report their findings to classmates.

iii. Enrichment
CE: B1.1D, B1.1E, B1.1g, B1.1h, B3.3b

Perform a laboratory activity to investigate the effects of nitrogen fertilizers on the growth of algae.

iv. General
CE: B1.1A, B1.1D, B1.1E, B1.1g, B1.2C, B3.2A, B3.2B, B3.2C, B3.3A

Investigate the effect of an invading species on a local ecosystem. Predict how local food webs are altered as the newcomer changes existing feeding relationships.

v. Intervention
CE: B3.1A, B3.3A

Provide, or allow students to draw or collect, common cartoon images and ask them to work in small groups to construct a food web showing the trophic interactions between the members of the web. They should label their images as producers, consumers and decomposers and be sure to include the Sun as the ultimate source of energy to the system.

Units by Content Expectation

BIOLOGY

Unit 8: Population Ecology and Human Impacts on Ecosystems

Code	Content Expectation
B2.2x	*Proteins* 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.
B2.2g	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.
B3.4	*Changes in Ecosystem* 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.
B3.4A	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.
B3.4C	Examine the negative impact of human activities.
B3.4x	*Human Impact* Humans can have tremendous impact on the environment. Sometimes their impact is beneficial, and sometimes it is detrimental
B3.4d	Describe the greenhouse effect and list possible causes.
B3.4e	List the possible causes and consequences of global warming.
B3.5	*Populations* 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.
B3.5A	Graph changes in population growth, given a data table.
B3.5B	Explain the influences that affect population growth.
B3.5C	Predict the consequences of an invading organism on the survival of other organisms.

B3.5x	*Environmental Factors* 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
B3.5e	Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of population dynamics within ecosystems.
B3.5f	Graph an example of exponential growth. Then show the population leveling off at the carrying capacity of the environment.

BIOLOGY

Unit 8: Population Ecology and Human Impacts on the Environment

Big Ideas (Core Concepts)
Populations relate to each other within their ecosystem.

Ecosystems usually establish equilibrium between their biotic inhabitants and abiotic factors. These relationships typically are stable for long periods of time.

Ecosystems are characterized by both stability and change, on which human populations can have an impact.

Standard:
B2: Organization and Development of Living Systems
B3: Interdependence of Living Systems and the Environment

Content Statements:
B2.2x: Proteins
B3.4: Changes in Ecosystems
B3.4x: Human Impact
B3.5: Populations
B3.5x: Environmental Factors

Content Expectations: (Content Statement Clarification)
B2.2g: 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.

Clarification: None

B3.4A: 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.

Clarification: None

B3.4C: Examine the negative impact of human activities.

Clarification: None

B3.4d: Describe the greenhouse effect and list possible causes.

Clarification: None

B3.4e: List the possible causes and consequences of global warming.

Clarification: None

B3.5A: Graph changes in population growth, given a data table.

Clarification: None

B3.5B: Explain the influences that affect population growth.

Clarification: None

B3.5C: Predict the consequences of an invading organism on the survival of other organisms.

Clarification: Predictions are limited to the effect of a non-native species on the populations of native species.

B3.5e: Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of population dynamics within ecosystems.

Clarification: Descriptions are limited to effects of abiotic factors (temperature, sunlight, pH, nutrient availability) on population dynamics.

B3.5f: Graph an example of exponential growth. Then show the population leveling off at the carrying capacity of the environment.

Clarification: None

B3.5g: 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.

Clarification: Predictions are limited to the effect of introducing a new species to an environment and the potential of this new species to be successful.

Vocabulary

abiotic component of the ecosystem
biological adaptations
carrying capacity
ecosystem stability
equilibrium of ecosystems
exponential growth
global warming
greenhouse effect
human modification of the ecosystem
population dynamics
reproductive capacity
succession

Real World Context

Populations initially often grow exponentially in a favorable environment, but all population growth ultimately will level off (carrying capacity) when a resources (e.g., food, nest sites, cover) become limiting. Abiotic factors, such as temperature, rainfall, pH of aquatic systems, and seasonal variations can influence a population's growth rate and the carrying capacity it reaches. In general, density-dependent factors such as habitat size, disease, competition, floods, etc. regulate a population's size within an ecosystem.

Natural disturbances in ecosystems (e.g. fires, floods, sedimentation, and volcanoes) are density-independent and disrupt the community structure and consequently affect all populations.

There is a relationship between the stability of an ecosystem and its biodiversity. External events, either natural or man-made, can cause an ecosystem to change in many ways. These external forces affect ecological succession adversely, but if the ecosystem is then left undisturbed it will ultimately revert to its earlier form through stages of succession.

Humans have created disturbances in most ecosystems and environments. These disturbances have been as varied as local and global climate change, altering the land to favor crops, human land uses, harvesting of fish stocks, causing various forms of pollution and aiding in the introduction of invasive species. Invasive species and nutrient loading has changed the population dynamics of species within the Great Lakes. These disturbances change the population dynamics of species within an ecosystem.

Examples of human impact on other species include reducing the amount of Earth's surface available as habitats, interfering with food sources, changing the temperature and chemical composition of habitats, introducing foreign species into ecosystems, and altering organisms directly through selective breeding and genetic engineering.

A displaced organism will be tested when it encounters a new environment, but its ability to survive will depend on the degree to which the new surroundings meet its physiological needs and the amount of competition it encounters from native species. If it is able to establish a new niche, it can be successful….so successful, in fact, that it may place stress on the natural inhabitant.

Many scientists believe the zebra mussel colonization of the Great Lakes is concentrating biomass and nutrient energies in the benthic or bottom region of the lakes. This is biomass that was once available to other (often native) species. The full implications of zebra mussel colonization of the Great Lakes are still playing out and are not yet fully understood. There is growing evidence that the mussels are responsible for the decline of the native aquatic invertebrate Dioperia, which are an important food item for many fish in the Great Lakes. The changing populations of fish will bring their consequences, creating a cascade

effect. Zebra mussels attach to most substrates including sand, silt, and harder substrates. Other examples of the interdependence of organisms include relationships between the environment and public health and between migration and the potential spread of diseases.

Instruments, Measurement and Representation

Qualitative descriptions of biodiversity in different ecosystems

Qualitative and graphical descriptions of fluctuations in populations due to natural and anthropogenic disturbances

Graphic or geographic representations of size, diversity, key species in ecosystems

Analysis of quantitative data on biodiversity

Exclusions: Mathematical calculations of population change.

Instructional Examples

i. Inquiry
CE: B1.1A, B1.1B, B1.1g, B1.1h, B1.1i, B1.2f, B1.2g, B3.4C

Design a science-based solution to a local, regional, or worldwide environmental issue.

ii. Reflection
CE: B1.2B, B1.2C, B1.2D, B1.2k, B3.4A, B3.5B

Predict positive and negative effects of various human activities on a local ecosystem.

iii. Enrichment
CE: B1.1A, B1.1B, B.3.4C, B3.5.C

Develop a protocol for introducing an organism that will control zebra mussel populations in the western basin of Lake Erie. The protocol must take into account the ecosystem that is being affected, explain the impact the zebra mussel is having on the ecosystem, suggest a response to the zebra mussel problem and provide an explanation of the impact the new organism will have on other organisms in the ecosystem. It should include a procedure for testing the hypothesis prior to implementation on a large scale. (Modified from Oakland Assessment Guide)

iv. General
CE: B1.1C, B1.1E, B1.1h, B3.4A, B3.5A, B3.5.B, B3.5e

Predict the effects of crowding on the growth of seedlings. In small groups, design and carry out an experiment that compares trays with different densities (concentration equally distributed) of plants (e.g., radishes). Observe the effects of crowding on the different populations of plants and the abiotic factors for which the plants were competing (e.g., light, water, nutrients, etc.).

v. Intervention
CE: B3.4A, B3.4C, B3.5C

Take a field trip to a "natural area" that is local and then walk close to the school. Talk about the differences and similarities between the "natural area" and the school's neighborhood. What caused these differences? What impact do these changes have on the plants and animals in the neighborhood?

Units by Content Expectation

BIOLOGY

Unit 9: Division and Chromosome Mutations

Code	Content Expectation
B2.1	*Transformation of Matter and Energy in Cells* In multicellular organisms, cells are specialized to carry out specific functions such as transport, reproduction, or energy transformation.
B2.1C	Explain cell division, growth, and development as a consequence of an increase in cell number, cell size, and/or cell products.
B2.1x	*Cell Differentiation* 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.
B2.1d	Describe how, through cell division, cells can become specialized for specific function.
B3.5	*Populations* 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.
B3.5d	Describe different reproductive strategies employed by various organisms and explain their advantages and disadvantages.
B4.2	*DNA* 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.
B4.2A	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 (non-inherited mutations).
B4.3	*Cell Division- Mitosis and Meiosis* Sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents.
B4.3A	Compare and contrast the processes of cell division (mitosis and meiosis), particularly as those processes relate to production of new cells and to passing on genetic information between generations.
B4.3B	Explain why only mutations occurring in gametes (sex cells) can be passed on to offspring.
B4.3C	Explain how it might be possible to identify genetic defects from just a karyotype of a few cells.

B4.3d	Explain that the sorting and recombination of genes in sexual reproduction result in a great variety of possible gene combinations from the offspring of two parents.
B4.3e	Recognize that genetic variation can occur form such processes as crossing over, jumping genes, and deletion and duplication of genes.
B4.3f	Predict how mutations may be transferred to progeny.
B4.4x	*Genetic Variation* 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.
B4.4b	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.

BIOLOGY

Unit 9: Cell Division and Chromosome Mutations

Big Ideas (Core Concepts):
The process of mitosis produces new cells needed for growth of an organism and these cells differentiate into specific cells with specialized functions.

Mitosis ensures genetic continuity. Mutations in genes that control mitosis may cause uncontrolled cell division which leads to cancer.

Meiosis produces sex cells for sexual reproduction that passes on genes to the next generation. Genetic mutations may be passed on from parent to offspring through these cells.

Standard:
B2: Organization and Development of Living Systems
B3: Interdependence of Living Systems and the Environment
B4: Genetics

Content Statements:
B2.1: Transformation of Matter and Energy in Cells
B2.1x: Cell Differentiation
B3.5: Populations
B4.2: DNA
B4.3: Cell Division- Mitosis and Meiosis
B4.4x: Genetic Variation

Content Expectations: (Content Statement Clarification)
B2.1C: Explain cell division, growth, and development as a consequence of an increase in cell number, cell size, and/or cell products.

Clarification: None

B2.1d: Describe how, through cell division, cells can become specialized for specific function.

Clarification: Limited to student recognition that the position of cells in early embryonic development influence their fate as tissue types. These influences may include chemical signals from neighboring cells or specialization due to the genetic switching on or off of genes within the cell that cause it to make products that, in turn, further influence specific developmental features.

B3.5d: Describe different reproductive strategies employed by various organisms and explain their advantages and disadvantages.

Clarification: None

B4.2A: 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 (non-inherited mutations).

Clarification: None

B4.3A: Compare and contrast the processes of cell division (mitosis and meiosis), particularly as those processes relate to production of new cells and to passing on genetic information between generations.

Clarification: Limited to identification of pictures or diagrams of cell division and explanation that mitosis produces new body cells and meiosis is responsible for the production of sex cells and passing genetic information on to the next generation.

B4.3B: Explain why only mutations occurring in gametes (sex cells) can be passed on to offspring.

Clarification: None

B4.3C: Explain how it might be possible to identify genetic defects from just a karyotype of a few cells.

Clarification: Limited to identification of Down syndrome and Turner's syndrome as examples of genetic defects by comparing those karyotypes to a normal karyotype.

B4.3d: Explain that the sorting and recombination of genes in sexual reproduction result in a great variety of possible gene combinations from the offspring of two parents.

Clarification: Recognize a diagram of meiosis and possible gene combinations that could occur through meiosis.

B4.3e: Recognize that genetic variation can occur from such processes as crossing over, jumping genes, and deletion and duplication of genes.

Clarification: Limited to recognizing diagrams or pictures that illustrate crossing over, duplication or deletion of parts of chromosomes.

B4.3f: Predict how mutations may be transferred to progeny.

Clarification: Recognize how gene mutations such as sickle cell anemia and PKU can be passed on to offspring.

B4.4b: 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.

Clarification: Limited to recognizing that gene mutations that control cell division cause cancer. These mutations can be passed on from parent to offspring, or more commonly can develop over the course of one's life due to exposure to chemicals and/or radiation.

Vocabulary:
cancer
carcinogenic
chromosome
chromosome pair
crossing over
deletion
DNA replication
diploid
duplication of genes
haploid
gametes
genetic variation
jumping genes
karyotype
meiosis
mitosis
mutation
new gene combinations
progeny
recombination of genetic material
sex cell
sex chromosomes

Real World Context
Students should know enough about atoms and molecules from earlier instruction to make sense of the idea that DNA carries instructions for the assembly of proteins, determining their structure and the rates at which they are made. Students' growing notion of systems can help them understand how turning instructions on and off can sequence developments over a lifetime and that each cell's immediate environment can influence its development, even though nearly all cells carry the same DNA instructions.

DNA provides for both the continuity of traits from one generation to the next and the variation that in time can lead to differences within a species and to entirely new species. Understanding DNA makes possible an explanation of such phenomena as the similarities and differences between parents and offspring,

hereditary diseases, and the evolution of new species. This understanding also makes it possible for scientists to manipulate genes and thereby create new combinations of traits and new varieties of organisms.

Instruments, Measurement, and Representations

Identify production of cells for growth and repair as from mitosis.

Identify a normal karyotype of a human cell as having 23 pairs of chromosomes.

Representations of pictures and diagrams of cell division (mitosis and meiosis)

Representations of chromosome diagrams with normal patterns, duplications, deletions and crossing over illustrated

Exclusion: Names of stages of mitosis and meiosis

Instructional Examples:

i. Inquiry
CE: B1.1A, B1.1D, B1.1i, B1.2C, B4.3f

Use an online database, such as NCBI, (National Center for Biotechnology Information: www.ncbi.nlm.nih.gov/), to investigate the location of PKU, sickle cell anemia, or cystic fibrosis on a chromosome. Use other tools at NCBI to determine the normal gene sequence of DNA-and the common mutation. How does the normal gene product function? (protein) What are the effects of the mutated gene product?

ii. Reflection
CE: B1.1i, B1.2B, B1.2C, B1.2f, B1.2k, B2.1C

How do embryonic stem cells differ from adult stem cells? What are the ethical dilemmas associated with the use of embryonic stem cells? Are there any dilemmas associated with the use of adult stem cells? What ways are stem cells currently being used in research?

iii. Enrichment
CE: B1.1i, B1.2C, B4.4b

Research the genetic cause of a specific type of cancer. (e.g. colon or breast cancer) Include the explanation of the role of oncogenes and tumor suppressor genes and which types are commonly implicated in different cancers.

iv. General
CE: B4.3C

Observe different karyotypes of individuals which include normal, Turner's Syndrome, and Down syndrome examples. Ask students to determine what the chromosome pattern is in each type.

v. Intervention
CE: B4.3A

Draw a cell going through mitotic divisions and meiotic divisions. Start with the same diploid number in each and show and explain what happens to the chromosome number at the end of division.

Units by Content Expectation

BIOLOGY

Unit 10: DNA/RNA and Protein Synthesis

Code	Content Expectation
B4.1	*Genetics and Inherited Traits* 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.
B4.1B	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.
B4.2	*DNA* 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.
B4.2B	Recognize that every species has its own characteristic DNA sequence.
B4.2C	Describe the structure and function of DNA.
B4.2D	Predict the consequences that changes in the DNA composition of particular genes may have on an organism (e.g., sickle cell anemia, other).
B4.2E	Propose possible effects (on the genes) of exposing an organism to radiation and toxic chemicals.
B4.2x	*DNA, RNA, and Protein Synthesis* 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.
B4.2f	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.
B4.2g	Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.

B4.4x	*Genetic Variation* 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.
B4.4c	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.

BIOLOGY

Unit 10 – DNA/RNA and Protein Synthesis

Big Ideas (Core Concepts):
The central dogma of biology states that DNA codes for proteins that are responsible for the production of inherited traits.

The processes by which proteins are made from DNA are transcription and translation.

DNA must replicate itself faithfully in order to pass all genetic information on to descendent cells, including sex cells.

Standard:
B4: Genetics

Content Statements:
B4.1: Genetics and Inherited Traits
B4.2: DNA
B4.2x: DNA, RNA and Protein Synthesis
B4.4x: Genetic Variation

Content Expectations: (Content Statement Clarification)
B4.1B: 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.

Clarification: None

B4.2B: Recognize that every species has its own characteristic DNA sequence.

Clarification: None

B4.2C: Describe the structure and function of DNA.

Clarification: DNA exists as a double stranded helix, joined by a sequence of nucleotides (subunits of DNA) of four types in specific sequences. Content expectation is limited to complementary sequencing and knowledge that sequences of DNA nucleotides "code" for the amino acid sequence of a protein.

B4.2D: Predict the consequences that changes in the DNA composition of particular genes may have on an organism (e.g., sickle cell anemia, other).

Clarification: Expectation is limited to understanding that if DNA sequence changes, non-functioning proteins may result that lead to adverse effects in the organism or its offspring. These adverse effects may take the form of commonly inherited disorders such as sickle cell anemia, phenylketonuria or cystic fibrosis.

B4.2E: Propose possible effects (on the genes) of exposing an organism to radiation and toxic chemicals.

Clarification: Effects are limited to understanding that certain chemicals and environmental hazards may change the structure of the DNA, altering the instructional function of the DNA molecule to make correct proteins.

B4.2f: 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.

Clarification: Demonstration is expected to use a DNA or messenger RNA coding chart to allow the code to be read and the correct amino acid to be identified.

B4.2g: Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.

Clarification: Content expectation is limited to understanding of replication of DNA by pairing of complementary nucleotides to exposed parent strands in the cell's nucleus. The expectation will not address directionality of the DNA strands. Content expectation is limited to understanding that transcription occurs in the nucleus and involves pairing of DNA nucleotides to RNA complementary nucleotides to form strands then released from the nucleus and travels to the cytoplasm, where it serves as a template for protein assembly. Content expectation is limited to understanding that translation is the process of taking the RNA strand formed in transcription and using it as a template for the assembly of amino acids, in sequence, to form a protein.

B4.4c: 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.

Clarification: Content expectation is limited to explanation of mutations in the DNA sequence that may sometimes cause changes in the traits of an organism and its offspring, or may cause no changes, depending on where in the protein sequence the change is made.

Vocabulary

amino acid sequence
anatomical characteristic
biochemical characteristic
biological adaptation
cell nucleus
chromosome
complementary sequence
degree of kinship
DNA
DNA molecule
DNA sequence
DNA subunit
double helix
enzyme
evidence for unity among organisms
gene
genetic diversity
genetic mutation
genetic variation
inherited trait
messenger RNA
molecular synthesis
new gene combinations
nucleated cell
phylogenetics
protein
protein structure
protein synthesis
recombination of genetic material
ribosome
storage of genetic information
transcription
translation
transfer RNA

Real World Context

The biochemical identity of an organism is determined by its DNA, which is characteristic for each species and sometimes for each individual within that species. DNA codes, in nucleotides, the directions for making all the protein types required by individuals to express their heredity. The function of each protein molecule depends on its specific sequence of amino acids and the shape of the molecule. These proteins are characteristic of each species and many of them, enzymes, in particular, are responsible for allowing individuals to express genetic traits specific to each species.

DNA duplication in cell division involves the copying of all genetic material for descendent cells, whereas the process of gamete formation involves the apportioning of DNA to eggs/sperm with only half the DNA.

The processes of DNA duplication, transcription and translation are very complex, but provide the basis for the central dogma of biology – that in most cases, DNA information is copied onto messenger RNA by the process of transcription and proteins are synthesized using messenger RNA as a template and transfer RNA as delivery molecules that bring the appropriate amino acids to the ribosome for assembly. This process is called translation.

When errors occur in any of the processes described above, the results may be positive, negative or neutral to the organism and/or its offspring. Mutations may result in changes in structure that render the protein non-functional, or they may result in insignificant changes that do no harm to the functioning of the protein and hence its expression in the individual. There are a number of common diseases that are inherited by offspring of parents who carry faulty genes. These include: sickle cell anemia which results in the manufacture of defective hemoglobin by the victim's red blood cells, phenylketonuria, a disease that results in the inability of a victim's liver to metabolize a common amino acid and cystic fibrosis, a disorder that causes lung damage in affected people.

Instruments, Measurement, and Representations

Double helix as a representation to include understanding that it is the sequence of nucleotides that gets passed from one generation to the next and is responsible for DNA functions

Representations of the DNA or messenger RNA coding system for amino acids – both "wheel" and table types are available. The representation used will include enough clarification so that students understand how to interpret the information included.

Representations of messenger RNA, transfer RNA and amino acid sequences

Representations showing degree of relatedness between species using DNA sequences

Diagrams of DNA duplication, transcription and translation

Exclusions: Structures of amino acids
Structures of nitrogen bases associated with DNA and RNA

Instructional Examples:

i. Inquiry
CE: B1.1A, B1.1B, B1.1C, B1.1D, B1.1E, B1.1g, B1.1h, B4.2E

Design and perform an investigation to determine the effects of exposing Wisconsin Fast Plants© (or radish seeds) to varying amounts of ultraviolet radiation, provided by a light box. Seeds will then be planted to determine the physical characteristics and reproductive success of these possible mutations.

ii. Reflection
CE: B1.1B, B1.2A, B1.2B, B1.2C, B1.2D, B1.2f, b1.2g, B1.2j, B1.2k

Research the levels of everyday radiation emitted by common devices as well as background from solar and other natural sources. Are these realistic hazards to genetic material and is it necessary to protect our DNA from these perils? Prepare a poster presentation to advise classmates of findings.

iii. Enrichment
CE: B4.2f, B4.2g

Design an organism using short amino acid sequences to stand for specific traits of a fictitious organism. Show how the DNA sequence codes for messenger RNA sequences that, in turn, code for amino acids. Draw a picture of your organism and share your design with a partner.

iv. General
CE: B4.2f, B4.2g

Play "Codon Bingo" with classmates, using the processes of translation and transcription to code for amino acids.

v. Intervention
CE: B4.2f, B4.2g

Play a DNA relay game, with students receiving an index card with a three nucleotide DNA sequence that corresponds to one of a group of cards with corresponding messenger RNA sequences that likewise corresponds to a group of cards bearing amino acid names. Teams will compete to correctly "perform" transcription and translation to win the game.

Units by Content Expectation

BIOLOGY

Unit 11: Mendelian and Molecular Genetics (includes Biotechnology)

Code	Content Expectation
B4.1	*Genetics and Inherited Traits* 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.
B4.1A	Draw and label a homologous chromosome pair with heterozygous alleles highlighting a particular gene location.
B4.1c	Differentiate between dominant, recessive, co-dominant, polygenic, and sex-linked traits.
B4.1d	Explain the genetic basis for Mendel's laws of segregation and independent assortment.
B4.1e	Determine the genotype and phenotype of monohybrid crosses using a Punnett Square.
B4.2x	*DNA, RNA, and Protein Synthesis* 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.
B4.2h	Recognize that genetic engineering techniques provide great potential and responsibilities.
B4.4x	*Genetic Variation* 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.
B4.4a	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 of no effect on the offspring's success in its environment.

BIOLOGY

Unit 11: Mendelian and Molecular Genetics (includes Biotechnology)

Big Ideas (Core Concepts):
DNA in genes codes for the production of proteins.

Mutations in the DNA code can lead to dysfunctional proteins -genetic disorders.

Cells differ in the genes they express-all genes are not used in all cells.

Standard:
B4: Genetics

Content Statements:
B4.1: Genetics and Inherited Traits
B4.2x: DNA, RNA, and Protein Synthesis
B4.4x: Genetic Variation

Content Expectations: (Content Statement Clarification)
B4.1A: Draw and label a homologous chromosome pair with heterozygous alleles highlighting a particular gene location.

Clarification: None

B4.1c: Differentiate between dominant, recessive, co-dominant, polygenic, and sex-linked traits.

Clarification: Traits identified by definition (dominant traits are expressed if the allele is present, recessive traits only if the dominant alleles are missing, co-dominant in which both alleles are expressed, polygenic having more than one gene active in determining trait and sex-linked traits as alleles on X chromosome). Also included are interpretations of Punnett Square results, given that the trait is identified as one of those listed in the content expectation. Interpretation may include prediction of phenotype or genotype ratios.

B4.1d: Explain the genetic basis for Mendel's laws of segregation and independent assortment.

Clarification: None

B4.1e: Determine the genotype and phenotype of monohybrid crosses using a Punnett Square.

Clarification: None

B4.2h: Recognize that genetic engineering techniques provide great potential and responsibilities.

Clarification: Limited to understanding that genetic engineering is used currently to produce gene products such as human insulin. The great responsibility is making sure that altered genes don't upset natural ecosystems or cause human suffering. There are also ethical decisions regarding use of stem cells and cloning.

B4.4a: 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 of no effect on the offspring's success in its environment.

Clarification: Recognize that only a cell that becomes a sex cell can pass these genetic changes on to the next generation.

Vocabulary:

allele
chromosome
chromosome pair
co-dominant traits
DNA replication
dominant trait
gene encoding
gene expression
genetic diversity
gene location
genetic mutation
genetic variation
genotype
heterozygous
homologous chromosome
human genetics
independent assortment
law of Segregation
meiosis
Mendelian genetics
new gene combinations
phenotype
phylogenetics
polygenic traits
protein
protein synthesis
Punnett Square
recessive traits
recombination of genetic material

sex cell
sex chromosomes
sex-linked traits
shared characteristics
storage of genetic information

Real World Context:

Organisms closely resemble their parents; their slight variations can accumulate over many generations and result in more obvious differences between organisms and their ancestors. Recent advances in biochemistry and cell biology have increased understanding of the mechanisms of inheritance and enabled the detection of disease related genes. Such knowledge is making it possible to design and produce large quantities of substances to treat disease and, in years to come, may lead to cures.

All plants and animals (and one-celled organisms) develop and have the capacity to reproduce. Reproduction, whether sexual or asexual, is a requirement for the survival of species. Characteristics of organisms are influenced by heredity and environment. Genetic differences among individuals and species are fundamentally chemical. Different organisms are made up of somewhat different proteins. Reproduction involves passing the DNA with instructions for making these proteins from one generation to the next with occasional modifications.

Instruments, Measurements, and Representations

Representations of changes in DNA (mutations)

Representations of genetic variation in cells arising from gamete formation and sexual reproduction-inherited traits, mutations

Representation of genotype frequency using Punnett squares

Representations of basic bioinformatics (DNA fingerprinting, reproductive and therapeutic cloning) used as context for items

Using microscopes to identify chromosomes

Use of electrophoresis as a technique for separating molecules based on differences in their properties (e.g., mass)

Double helix as a representation to include understanding that it is the sequence of nucleotides that gets passed from one generation to the next and is responsible for DNA functions

Graphic results of electrophoresis

Exclusions:
PCR
Details of how electrophoresis works
Structure of nucleotides
Names of stages of mitosis and meiosis

Instructional Examples:

i. Inquiry
CE: B1.1A, B1.1B, B1.1C, B1.1D, B1.1f, B1.1G, B4.1e

Genetic studies of Fast Plants or *Drosophila* to determine observable traits

ii. Reflection
CE: B1.2A, B1.2B, B1.2C, B1.2D, B1.2f, B1.2k

Research the effects of Genetically Modified Organisms on the environment. Students work in groups and present their findings to classmates.

iii. Enrichment
CE: B4.2h, B4.4a, B1.1C, B1.1g, B1.1D

Use of online DNA databases (such as the Genetic Science Learning Center from the University of Utah (http://learn.genetics.utah.edu)) to link DNA sequence to protein structure and function

iv. General
CE: B4.2h, B1.1D, B1.1E, B1.1g

DNA fingerprinting Lab or DNA fingerprinting Simulation

v. Intervention
CE: B4.1c, B4.1e, B1.1D, B1.1E

Perform pedigree study of family members (or simulation study).

Units by Content Expectation

BIOLOGY

Unit 12: Evolution

Code	Content Expectation
B2.4	*Cell Specialization* 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.
B2.4A	Explain that living things can be classified based on structural, embryological, and molecular (relatedness of DNA sequence) evidence.
B2.4d	Analyze the relationships among organisms based on their shared physical, biochemical, genetic, and cellular characteristics and functional processes.
B3.4	*Changes in Ecosystems* 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.
B3.4B	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.
B5.1	*Theory of Evolution* 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.
B5.1A	Summarize the major concepts of natural selection (differential survival and reproduction of chance inherited variants, depending on environmental conditions).
B5.1B	Describe how natural selection provides a mechanism for evolution.
B5.1c	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).
B5.1d	Explain how a new species or variety originates through the evolutionary process of natural selection.
B5.1e	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).

B5.1f	Explain, using examples, how the fossil record, comparative anatomy and other evidence supports the theory of evolution.
B5.1g	Illustrate how genetic variation is preserved or eliminated from a population through natural selection (evolution) resulting in biodiversity.
B5.2x	*Molecular Evidence* Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descents branched.
B5.2a	Describe species as reproductively distinct groups of organisms that can be classified based on morphological, behavioral, and molecular structures.
B5.2b	Explain that the degree of kinship between organisms or species can be estimated from similarity of their DNA and protein sequences.
B5.2c	Trace the relationship between environmental changes and changes in the gene pool, such as genetic drift and isolation of subpopulations.
B5.3	*Natural Selection* Evolution is the consequence of natural selection, the interactions of (1) the potential for a population to 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.
B5.3C	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 a new species.
B5.3f	Demonstrate and explain how biotechnology can improve a population and species.

BIOLOGY

Unit 12: Evolution

Big Ideas (Core Concepts)
Evolution provides a scientific explanation for the history of life on Earth.

Evolution is the consequence of natural selection.

The millions of different species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors.

Standards:
B2: Organization And Development Of Living Systems
B3: Interdependence Of Living Things And The Environment
B5: Evolution And Biodiversity

Content Statements:
B2.4: Cell Specialization
B3.4: Changes in Ecosystems
B5.1: Theory of Evolution
B5.2x: Molecular Evidence
B5.3: Natural Selection

Content Expectations: (Content Statement Clarification)
B2.4A: Explain that living things can be classified based on structural, embryological, and molecular (relatedness of DNA sequence) evidence.

Clarification: None

B2.4d: Analyze the relationships among organisms based on their shared physical, biochemical, genetic, and cellular characteristics and functional processes.

Clarification: Explanations will be limited to given numerical estimates of DNA similarity between different groups of organisms as well as structural similarities. Embryological evidence will not be considered.

B3.4B: 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.

Clarification: Descriptions will be limited to relationship between biodiversity and genetic variation as indicators of stability within an ecosystem.

B5.1A: Summarize the major concepts of natural selection (differential survival and reproduction of chance inherited variants, depending on environmental conditions).

Clarification: Summary will be limited to four concepts: 1.) the potential for a population to increase its numbers, 2.) the genetic variability of offspring due to mutation and recombination of genes, 3.) a finite supply of resources required for life and 4.). The ensuing selection from environmental pressure leaves some of those organisms better able to survive and leave offspring. (Michigan Curriculum Framework, 1996)

B5.1B: Describe how natural selection provides a mechanism for evolution.

Clarification: Descriptions will be limited to the concepts of variation in inherited traits among offspring giving some an advantage in ability to survive and reproduce over offspring.

B5.1c: 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).

Clarification: None

B5.1d: Explain how a new species or variety originates through the evolutionary process of natural selection.

Clarification: None

B5.1e: 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).

Clarification: None

B5.1f: Explain, using examples, how the fossil record, comparative anatomy, and other evidence supports the theory of evolution.

Clarification: None

B5.1g: Illustrate how genetic variation is preserved or eliminated from a population through natural selection (evolution) resulting in biodiversity.

Clarification: Explanations are limited to advantages or disadvantages that are the result of new combinations of genetic material through sexual reproduction. Those offspring with new combinations that have advantages (more success in environment and increased numbers of offspring) will have access to more resources and eventually those with genetic disadvantages will be decreased or eliminated from the environment.

B5.2a: Describe species as reproductively distinct groups of organisms that can be classified based on morphological, behavioral, and molecular structures.

Clarification: None

B5.2b: Explain that the degree of kinship between organisms or species can be estimated from similarity of their DNA and protein sequences.

Clarification: None

B5.2c: Trace the relationship between environmental changes and changes in the gene pool, such as genetic drift and isolation of subpopulations.

Clarification: None

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.

Clarification: None

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

Clarification: None

B5.3C: Give examples of ways in which genetic variation and environmental factors are causes of evolution and the diversity of organisms.

Clarification: None

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

Clarification: None

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

Clarification: None

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

Clarification: Explanations are limited to genetic modifications that allow a species to be more successful in its environment and ability to leave offspring.

Vocabulary

behavioral structures
biodiversity
biological evolution
chance inherited variants
comparative anatomy
degree of kinship
differential survival
DNA
DNA molecule
embryonic stages of development
evidence for the unity among organisms
gene pool
genetic drift
genetic diversity
genetic mutation
genetic variation
homologous structures
molecular structures
morphological structures
natural selection
origin of life
phylogenetics
recombination of genetic material
speciation

Real World Context

Current thinking about evolution (including natural selection and common descent) provide scientific explanations for life history on Earth. Evolution is depicted in the fossil record and in similarities evident within the diversity of existing organisms.

Evolution generally results from three processes: random mutation to genetic material, random genetic drift, and non-random natural selection within populations and species. These three processes result in major consequences, including the diversification of all forms of life from shared ancestors, and observable changes in the fossil record over long periods of time. Some examples of modern evolutionary changes in populations relating to natural selection are evident today (e.g., development of insect resistance to pesticides, bacterial resistance to antibiotics and viral strains).

There are many sources of similarities among all living organisms. They are due to common ancestry and the more closely related organisms share more recent common ancestors. Molecular evidence, shown by DNA similarity, supports the anatomical evidence for evolution and provides substantial detail about the branching of various lines of descent.

Biological classification is based on how closely organisms are related. Organisms are classified into a hierarchical groups and subgroups based on similarities which reflect their evolutionary relationships.

Greater diversity of species in an ecosystem often relates to greater stability. Increased numbers of species, with widely varied adaptations, provide enhanced opportunities that at least some will be able to survive major ecosystem change. This diversity generally originated over long periods of time and through natural selection.

Natural selection provides the following mechanism for evolution: some variation in heritable traits exists within any given species. Some of these characteristics give individuals an advantage in surviving and reproducing more offspring and those offspring, in turn, are more likely to survive and reproduce successfully. Over time, the proportion of these advantaged individuals in the population will increase. Since mutations occur randomly and are selected for if they help organisms survive and reproduce more successfully in their environment, the population changes as a result of this selection. Of course, those individuals that inherit traits that are selected against, are not as successful reproductively and eventually these traits may even die out of the population.

A species consists of individuals that are very similar in appearance, anatomy, physiology and genetics because they share relatively recent common ancestors. A species is often defined as all the individual organisms of a natural population that are capable of successfully interbreeding at maturity in the wild and whose interbreeding produces fertile offspring.

A population that becomes separated reproductively from others, either through geographic isolation or some other segregating factor, may be subject to different environmental conditions. Changes in the environment may select for different heritable traits that allow some individuals to be more reproductively successful. This selection may increase traits differentially in the divided population. If enough time passes, the selection for those specific traits might result in the development of a new species or variety.

Genetic drift is a cumulative process that involves the chance loss of some genes and the disproportionate replication of others over successive generations in a small population, so that the frequencies of genes in the population are altered. The process can lead to a population that differs genetically and in appearance from the original. The occurrence of random changes in gene frequencies within a small, isolated population over a short period of time, without mutation or selection, results in unique subpopulations. Along with natural selection, genetic drift is a principal force in evolution.

Instruments, Measurement and Representations
Graphs and/or tables showing distribution of traits in populations

Representations of degree of biochemical similarity in terms of percentages (e.g., 85% of DNA in common)

Representations of phylogenetic relationships or cladograms of life forms

Examples of fossil records and existing organisms with evident similarities, including humans

Examples of lines of descent accompanied by molecular evidence, including humans

Instructional Examples
i. Inquiry
CE: B1.1A, B1.1B, B1.1C, B1.1E, B1.1g, B1.1h, B5.1A, B5.1e

Design, conduct, interpret and relate natural selection to antibiotic resistance by performing an experiment using non-pathogenic bacteria.

ii. Reflection
CE: B1.2C, B1.2D, B5.1f, B5.2a, B5.2b

An animal genus is chosen and compared to humans for evidence of evolutionary relationship. Multiple comparisons are to be made and visually represented (e.g., structurally-skull, facial features, limbs; molecularly-blood proteins, DNA; stages of development).

iii. Enrichment
CE: B5.1c, B5.1f, B5.2a, B5.2b

An evolutionary biologist has been given the following information about the amino acid sequences of a protein (e.g., hemoglobin) found in the following animals.

Working in pairs, students will write an essay explaining how they might compare amino acid sequences and describe the possible evolutionary relationships between two animals.

	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101
Human	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Chimpanzee	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Gorilla	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Rhesus monkey	GLN	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Horse	ALA	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Kangaroo	LYS	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU

	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116
Human	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Chimpanzee	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Gorilla	ASN	PHE	LYS	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Rhesus monkey	ASN	PHE	LYS	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Horse	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	ALA	LEU	VAL	VAL	ALA	ARG
Kangaroo	ASN	PHE	LYS	LEU	LEU	GLY	ASN	ILE	ILE	VAL	ILE	CYS	LEU	ALA	GLU

Human hemoglobin is being used as the standard for comparison.

Ref: Oakland County Assessment Document

iv. General
CE: B5.1A, B5.1e

How are new populations developed through natural selection?
Small groups of students will grow bacterial colonies, approved for classroom use, on agar plates containing a 0.5% concentration of antiseptic. Students should transfer the surviving bacteria to agar with increasing concentrations of antiseptic agar. When the maximum concentration is reached (about 15%), some of the original stock colony (0%) will be transferred directly to another plate with the highest concentration (15%). Growth on the two plates with the highest concentration will be analyzed. Students should develop an explanation for the difference between the two plates (A new population developed through natural selection when the surviving bacteria were transferred from plate to plate of increasing concentration). Each student will write a lab report demonstrating that he or she has followed the steps of the scientific method.

v. Intervention
CE: B5.1A, B5.1B, B5.1d, B5.1e

An earthquake has struck in San Diego and the zoo has been destroyed. The animals have all escaped and are free to migrate outside the city limits and into the surrounding environment. A list of the animals that have escaped is given; this list will only include animals that are very different from native species. The food and climate in California is different than the home of the animals. In order to survive the animal species must adapt. What is an evolutionary pathway for one of the animals that need to take place for this species to survive? (Oakland Assessment Guide)

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