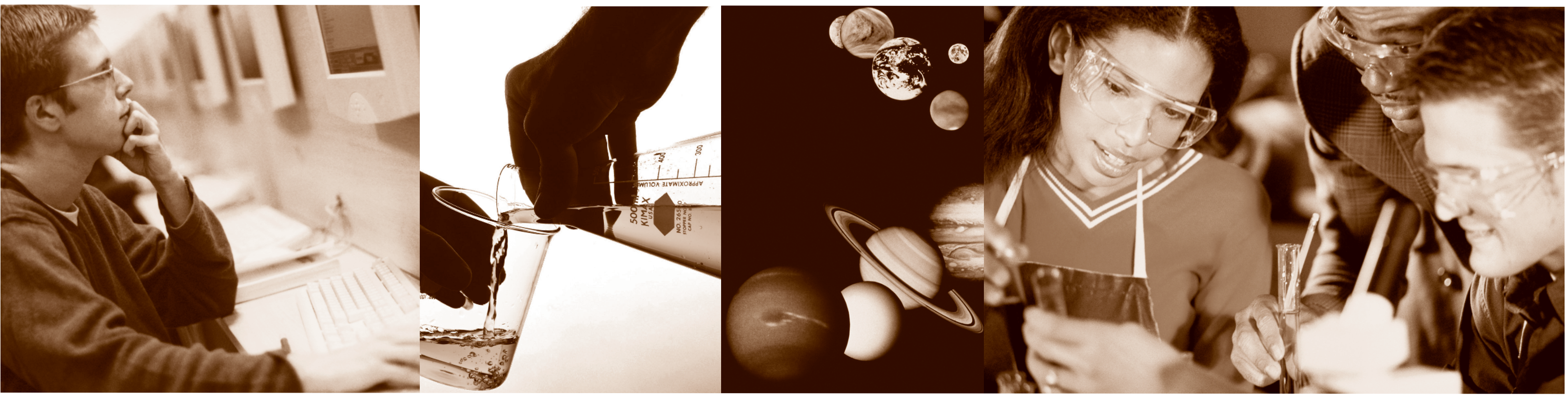
High School Content Expectations



SCIENCE

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

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Welcome to Michigan's High School Science Content Standards and Expectations

Why Develop Content Standards and Expectations for High School?

To prepare Michigan's students with the knowledge and skills to succeed in the 21st Century, the State of Michigan has enacted a rigorous new set of statewide graduation requirements that are among the best in the nation. These requirements, called the Michigan Merit Curriculum, are the result of a collaborative effort between Governor Jennifer M. Granholm, the State Board of Education, and the State Legislature.

In preparation for the implementation of the new high school graduation requirements, the Michigan Department of Education's Office of School Improvement is leading the development of high school content expectations. An Academic Work Group of science experts chaired by nationally known scholars was commissioned to conduct a scholarly review and identify content standards and expectations. The Michigan Department of Education conducted an extensive field review of the expectations by high school, university, and business and industry representatives.

The Michigan High School Science Content Expectations (Science HSCE) establish what every student is expected to know and be able to do by the end of high school and define the expectations for high school science credit in Earth Science, Biology, Physics, and Chemistry.

An Overview

In developing these expectations, the Academic Work Group depended heavily on the *Science Framework for the 2009 National Assessment of Educational Progress* (National Assessment Governing Board, 2006). In particular, the group adapted the structure of the NAEP framework, including Content Statements and Performance Expectations. These expectations align closely with the NAEP framework, which is based on *Benchmarks for Science Literacy* (AAAS Project 2061, 1993) and the *National Science Education Standards* (National Research Council, 1996).

The Academic Work Group carefully analyzed other documents, including the Michigan Curriculum Framework Science Benchmarks (2000 revision), the Standards for Success report *Understanding University Success*, ACT's *College Readiness Standards*, College Board's *AP Biology, AP Physics, AP Chemistry,* and *AP Environmental Science Course Descriptions*, ACT's *On Course for Success*, South Regional Education Board's *Getting Ready for College-Preparatory/Honors Science: What Middle Grades Students Need to Know and Be Able to Do,* and standards documents from other states.

Earth Science	Biology	Physics	Chemistry
STANDARDS *(and number of content statements in each standard)*			
E1 Inquiry, Reflection, and Social Implications (2) E2 Earth Systems (4) E3 The Solid Earth (4) E4 The Fluid Earth (3) E5 Earth in Space and Time (4)	B1 Inquiry, Reflection, and Social Implications (2) B2 Organization and Development of Living Systems (6) B3 Interdependence of Living Systems and the Environment (5) B4 Genetics (4) B5 Evolution and Biodiversity (3)	P1 Inquiry, Reflection, and Social Implications (2) P2 Motion of Objects (3) P3 Forces and Motion (8) P4 Forms of Energy and Energy Transformations (12)	C1 Inquiry, Reflection, and Social Implications (2) C2 Forms of Energy (5) C3 Energy Transfer and Conservation (5) C4 Properties of Matter (10) C5 Changes in Matter (7)

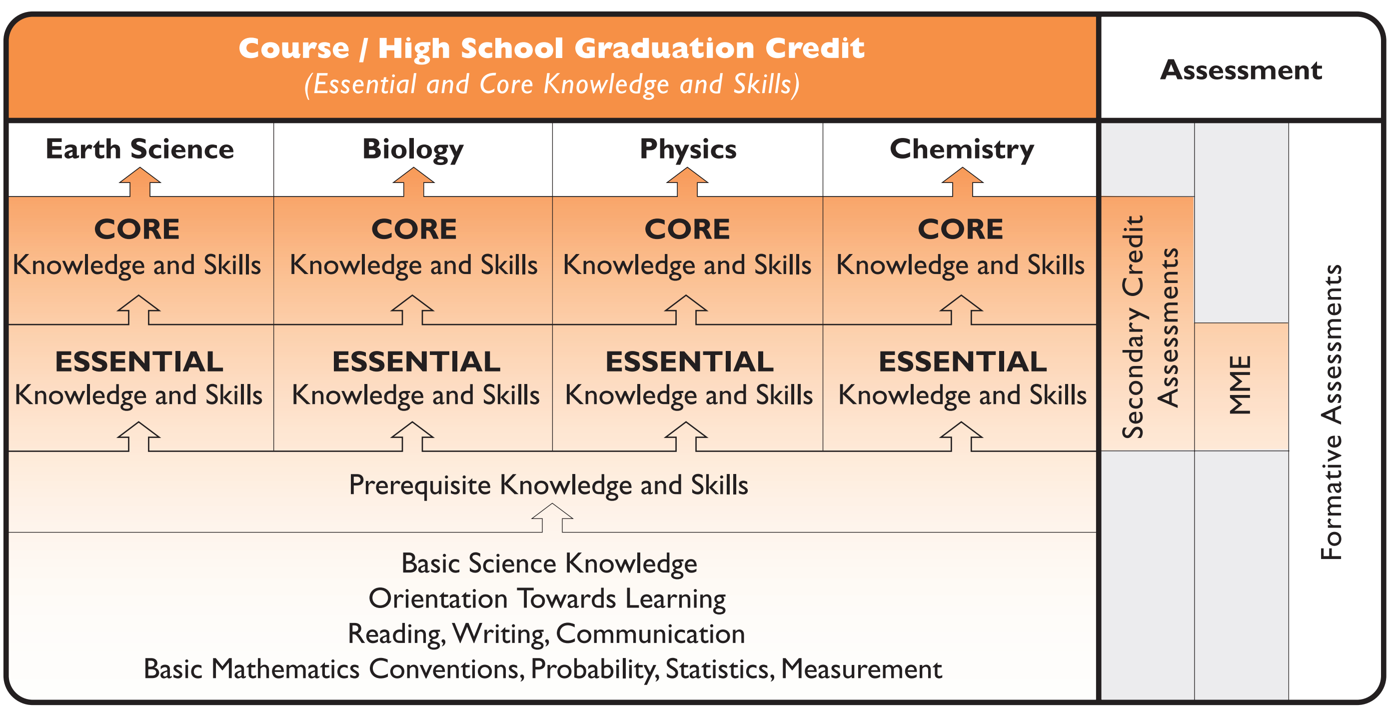
Useful and Connected Knowledge for All Students

This document defines expectations for Michigan High School graduates, organized by discipline: Earth Science, Biology, Physics, and Chemistry. It defines ***useful*** and ***connected knowledge*** at four levels:

- **Prerequisite knowledge**
  Useful and connected knowledge that all students should bring as a prerequisite to high school science classes. Prerequisite expectation codes include a "**p**" and an upper case letter (e.g., **E3.p1A**). Prerequisite content could be assessed through formative and/or large scale assessments.
- **Essential knowledge**
  Useful and connected knowledge for all high school graduates, regardless of what courses they take in high school. Essential expectation codes include an upper case letter (e.g., **E2.1A**). Essential content knowledge and performance expectations are required for graduation and are assessable on the Michigan Merit Exam (MME) and on future secondary assessments. Essential knowledge can also be assessed with formative assessments.
- **Core knowledge**
  Useful and connected knowledge for all high school graduates who have completed a discipline-specific course. In general core knowledge includes content and expectations that students need to be prepared for more advanced study in that discipline. Core content statement codes include an "x" and core expectation codes include a lower case letter (e.g., **B2.2x** Proteins; **B2.2f**) to indicate that they are NOT assessable on existing large-scale assessments (MME, NAEP), but will be assessed on future secondary credit assessments. Core knowledge can also be assessed with formative assessments.
- **Recommended knowledge**
  Useful and connected knowledge that is desirable as preparation for more advanced study in the discipline, but not required for graduation credit. Content and expectations labeled as recommended represent extensions of the core. Recommended content statement codes include an "**r**" and an "**x**"; recommended expectations include an "**r**" and a lower case letter (e.g., **P4.r9x Nature of Light**; **P4.r9a**). They will not be assessed on either the MME or secondary credit assessments.

Useful and connected knowledge is contrasted with ***procedural display***—learning to manipulate words and symbols without fully understanding their meaning. When expectations are excessive, procedural display is the kind of learning that takes place. Teachers and students "cover the content" instead of "uncovering" useful and connected knowledge.

Credit for high school Earth Science, Biology, Physics, and Chemistry will be defined as meeting both essential and core subject area content expectations. Credit requirements are outlined in separate Michigan Merit Curriculum Course/Credit Requirement documents.



Preparing Students for Successful Post-Secondary Engagement

Students who have useful and connected knowledge should be able to apply knowledge in new situations; to solve problems by generating new ideas; to make connections among what they read and hear in class, the world around them, and the future; and through their work, to develop leadership qualities while still in high school. In particular, high school graduates with useful and connected knowledge are able to engage in four key practices of science literacy.

Successful Post-Secondary Engagement

Practices of Science Literacy

Communicate accurately and effectively...

Identifying Science Principles

- Describe, measure, or classify observations.
- State or recognize correct science principles.
- Demonstrate relationships among closely related science principles.
- Demonstrate relationships among different representations of principles.

Using Science Principles

- Explain observations of phenomena.
- Predict observations of phenomena.
- Suggest examples of observations that illustrate a science principle.
- Propose, analyze, and evaluate alternative explanations or predictions.

Scientific Inquiry

- Generate new questions that can be investigated in the laboratory or field.
- Critique aspects of scientific investigations.
- Conduct scientific investigations using appropriate tools and techniques.
- Identify patterns in data: relate patterns to theoretical models.
- Describe a reason for a given conclusion using evidence from an investigation.
- Explain how scientific evidence supports or refutes claims or explanations of phenomena.
- Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable. Gather data and organized the results in graphs, tables, and/or charts.

Reflection and Social Implications

- Critique whether questions can be answered through scientific investigations.
- Identify and critique arguments based on scientific evidence.
- Use appropriate scientific knowledge in social arguments, recognizing their limitations.
- Gather, synthesize, and evaluate information from multiple sources.
- Discuss scientific topics in groups, make presentations summarize what others have said, ask for clarification, take alternative perspectives, and defend a position.
- Evaluate the future career and occupational prospects of science fields.
- Explain why a claim or a conclusion is flawed.
- Critique solutions to problems, given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Apply science principles or scientific data to anticipate effects of technological design decisions.

State / National Landscape

- Expert perspective
- Education reform environment
- Research-based practices
- Work force requirements

State / Federal Expectations

- No Child Left Behind (NCLB)
- National Governors' Association (NGA)
- Legislation/Policy

Michigan High School Science Content Standards and Expectations

Earth Science

Biology

Physics

Chemistry

Models for District Alignment / Mapping

- District curriculum documents
- Documents from other districts/states
- Backmapping to standards and expectations

Other MI Documents / Programs

- State Standards – teaching and learning, content (all areas), assessment
- Grade Level Content Expectations
- State Assessments
- Career/Technical Education Department of Labor and Economic Growth

K-8 Educational Experience

Content Knowledge

- English Language Arts
- Mathematics
- Science
- Social Studies
- Other

Learning Processes

- Strategies & Skills
- Reasoning
- Analytical Thinking
- Constructing New Meaning
- Communication

This chart includes talking points for professional development.

Practices of Science Literacy

- **Identifying**
  Identifying performances generally have to do with stating models, theories, and patterns inside the triangle in Figure 1.

- **Using**
  Using performances generally have to do with the downward arrow in Figure 1—using scientific models and patterns to explain or describe specific observations.

- **Inquiry**
  Inquiry performances generally have to do with the upward arrow in Figure 1—finding and explaining patterns in data.

- **Reflection and Social Implications**
  Reflecting and Social Implications performances generally have to do with the figure as a whole (reflecting) or the downward arrow (technology as the application of models and theories to practical problems).

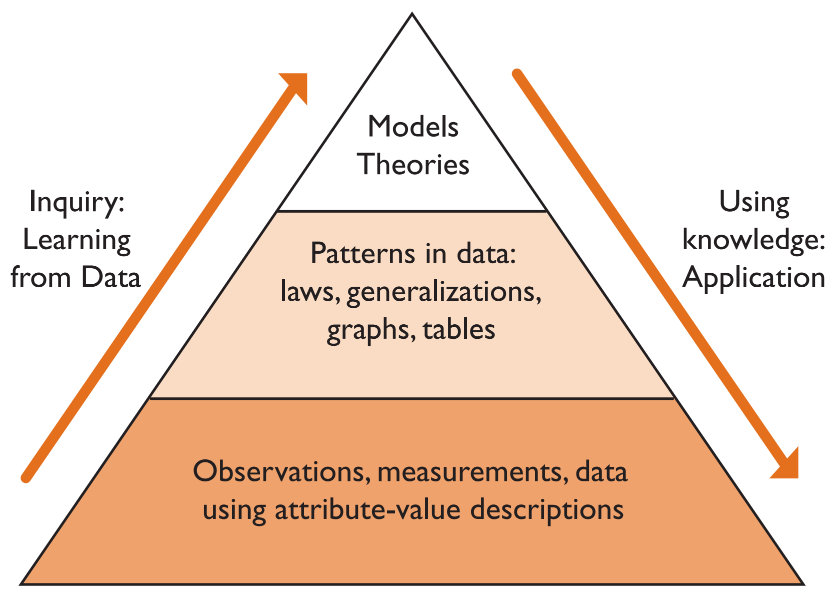


Figure 1: Knowledge and practices of model-based reasoning

Identifying Science Principles

This category focuses on students' abilities to recall, define, relate, and represent basic science principles. The content statements themselves are often closely related to one another conceptually. Moreover, the science principles included in the content statements can be represented in a variety of forms, such as words, pictures, graphs, tables, formulas, and diagrams (AAAS, 1993; NRC, 1996). Identifying practices include describing, measuring, or classifying observations; stating or recognizing principles included in the content statements; connecting closely related content statements; and relating different representations of science knowledge.

Identifying Science Principles comprises the following general types of practices:

- Describe, measure, or classify observations (e.g., describe the position and motion of objects, measure temperature, classify relationships between organisms as being predator/prey, parasite/host, producer/consumer).
- State or recognize correct science principles (e.g., mass is conserved when substances undergo changes of state; all organisms are composed of cells; the atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor).
- Demonstrate relationships among closely related science principles (e.g., statements of Newton's three laws of motion, energy transfer and the water cycle).
- Demonstrate relationships among different representations of principles (e.g., verbal, symbolic, diagrammatic) and data patterns (e.g., tables, equations, graphs).

Identifying Science Principles is integral to all of the other science practices.

Using Science Principles

Scientific knowledge is useful for making sense of the natural world. Both scientists and informed citizens can use patterns in observations and theoretical models to predict and explain observations that they make now or that they will make in the future.

Using Science Principles comprises the following general types of performance expectations:

- Explain observations of phenomena (using science principles from the content statements).
- Predict observations of phenomena (using science principles from the content statements, including quantitative predictions based on science principles that specify quantitative relationships among variables).
- Suggest examples of observations that illustrate a science principle (e.g., identify examples where the net force on an object is zero; provide examples of observations explained by the movement of tectonic plates; given partial DNA sequences of organisms, identify likely sequences of close relatives).
- Propose, analyze, and evaluate alternative explanations or predictions.

The first two categories—***Identifying Science Principles*** and ***Using Science Principles***—both require students to correctly state or recognize the science principles contained in the content statements. A difference between the categories is that Using Science Principles focuses on what makes science knowledge valuable—that is, its usefulness in making accurate predictions about phenomena and in explaining observations of the natural world in coherent ways (i.e., "knowing why"). Distinguishing between these two categories draws attention to differences in depth and richness of individuals' knowledge of the content statements. Assuming a continuum from "just knowing the facts" to "using science principles," there is considerable overlap at the boundaries. The line between the Identifying and Using categories is not distinct.

Scientific Inquiry

Scientifically literate graduates make observations about the natural world, identify patterns in data, and propose explanations to account for the patterns. Scientific inquiry involves the collection of relevant data, the use of logical reasoning, and the application of imagination in devising hypotheses to explain patterns in data. Scientific inquiry is a complex and time-intensive process that is iterative rather than linear. Habits of mind—curiosity, openness to new ideas, informed skepticism—are part of scientific inquiry. This includes the ability to read or listen critically to assertions in the media, deciding what evidence to pay attention to and what to dismiss, and distinguishing careful arguments from shoddy ones. Thus, Scientific Inquiry depends on the practices described above—Identifying Science Principles and Using Science Principles.

Scientific Inquiry comprises the following general types of performance expectations:

- Generate new questions that can be investigated in the laboratory or field.
- 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.
- 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).
- Identify patterns in data and relate them to theoretical models.
- Describe a reason for a given conclusion using evidence from an investigation.
- Predict what would happen if the variables, methods, or timing of an investigation were changed.
- Based on empirical evidence, explain and critique the reasoning used to draw a scientific conclusion or explanation.
- Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.
- Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.

Scientific inquiry is more complex than simply making, summarizing, and explaining observations, and it is more flexible than the rigid set of steps often referred to as the "scientific method." The *National Standards* makes it clear that inquiry goes beyond "science as a process" to include an understanding of the nature of science (p. 105).

It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations (p. 171).

When students engage in Scientific Inquiry, they are drawing on their understanding about the nature of science, including the following ideas (see Benchmarks for Science Literacy):

- Arguments are flawed when fact and opinion are intermingled or the conclusions do not follow logically from the evidence given.
- A single example can never support the inference that something is always true, but sometimes a single example can support the inference that something is not always true.
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables.
- The way in which a sample is drawn affects how well it represents the population of interest. The larger the sample, the smaller the error in inference to the population. But, large samples do not necessarily guarantee representation, especially in the absence of random sampling.

Students can demonstrate their abilities to engage in Scientific Inquiry in two ways: students can *do* the practices specified above, and students can *critique examples* of scientific inquiry. In *doing*, practices can include analyzing data tables and deciding which conclusions are consistent with the data. Other practices involve hands-on performance and/or interactive computer tasks—for example, where students collect data and present their results or where students specify experimental conditions on computer simulations and observe the outcomes. As to *critiquing*, students can identify flaws in a poorly designed investigation or suggest changes in the design in order to produce more reliable data. Students should also be able to critique print or electronic media—for example, items may ask students to suggest alternative interpretations of data described in a newspaper article.

Scientific Reflection and Social Implications

Scientifically literate people recognize the strengths and limitations of scientific knowledge, which will provide the perspective they need to use the information to solve real-world problems. Students must learn to decide who and what sources of information they can trust. They need to learn to critique and justify their own ideas and the ideas of others. Since knowledge comes from many sources, students need to appreciate the historical origins of modern science and the multitude of connections between science and other disciplines. Students need to understand how science and technology support one another and the political, economic, and environmental consequences of scientific and technological progress. Finally, it is important that the ideas and contributions of men and women from all cultures be recognized as having played a significant role in scientific communities.

Scientific Reflection and Social Implications include the following general types of practices, all of which entail students using science knowledge to:

- Critique whether or not specific questions can be answered through scientific investigations.
- Identify and critique arguments about personal or societal issues based on scientific evidence.
- Develop an understanding of a scientific concept by accessing information from multiple sources. Evaluate the scientific accuracy and significance of the information.
- Evaluate scientific explanations in a peer review process or discussion format.
- Evaluate the future career and occupational prospects of science fields.
- Critique solutions to problems, given criteria and scientific constraints.
- Identify scientific tradeoffs in design decisions and choose among alternative solutions.
- Describe the distinctions between scientific theories, laws, hypotheses, and observations.
- Explain the progression of ideas and explanations that lead to science theories that are part of the current scientific consensus or core knowledge.
- Apply science principles or scientific data to anticipate effects of technological design decisions.
- Analyze how science and society interact from a historical, political, economic, or social perspective.

Organization of the Expectations

The Science Expectations are organized into Disciplines, Standards, Content Statements, and specific Performance Expectations.

Disciplines

Earth Science, Biology, Physics, and Chemistry

Organization of Each Standard

Each standard includes three parts:

- A standard statement that describes what students who have mastered that standard will be able to do.
- Content statements that describe Prerequisite, Essential, Core, and Recommended science content understanding for that standard.
- Performance expectations that describe Prerequisite, Essential, Core, and Recommended performances for that standard.

NOTE: Boundary statements that clarify the standards and set limits for expected performances, technical vocabulary, and additional discipline-specific inquiry and reflection expectations will be included in a companion document.

Standard Statement

The Standard Statement describes how students who meet that standard will engage in Identifying, Using, Inquiry, or Reflection for that topic.

Content Statements

Content statements describe the Prerequisite, Essential, Core, and Recommended *knowledge* associated with the standard.

1. ***Prerequisite science content*** that all students should bring as a prerequisite to high school science classes. Prerequisite content statement codes include a "**p**" and are organized by topic [e.g., **E3.p1 Landforms and Soils *(prerequisite)***].
2. ***Essential science content*** that all high school graduates should master. Essential content and expectations are organized by topic (e.g., **E2.1 Earth Systems Overview**).
3. ***Core science content*** that high school graduates need for more advanced study in the discipline and for some kinds of work. Core content and expectations are organized by topic (e.g., **B2.2x Proteins)**; "**x**" designates a core topic).
4. ***Recommended science content*** that is desirable as preparation for more advanced study in the discipline, but is not required for credit. Content and expectations labeled as recommended represent extensions of the core. Recommended content statement codes include an "**r**" and an "**x**"; expectations include an "**r**" and a lower case letter (e.g., **P4.r9x Nature of Light**; **P4.r9a**).

NOTE: Basic mathematics and English language arts skills necessary for meeting the high school science content expectations will be included in a companion document.

Performance Expectations

Performance expectations are derived from the intersection of content statements and practices—if the content statements from the Earth Sciences, Biology, Physics, and Chemistry are the columns of a table and the practices (Identifying Science Principles, Using Science Principles, Using Scientific Inquiry, Reflection and Social Implications) are the rows, the cells of the table are inhabited by performance expectations.

Performance expectations are written with particular verbs indicating the desired performance expected of the student. The action verbs associated with each practice are contextualized to generate performance expectations. For example, when the "conduct scientific investigations" is crossed with a states-of-matter content statement, this can generate a performance expectation that employs a different action verb, "heats as a way to evaporate liquids."

Michigan High School Science

BIOLOGY

Prerequisite, Essential, Core, and Recommended Content Statements and Expectations

C E • **R I G O R** • R E L E V A N C E • R E L A T I O N S H I P S • R I G O R • R E
I P S • R E L A T I O N S H I P S • R I G O R • **R E L E V A N C E** • R E L A T
C E • R I G O R • R E L E V A N C E • R E L A T I O N S H I P S • R I G O R • R E
I P S • **R E L A T I O N S H I P S** • R I G O R • R E L E V A N C E • R E L A T

MICHIGAN Department of Education
10/06

BIOLOGY (B)

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

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

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

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

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

Biology Content Statement Outline

STANDARD B1: INQUIRY, REFLECTION, AND SOCIAL IMPLICATIONS

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

B1.1 Scientific Inquiry

Science is a way of understanding nature. Scientific research may begin by generating new scientific questions that can be answered through replicable scientific investigations that are logically developed and conducted systematically. Scientific conclusions and explanations result from careful analysis of empirical evidence and the use of logical reasoning. Some questions in science are addressed through indirect rather than direct observation, evaluating the consistency of new evidence with results predicted by models of natural processes. Results from investigations are communicated in reports that are scrutinized through a peer review process.

B1.1A Generate new questions that can be investigated in the laboratory or field.

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.

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).

B1.1D Identify patterns in data and relate them to theoretical models.

B1.1E Describe a reason for a given conclusion using evidence from an investigation.

B1.1f Predict what would happen if the variables, methods, or timing of an investigation were changed.

B1.1g Use empirical evidence to explain and critique the reasoning used to draw a scientific conclusion or explanation.

B1.1h Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.

B1.1i Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.

B1.2 Scientific Reflection and Social Implications

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

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

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

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

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

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

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

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

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

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

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

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

STANDARD B2: ORGANIZATION AND DEVELOPMENT OF LIVING SYSTEMS

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

L2.p1 Cells *(prerequisite)*

All organisms are composed of cells, from just one cell to many cells. Water accounts for more than two-thirds of the weight of a cell, which gives cells many of their properties. In multicellular organisms, specialized cells perform specialized functions. Organs and organ systems are composed of cells and function to serve the needs of organisms for food, air, and waste removal. The way in which cells function is similar in all living organisms. *(prerequisite)*

L2.p1A Distinguish between living and nonliving systems. *(prerequisite)*

L2.p1B Explain the importance of both water and the element carbon to cells. *(prerequisite)*

L2.p1C Describe growth and development in terms of increase in cell number, cell size, and/or cell products. *(prerequisite)*

L2.p1D Explain how the systems in a multicellular organism work together to support the organism. *(prerequisite)*

L2.p1E Compare and contrast how different organisms accomplish similar functions (e.g., obtain oxygen for respiration, and excrete waste). *(prerequisite)*

L2.p2 Cell Function *(prerequisite)*

Cells carry out the many functions needed to sustain life. They grow and divide, thereby producing more cells. Food is used to provide energy for the work that cells do and is a source of the molecular building blocks from which needed materials are assembled. *(prerequisite)*

L2.p2A Describe how organisms sustain life by obtaining, transporting, transforming, releasing, and eliminating matter and energy. *(prerequisite)*

L2.p2B Describe the effect of limiting food to developing cells. *(prerequisite)*

L2.p3 Plants as Producers *(prerequisite)*

Plants are producers; they use the energy from light to make sugar molecules from the atoms of carbon dioxide and water. Plants use these sugars, along with minerals from the soil, to form fats, proteins, and carbohydrates. This food can be used immediately, incorporated into the cells of a plant as the plant grows, or stored for later use. *(prerequisite)*

L2.p3A Explain the significance of carbon in organic molecules. *(prerequisite)*

L2.p3B Explain the origins of plant mass. *(prerequisite)*

L2.p3C Predict what would happen to plants growing in low carbon dioxide atmospheres. *(prerequisite)*

L2.p3D Explain how the roots of specific plants grow. *(prerequisite)*

L2.p4 Animals as Consumers *(prerequisite)*

All animals, including humans, are consumers; they obtain food by eating other organisms or their products. Consumers break down the structures of the organisms they eat to obtain the materials they need to grow and function. Decomposers, including bacteria and fungi, use dead organisms or their products for food. *(prerequisite)*

L2.p4A Classify different organisms based on how they obtain energy for growth and development. *(prerequisite)*

L2.p4B Explain how an organism obtains energy from the food it consumes. *(prerequisite)*

L2.p5 Common Elements *(prerequisite)*

Living systems are made of complex molecules that consist mostly of a few elements, especially carbon, hydrogen, oxygen, nitrogen, and phosphorous. *(prerequisite)*

L2.p5A Recognize the six most common elements in organic molecules (C, H, N, O, P, S). *(prerequisite)*

L2.p5B Identify the most common complex molecules that make up living organisms. *(prerequisite)*

L2.p5C Predict what would happen if essential elements were withheld from developing cells. *(prerequisite)*

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.

B2.1C 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.

B2.1e Predict what would happen if the cells from one part of a developing embryo were transplanted to another part of the embryo.

B2.2 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 (C, H, N, O, P, S).

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).

B2.2g 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.

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.

B2.3d 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.

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.

B2.3g 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).

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.

B2.4B 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).

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

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

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.

B2.4g 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.

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

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.

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

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.

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 function.

B2.6x Internal/External Cell Regulation

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

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

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

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

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

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

STANDARD B3: INTERDEPENDENCE OF LIVING SYSTEMS AND THE ENVIRONMENT

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

L3.p1 Populations, Communities, and Ecosystems *(prerequisite)*

Organisms of one species form a population. Populations of different organisms interact and form communities. Living communities and the nonliving factors that interact with them form ecosystems. *(prerequisite)*

L3.p1A Provide examples of a population, community, and ecosystem. *(prerequisite)*

L3.p2 Relationships Among Organisms *(prerequisite)*

Two types of organisms may interact with one another in several ways; they may be in a producer/consumer, predator/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other. *(prerequisite)*

L3.p2A Describe common relationships among organisms and provide examples of producer/consumer, predator/prey, or parasite/host relationship. *(prerequisite)*

L3.p2B Describe common ecological relationships between and among species and their environments (competition, territory, carrying capacity, natural balance, population, dependence, survival, and other biotic and abiotic factors). *(prerequisite)*

L3.p2C Describe the role of decomposers in the transfer of energy in an ecosystem. *(prerequisite)*

L3.p2D Explain how two organisms can be mutually beneficial and how that can lead to interdependency. *(prerequisite)*

L3.p3 Factors Influencing Ecosystems *(prerequisite)*

The number of organisms and populations an ecosystem can support depends on the biotic resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. *(prerequisite)*

L3.p3A Identify the factors in an ecosystem that influence fluctuations in population size. *(prerequisite)*

L3.p3B Distinguish between the living (biotic) and nonliving (abiotic) components of an ecosystem. *(prerequisite)*

L3.p3C Explain how biotic and abiotic factors cycle in an ecosystem (water, carbon, oxygen, and nitrogen). *(prerequisite)*

L3.p3D Predict how changes in one population might affect other populations based upon their relationships in a food web. *(prerequisite)*

L3.p4 Human Impact on Ecosystems *(prerequisite)*

All organisms cause changes in their environments. Some of these changes are detrimental, whereas others are beneficial. *(prerequisite)*

L3.p4A Recognize that, and describe how, human beings are part of Earth's ecosystems. Note that human activities can deliberately or inadvertently alter the equilibrium in ecosystems. *(prerequisite)*

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.

B3.1f Summarize the process of photosynthesis.

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.

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.

B3.4A 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.

B3.4B 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.

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.

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

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.

B3.r5g Diagram and describe the stages of the life cycle for a human disease-causing organism. *(recommended)*

STANDARD B4: GENETICS

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

L4.p1 Reproduction *(prerequisite)*

Reproduction is a characteristic of all living systems; because no individual organism lives forever, reproduction is essential to the continuation of every species. Some organisms reproduce asexually. Other organisms reproduce sexually. *(prerequisite)*

L4.p1A Compare and contrast the differences between sexual and asexual reproduction. *(prerequisite)*

L4.p1B Discuss the advantages and disadvantages of sexual vs. asexual reproduction. *(prerequisite)*

L4.p2 Heredity and Environment *(prerequisite)*

The characteristics of organisms are influenced by heredity and environment. For some characteristics, inheritance is more important. For other characteristics, interactions with the environment are more important. *(prerequisite)*

L4.p2A Explain that the traits of an individual are influenced by both the environment and the genetics of the individual. Acquired traits are not inherited; only genetic traits are inherited. *(prerequisite)*

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.

B4.1B 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.

B4.1c Differentiate between dominant, recessive, codominant, 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.

B4.2 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 (noninherited mutations).

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.

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

B4.r2i Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes. *(recommended)*

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 from such processes as crossing over, jumping genes, and deletion and duplication of genes.

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

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

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 or no effect on the offspring's success in its environment.

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.

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.

B4.r5x Recombinant DNA

Recombinant DNA technology allows scientists in the laboratory to combine the genes from different sources, sometimes different species, into a single DNA molecule. This manipulation of genes using bacterial plasmids has been used for many practical purposes including the mass production of chemicals and drugs. *(recommended)*

B4.r5a Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes. *(recommended)*

B4.r5b Evaluate the advantages and disadvantages of human manipulation of DNA. *(recommended)*

STANDARD B5: EVOLUTION AND BIODIVERSITY

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

L5.p1 Survival and Extinction *(prerequisite)*

Individual organisms with certain traits in particular environments are more likely than others to survive and have offspring. When an environment changes, the advantage or disadvantage of characteristics can change. Extinction of a species occurs when the environment changes and the characteristics of a species are insufficient to allow survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the Earth no longer exist. *(prerequisite)*

L5.p1A Define a species and give examples. *(prerequisite)*

L5.p1B Define a population and identify local populations. *(prerequisite)*

L5.p1C Explain how extinction removes genes from the gene pool. *(prerequisite)*

L5.p1D Explain the importance of the fossil record. *(prerequisite)*

L5.p2 Classification *(prerequisite)*

Similarities among organisms are found in anatomical features, which can be used to infer the degree of relatedness among organisms. In classifying organisms, biologists consider details of internal and external structures to be more important than behavior or general appearance. *(prerequisite)*

L5.p2A Explain, with examples, that ecology studies the varieties and interactions of living things across space while evolution studies the varieties and interactions of living things across time. *(prerequisite)*

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 similarities.

B5.2b Explain that the degree of kinship between organisms or species can be estimated from the 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.r2d Interpret a cladogram or phylogenetic tree showing evolutionary relationships among organisms. *(recommended)*

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.

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

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

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

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

NOTES

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