Test Specifications: Biology 2.0

Introduction

The Biology Test Specifications provide an overview of the structure and content of the test. This overview includes a description of the test design as well as information on the types of items that will appear on the test. Also included is a test blueprint composed of a table identifying the range and distribution of items and points grouped by categories. The test specifications also provide specific guidelines for the development of all items used for the Biology Test. This document is intended to be a resource not only for item writers and test designers, but for Ohio educators and other stakeholders who are interested in a deeper understanding of the test. The *Content Limits* and *Do Not Assess* sections identify boundaries for the content that will appear on the Biology Test. The *Do Not Assess* section lists content that is either beyond the scope of the standard or which is pertinent to the standard but will not be explicitly tested in isolation. Do not assess does not necessarily mean do not instruct.

General Description of the Biology Test

In 2018 Ohio adopted revised academic content standards for Biology. A model curriculum based on these standards was adopted in 2019.

An achievement assessment that aligns to the new standards and model curriculum is mandated by Ohio Revised code 3301.079. The assessment will be administered as a two-part test, in an online format, to measure progress toward the standards and to provide information to teachers and administrators. Test results are reported back to schools by June 30th.

Test Design

The structure of the Biology Test will consist of two parts that will be given near the end of the course. Both parts of the test are fixed forms that are administered in an online format. The sequence and timing of the administration of Part 1 and Part 2 is determined by the district. After the student has completed both parts of the test, his or her scores will be combined to yield a comprehensive view of the student's progress.

Test Blueprint

The following test blueprint shows the content statements assessed in each reporting category and the distribution of points.

Biology Test Blueprint

Reporting Category	Topic	Points	Total Points on Form	Approximate Percent of Test
B.H: Heredity	B.H.1: Cellular genetics B.H.2: Structure and function of DNA in cells B.H.3: Genetic mechanisms and inheritance B.H.4: Mutations B.H.5: Modern genetics	13-15	54-56	23%-28%
B.E: Evolution	B.E.1: Mechanisms of evolution B.E.2: Speciation	13-15		23%-28%
B.DI: Diversity and Interdependence of Life	B.DI.1: Biodiversity B.DI.2: Ecosystems B.DI.3: Loss of diversity	13-15		23%-28%
B.C: Cells	B.C.1: Cell structure and function B.C.2: Cellular processes	13-15		23%-28%

Cognitive Demands	Approximate Portion of Test
Designing Technological/ Engineering Solutions Using Science Concepts (T)	**0-15 %**
Demonstrating Science Knowledge (D)	**10-25%**
Interpreting and Communicating Science Concepts (C)	**30-50%**
Recalling Accurate Science (R)	**25-40%**

Cognitive Demands: Expectations for Learning

Cognitive Demand	Description	Approximate Portion of Test
Designing Technological/ Engineering Solutions Using Science Concepts (T)	Requires student to solve science-based engineering or technological problems through application of scientific inquiry. Within given scientific constraints, propose or critique solutions, analyze and interpret technological and engineering problems, use science principles to anticipate effects of technological or engineering design, find solutions using science and engineering or technology, consider consequences and alternatives, and/or integrate and synthesize scientific information.	0-15%
Demonstrating Science Knowledge	Requires student to use scientific practices and develop the ability to think and act in ways associated with inquiry, including asking question, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments (Slightly altered from Nation Science Education Standards)	10- 25%
Interpreting and Communicating Science Concepts	Requires student to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experience using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.	30-50%
Recalling Accurate Science	Requires student to provide accurate statements about scientifically valid facts, concepts and relationships. Recall only requires students to provide a rote response, declarative knowledge or perform routine mathematical tasks. This cognitive demand refers to students' knowledge of science fact, information, concepts, tools, procedures (being able to describe how) and basic principles.	25-40%

Resources: Frameworks that were consulted in the development of the draft cognitive demands are listed below. Each links to a brief description of the framework.

NAEP: Science Framework for the 2015 National Assessment of Educational Progress (2015), https://www.nagb.gov/naep-frameworks/science/2015-science-framework.html

Revised Bloom's Taxonomy: See Anderson, et.al. A Taxonomy for Learning, Teaching and Assessing (2001), http://www.celt.iastate.edu/teaching/effective-teaching-practices/revised-blooms-taxonomy/.

TIMSS: TIMSS 2007 Assessment Frameworks (2005), https://timssandpirls.bc.edu/

Survey of Enacted Curriculum: Coding Procedures for Curriculum Content Analyses (2004), https://secure.wceruw.org/seconline/Reference/K12Taxonomy08.pdf

PISA: The PISA 2003 Assessment Domains (2003), http://www.oecd.org/education/school/programmeforinternationalstudentassessmentpisa/33694881.pdf

Ohio's Technology Standards: Ohio Academic Content Standards in Technology (2017), https://education.ohio.gov/getattachment/Topics/Learning-in-Ohio/Technology/Ohio-s-2003-Academic-Content-Standards-in-Technolo/The-2017-Ohio-Learning-Standards-in-Technology.pdf.aspx.

Interaction Types

Ohio's State Tests are composed of several interaction types. Currently, there are ten interaction types that may appear on a science computer-based assessment:

Interaction Types	Description
Equation Item (EQ)	The student is presented with a keypad that includes a variety of mathematical symbols that can be used to create a response. Responses may be in the form of a number, variable, expression, or equation, as appropriate to the test item. The student enters their response in the response box which may be on a line by itself or embedded in a sentence or phrase. For paper-based assessments, this interaction type may be replaced with a modified version of the item that can be scanned and scored electronically or the student may be given an answer box to write their answer.
Gap Match Item (GM)	Given a set of options (e.g., numbers, words, phrases, or sentences) the student hovers over the options which then highlight, indicating that the option is selectable. The student can then click on the object, hold down the mouse button, and drag it to an answer area, indicated by a dotted box, in a graphic, table, or paragraph. For paper-based assessments, the options are associated with a letter, and students write a letter for their response in each response area.
Grid Item (GI)	The student may select numbers, words, phrases, or images to display their response. The student may also use the drag-and-drop feature to place objects into a response area. This interaction type may also require the student to use the point, line, or arrow tools to create a response on a graph or gridded area. For paper-based assessments, the student may be given the response space to draw their answer, or this interaction type may be replaced with another interaction type that assesses the same standard at the same level of difficulty and can be scanned and scored electronically.
Hot Text Item (HT)	**Selectable Hot Text -** Given a set of options (e.g., phrases, sentences, or numbers) the student hovers over the options which then highlight, indicating that the text is selectable ("hot"). The student can then click on an option to select it as their response. For paper-based assessments, a "selectable" hot text item is modified so that it can be scanned and scored electronically. The student fills in a circle to indicate the correct response. **Drag-and-Drop Hot Text -** Given a set of options (e.g., numbers, words, phrases, or sentences) the student hovers over the options which then highlight, indicating that the option is selectable ("hot"). The student can then click on the object, hold down the mouse button, and drag it to a graphic, table, or paragraph. For paper-based assessments, the options are associated with a letter, and students write a letter for their response in each response area
Inline Choice Item (IC)	Given a sentence, paragraph, or table, the student clicks a blank box embedded within a sentence or table which reveals a drop-down menu containing options for completing a sentence or table. The student then selects an option from the drop-down menu to respond. For paper-based assessments, the interaction is modified so that it can be scanned and scored electronically. The student fills in a circle to indicate the correct response.
Matching Item (MI)	Given column and row headers in a table format, the student checks a box to indicate if information from a column header matches information from a row

	header. For paper-based assessments, the interaction is modified so that it can be scanned and scored electronically. The student fills in a circle to indicate the correct response.
Multiple Choice Item (MC)	The student selects one correct answer from four options. For paper-based assessments, the student fills in a circle to indicate the correct response.
Multi Select Item (MS)	The student is directed to either select an indicated number of correct answers or to select all of the correct answers. Students in grades 3-5 always select an indicated number of correct answers; students in grades 6-8 select an indicated number of correct answers on 50% of the items and select all on 50% of the items; and students taking high school end-of-course tests are always directed to select all correct answers. These items are different from multiple choice items and require the student to select 2 or more correct answers. For paper-based assessments, the student fills in circles to indicate the correct responses.
Simulation Item (Sim)	Given a set of instructions, the student may interact with any of the following controls to generate data: radio buttons, drop-down menus, slide bars, or selecting a number by clicking arrows. Once the student has set the parameters, they click the start button to begin the simulation and generate a data set. Once the student has enough data, they may answer questions about the data using a different interaction type. For paper-based assessments, this interaction will be replaced with another interaction type that assesses the same standard at the same level of difficulty and can be scanned and scored electronically.
Table Item (TI)	The student types numeric values into a given table. The student may complete the entire table or portions of the table depending on what is being asked. For paper-based assessments, the student writes their responses in the blank boxes of the table.

Note: The examples provided are not science related but inform students how to interact with the different item types.

For paper-based assessments (including those for students with an IEP or 504 plan that specifies a paper-based accommodation), the items may be modified so that they can be scanned and scored electronically or hand-scored.

Stimulus Types

A simulation stimulus consists of the following

- An interactive graphic interface that presents a set of interactive stimulus materials or simulates an investigative experiment, physical situation, or an aspect of the inquiry process. The graphics may be static or contain animation. Information is displayed in the form of dynamic illustrations or maps, statistical tables, texts, charts or graphs. Data "inputs" can be adjusted by the students, depending on the requirements of the scenario or the associated items, and the graphics adjust themselves to account for the new inputs.
- When a simulation is used as part of a task, the simulation is accompanied by one or more items of various types. The simulation functions as an interactive stimulus that provides information for the student to reflect on, analyze or synthesize with other knowledge into a cognitively demanding set of answers. This can be used to simulate an aspect of scientific inquiry.

Other stimulus types associated with discrete items or tasks may include but not limited to:

- Document excerpts and other texts
- Images and illustrations
- Graphs
- Charts
- Data tables
- Maps
- Timelines

Nature of Science One goal of science education is to help students become scientifically literate citizens that are able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**High School**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	● Identify questions and concepts that guide scientific investigations. ● Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. ● Use technology and mathematics to improve investigations and communications. ● Formulate and revise explanations and models using logic and scientific evidence (critical thinking). ● Recognize and analyze explanations and models. ● Communicate and support scientific arguments.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	● Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method). ○ Make observations and look for patterns. ○ Determine relevant independent variables affecting observed patterns. ○ Manipulate an independent variable to affect a dependent variable. ○ Conduct an experiment with controlled variables based on a question or hypothesis. ○ Analyze data graphically and mathematically. ● Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments, and peer reviews. ○ Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings. ○ Logical arguments should be evaluated with open-mindedness, objectivity and skepticism. ● Science arguments are strengthened by multiple lines of evidence supporting a single explanation. ● The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, disabilities, family backgrounds and incomes.	● Science depends on curiosity, imagination, creativity, and persistence. ● Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. ● Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. ● Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	● Science can advance through critical thinking about existing evidence. ● Science includes the process of comparing patterns of evidence with current theory. ● Some science knowledge pertains to probabilities or tendencies. ● Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. ● Improvements in technology allow us to gather new scientific evidence.

Item Specifications: Biology

Course Description

The Ohio Revised Code (ORC) Section 3313.603 requires students graduating from every public and chartered nonpublic high school complete three science units with experiences using scientific and engineering practices that engages students in asking valid scientific questions and gathering and analyzing information. Biology is a high school level course, which satisfies the Ohio Curriculum Graduation Requirements for life sciences in ORC Section 3313.603.

This course investigates the composition, diversity, complexity and interconnectedness of life on Earth. Fundamental concepts of heredity and evolution provide a framework through inquiry-based instruction to explore the living world, the physical environment and the interactions within and between them.

Students engage in investigations to understand and explain the behavior of living things in a variety of scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications.

Course Content

The following information may be taught in any order; there is no ODE-recommended sequence.

Biology

B.H: Heredity	**B.DI: Diversity and Interdependence of Life**
B.H.1: Cellular genetics B.H.2: Structure and function of DNA in cells B.H.3: Genetic mechanisms and inheritance B.H.4: Mutations B.H.5: Modern genetics	B.DI.1: Biodiversity • Genetic diversity • Species diversity B.DI.2: Ecosystems • Equilibrium and disequilibrium • Carrying capacity B.DI.3: Loss of diversity • Climate change • Anthropocene effects • Extinction • Invasive species
B.E: Evolution	**B.C: Cells**
B.E.1: Mechanisms • Natural selection • Mutation • Genetic drift • Gene flow (immigration, emigration) • Sexual selection B.E.2: Speciation • Biological classification expanded to molecular evidence • Variation or organisms within a species due to population genetics and gene frequency	B.C.1: Cell structure and function • Structure, function and interrelatedness of cell organelles • Eukaryotic cells and prokaryotic cells B.C.2: Cellular processes • Characteristics of life regulated by cellular processes • Photosynthesis, chemosynthesis, cellular respiration, biosynthesis of macromolecules

B.H: Heredity

B.H.1: Cellular genetics
B.H.2: Structure and function of DNA in cells
B.H.3: Genetic mechanisms and inheritance
B.H.4: Mutations
B.H.5: Modern genetics

CONTENT ELABORATION: HEREDITY

Building on knowledge from elementary school (plants and animals have life cycles and offspring resemble their parents) and knowledge from middle school (reproduction, Mendelian genetics, inherited traits and diversity of species), Heredity focuses on the explanation of genetic patterns of inheritance. In middle school, students learn that living things are a result of one or two parents, and traits are passed to the next generation through either asexual or sexual reproduction. Foundational concepts of mitosis and meiosis are introduced in grades 6 and 8. In addition, they learned that traits are defined by instructions encoded in many discrete genes and that a gene may come in more than one form called alleles.

B.H.1: Cellular genetics

Life is specified by genomes. Each organism has a genome that contains all the biological information needed to develop and maintain that organism. The biological information contained in a genome is encoded in its deoxyribonucleic acid (DNA) and is divided into discrete units called genes. Genes code for proteins. Different parts of the genetic instructions are used in different types of cells, influenced by the cell's environment and history. The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions. (AAAS)

B.H.2: Structure and function of DNA in cells

Mendel's laws of inheritance (introduced in grade 8) are interwoven with current knowledge of DNA and chromosome structure and function to build toward basic knowledge of modern genetics. Genes are segments of DNA molecules. The sequence of DNA bases in a chromosome determines the sequence of amino acids in a protein. Inserting, deleting or substituting segments of DNA molecules can alter genes. Sorting and recombination of genes in sexual reproduction and meiosis specifically result in a variance in traits of the offspring of any two parents. This content can be explicitly connected to evolution.

B.H.3: Genetic mechanisms and inheritance

Genetic variation in traits among offspring is a result of the movement of chromosomes crossing over, independent assortment, and recombination during gamete formation. Gene interactions described in middle school were limited primarily to dominant and codominant traits. In high school, genetic mechanisms, both classical and modern, including incomplete dominance, sex-linked traits and dihybrid crosses, are investigated through real-world examples. Statistics and probability allow us to compare observations made in the real world with predicted outcomes. Dihybrid crosses can be used to explore linkage groups, gene interactions and phenotypic variations. Chromosome maps reveal linkage groups.

B.H.4: Mutations

Genes can be altered by insertion, deletion, or substitution of a segment of DNA molecules. An altered gene is a mutation and will 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 environments. Gene mutations in gametes are passed on to offspring.

B.H.5: Modern genetics

Technological developments that lead to the current knowledge of heredity are introduced for study. The development of the model for DNA structure was the result of experimentation, hypothesis, testing, statistical analysis and technology as well as the studies and ideas of many scientists. James Watson and Francis Crick developed the current model based on the work of Rosalind Franklin and others. Scientists continue to extend the model and use it to devise technologies to further our understanding and

application of genetics. The emphasis is not on the memorization of specific steps of gene technologies, but rather on the interpretation and application of the results.

Content Limits:

- Genes are segments of DNA and code for protein;
- Concept of differentiation – although all cells have identical genetic information, different genes are active in different types of cells;
- Cellular and molecular mechanisms for inheritance and the expression of genetic information (e.g., complementary base pairs in DNA and RNA, transcription/translation);
- Importance of crossing over, independent assortment, and recombination in producing variation in traits as a result of meiosis;
- Connect Mendel's laws of segregation and independent assortment to the movement of chromosomes (crossing over, sorting, and recombination) during meiosis;
- Gene mutations and their short-term and long-term implications;
- Mendelian and Non-Mendelian inheritance (e.g., dihybrid crosses, sex-linked traits, linkage);
- The goals of genetic engineering and the role of restriction enzymes;
- Nature of Science skills and attributes related to this content.

Do Not Assess:

- Examples using human genetics;
- Mechanisms of differentiation;
- Monohybrid crosses (including co-dominance) except those beyond Grade 8 (incomplete dominance and sex-linked traits are appropriate for high school);
- Mitosis is considered in Grade 6, not assessed in high school;
- Specific molecular structure of nucleic acids or types of RNA (e.g., sugars, single vs. double strands);
- Labeling specific phases of meiosis;
- Identifying or naming enzymes, introns or exons for the steps of replication, transcription/translation and protein synthesis;
- Details about genetic engineering procedural steps.

Stimulus Attributes:

- Diagrams of DNA to illustrate protein synthesis;
- Diagrams that illustrate crossing over;
- Codon chart to build a protein;
- Parent and daughter cells before and after meiosis;
- Diagrams of a variety of genetic crosses;
- Diagrams of gene sequences showing a mutation;
- Scenarios involving applications of biotechnology and genetic engineering including, but not limited to: cloning, gene therapy, or gel electrophoresis;
- Historical data and primary sources relating to DNA discoveries;

Response Attributes: Response options may include, but are not limited to, the following:

- Demonstrating how the complementary DNA base pairing within genes determines the sequence of amino acids in a protein;
- Illustrating how non-Mendelian genetics affects inheritance (including Punnett squares);
- Predicting the probability of two traits in offspring given the parental genotypes;
- Comparing and contrasting the genetic makeup of two different types of cells in the same organism;
- Demonstrating how sorting and recombination of genes in sexual reproduction and meiosis result in variation of traits in offspring;
- Explaining how gene mutations might impact organisms;
- Interpreting data from a real-world scenario involving biotechnology (e.g., gel electrophoresis, gene therapy, cloning);
- Explaining the importance of historical discoveries after Mendel to our understanding of the structure and function of DNA;
- Explaining the scientific implications of a biotechnology (e.g., oil-eating bacteria);
- Given a scenario, making and justifying conclusions about the type of inheritance involved;
- Designing or conducting an investigation involving genetics and inheritance (e.g., fruit flies, fast plants, matching genes to traits);
- Explaining the effect that a gene mutation can have on protein synthesis or traits.

Distractors may include, but are not limited to, the following common misconceptions:

- Mutations are all bad;
- Unrealistic idea of mutations;
- All mutations have effects;
- “Cloning” refers to only the whole organism;
- Each type of cell has unique genetic material;
- Male genes are always dominant;
- Dominant genes are more frequent in a population;
- Chromosomes are totally dominant or recessive;
- All dominant genes are advantageous.
- “Cloning” refers to only the whole organism;
- Each type of cell has unique genetic material;
- Male genes are always dominant;
- Dominant genes are more frequent in a population;
- Chromosomes are totally dominant or recessive;
- All dominant genes are advantageous.

B.E: EVOLUTION

B.E.1: Mechanisms

- Natural selection
- Mutation
- Genetic drift
- Gene flow (immigration, emigration)
- Sexual selection

B.E.2: Speciation

- Biological classification expanded to molecular evidence
- Variation of organisms within a species due to population genetics and gene frequency

CONTENT ELABORATION: EVOLUTION

The basic concept of biological evolution is that Earth's present-day species descended from earlier, common ancestral species. At the elementary school level, evolution concepts include the relationship between organisms and the environment, interactions among parents and offspring and an introduction to the fossil record and extinction. At the middle school level, concepts include biodiversity (as part of biomes) and speciation, further exploration of the fossil record and Earth's history, changing environmental conditions (abiotic factors), natural selection and biological evolution. At the high school level, the study of evolution includes Modern Synthesis, the unification of genetics and evolution, historical perspectives of evolutionary theory, gene flow, mutation, speciation, natural selection, genetic drift and sexual selection.

B.E.1: Mechanisms

Natural selection is used to describe the process by which traits become more or less common in a population due to consistent environmental pressures upon the survival and reproduction of individuals with the trait. Mathematical reasoning is applied to solve problems (e.g., use Hardy-Weinberg principle to explain deviations in observed gene frequency patterns in a population compared to expected patterns based on the assumptions of the principle). Populations evolve over time. Evolution through natural selection is the consequence of 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 differential survival and reproduction of individuals based on phenotype(s).

Mutations are described in the content elaboration for Heredity. Apply the knowledge of mutation and genetic drift to real-world examples. Biological evolution explains the natural origins for the diversity of life. Emphasis shifts from thinking in terms of selection of individuals with a particular trait to changing proportions of a trait in populations as a result of the mechanisms of natural selection, genetic drift, movement of genes into and out of populations and sexual selection.

B.E.2: Speciation

Biological classification expanded to molecular evidence

Classification systems are frameworks, developed by scientists, for describing the diversity of organisms; indicating the degree of relatedness among organisms. Recent molecular sequence data generally support earlier hypotheses regarding lineages of organisms based upon morphological comparisons. Both morphological and molecular comparisons can be used to describe patterns of biodiversity (cladograms present hypotheses to explain descent from a common ancestor with modification). The concept of descent from a common ancestor with modification provides a natural explanation for the diversity of life on Earth as partially represented in the fossil record and in the similarities of existing species.

Variation of organisms within a species due to population genetics and gene frequency

Different phenotypes result from new combinations of existing genes or from mutations of genes in

reproductive cells. At the high school level, the expectation is to combine grade 8 knowledge with an explanation of genes and the function of chromosomes. Natural selection works on the phenotype.

Heritable characteristics influence how likely an organism is to survive and reproduce in a particular environment. When an environment changes, the survival value of inherited characteristics may change. This may or may not cause a change in species that inhabit the environment. Use real-world examples to illustrate natural selection, gene flow, sexual selection, and genetic drift.

Content Limits:

- Evolution of a species (change in gene frequency in a population and the Hardy-Weinberg Law);
- Mechanisms of speciation (gene flow, mutation, speciation, natural selection, genetic drift, sexual selection);
- Evidence for evolution (e.g., fossil record, molecular and structural homology, biogeography).
- Nature of Science skills and attributes related to this content.

Do Not Assess:

- Human evolution;
- The fossil record as evidence for biodiversity, diversity within a species, and the fact that most species that have lived on Earth are now extinct (this assessed in Grade 8);
- Formation of fossils and/or geologic strata;
- Calculations using the Hardy-Weinberg Law;
- Genes as they relate to specific traits in individuals; (This is assessed in Heredity)

Stimulus Attributes:

- Evidence of evolutionary theory from real-world examples (e.g., antibiotic resistant bacteria, fossil record, molecular and structural homology);
- Cladograms showing relationships between species;
- Scenarios in which environmental changes influence selective pressure on a population;
- Examples of speciation between isolated populations (e.g., leopard frogs, anole lizard, Central American hummingbirds);
- Tables or data showing gene frequency changes over time (e.g., bottleneck cheetahs).
- Primary sources including current research on environmental changes and its impact on populations.

Response Attributes: Response options may include, but are not limited to, the following:

- Using mathematical reasoning related to the Hardy-Weinberg Law to explain or predict changes in a population;
- Predicting how factors affect evolution of a population or populations;
- Given evidence, determining the relatedness of groups;
- Comparing the survivability of traits between populations in different environments;
- Comparing evolutionary mechanisms illustrated in a variety of populations;
- Given data and/or a scenario, making and justifying a conclusion about evolutionary mechanisms in a population;
- Explaining how variations within populations in a changing environment can lead to evolution;
- Describing how speciation occurred in two related populations;
- Using examples to explain how evidence supports the theory of evolution;
- Explain and/or predict how a population has responded to environmental changes.
- Completing cladograms to determine relationships among organisms

Distractors may include, but are not limited to, the following common misconceptions:

- Evolution always results in new species;
- Non-genetic traits can be passed to offspring;
- Genetic traits can be acquired when needed or lost when not needed;
- Evolution happens to an individual;
- Individual organisms choose to evolve;
- Variation is a response to selection pressure;
- The “strongest” organisms survive.

B.DI: DIVERSITY AND INTERDEPENDENCE OF LIFE

B.DI.1: Biodiversity
- Genetic diversity
- Species diversity

B.DI.2: Ecosystems
- Equilibrium and disequilibrium
- Carrying capacity

B.DI.3: Loss of diversity
- Climate change
- Anthropocene effects
- Extinction
- Invasive species

CONTENT ELABORATION: DIVERSITY AND INTERDEPENDENCE OF LIFE

Building on knowledge from elementary school (interactions of organisms within their environment and the law of conservation of matter and energy, food webs) and from middle school (flow of energy through organisms, biomes and biogeochemical cycles), this topic at the high school level focuses on the study of diversity and similarity at the molecular level of organisms. Additionally, the effects of physical/chemical constraints on all biological relationships and systems are investigated. The unidirectional flow of energy and the cycling of matter as organisms grow, reproduce and die occurs at all levels of biological organization. Previous knowledge focused on biological systems at equilibrium; at the high school level, biological systems not at equilibrium and their responses are considered. Diagrams and models are used to explain the effects of real-world interactions and events within an ecosystem.

B.DI.1: Biodiversity

The great diversity of organisms and ecological niches they occupy result from more than 3.8 billion years of evolution. Populations of individual species and groups of species comprise a vast reserve of genetic diversity. Loss of diversity alters energy flow, cycles of matter and persistence within biological communities. Loss of genetic diversity in a population increases its probability of extinction.

B.DI.2: Ecosystems

Ecosystems change as geological and biological conditions vary due to natural and anthropogenic factors. Like many complex systems, ecosystems have cyclical fluctuations around a state of equilibrium. The rate of these fluctuations in ecosystems can increase due to anthropogenic factors. Changes in ecosystems may lead to disequilibrium, which can be seen in variations in carrying capacities for many species. Authentic data are used to study the rate of change in matter and energy relationships, population dynamics, carbon and nitrogen cycling, population changes and growth within an ecosystem. Graphs, charts, histograms and algebraic thinking are used to explain concepts of carrying capacity of populations and homeostasis within ecosystems by investigating changes in populations that occur locally or regionally. Mathematical models can include the exponential growth model and the logistic growth model. The simplest version of the logistic growth model is Population Growth Rate = rN(K-N)/K, which incorporates the biological concept of limited (non-infinite) carrying capacity, based upon intra- and interspecies competition for resources such as food, as represented by the variable K. Carrying capacity is defined as the population equilibrium size when births and deaths are equal; hence Population Growth Rate = zero.

B.DI.3: Loss of diversity

An ecosystem will maintain equilibrium with small fluctuations in its abiotic and biotic components, but significant fluctuations can result in long-term alterations of the ecosystem and ultimately a loss of biodiversity. This can be caused by natural and anthropogenic events. Humans are a biotic factor in ecosystems and can impact critical variables within these systems. Climate is dependent on a number of feedback loops between sunlight, the ocean, the atmosphere and the biosphere. Increasing mean global temperatures cause increased variance in weather that impacts both biotic and abiotic factors. Multiple

changes happening simultaneously can stress ecosystems. Extreme events such as prolonged drought, floods, or the introduction or removal of species can result in long-term alterations to ecosystems and their functions. The current rate of extinction is at least 100-1000 times the average background rate observed in the fossil record. The observed rates of biodiversity loss are indicative of a severe and pervasive disequilibrium in ecosystems. At the high school level, students should examine the factors that contribute to the accelerated extinction rates observed today and the implications of declining biodiversity carrying capacity. Misconceptions about population growth capacity, interspecies and intraspecies competition for resources, and what occurs when members of a species immigrate to or emigrate from ecosystems are included in this topic. Technology can be used to access real-time/authentic data to study population changes and growth in specific locations.

Content Limits:

- Cyclical fluctuations and their impact on ecosystems around a rough state of equilibrium/disequilibrium;
- Energy flow at ecosystem and molecular levels;
- Demonstrating biodiversity through studying classification using morphological and molecular evidence;
- Diversity of species and ecological niches resulting from billions of years of evolution;
- Models describing carrying capacity and homeostasis within ecosystems supported with mathematical evidence**.**
- Nature of Science skills and attributes related to this content.
- Causes of biodiversity loss
- Impacts of biodiversity loss

Do Not Assess:

- Identification of trophic levels, consumers, producers, predator-prey and symbiotic relationships;
- Construction of food chains and/or webs;
- Features or definition of biomes;
- Steps of biogeochemical cycles;
- Memorization of Linnaeus' classification of living things;
- Calculations involving logistic growth or other models.
- Procedural steps involved in equipment use in biodiversity research and acquisition of data.

Stimulus Attributes:

- Population graphs or charts containing authentic, real-world data;
- Diagrams of food chains and webs to explain real-world relationships or events within an ecosystem (e.g., biomagnification, invasive species, energy flow and nutrient cycle changes);
- Scenarios involving remediation and habitat restoration programs (e.g., fish populations in the Great Lakes);
- Scenarios involving niche partitioning, competition for resources, immigration/emigration from an ecosystem, or environmental change;
- Cladograms;
- Data tables showing biodiversity between organisms.

Response Attributes: Response options may include, but are not limited to, the following:

- Using mathematical reasoning to interpret exponential or logistic growth models;
- Designing or simulating a population growth model by manipulating environmental conditions;
- Given population graphs or charts containing data, analyzing the history or predict the future of an ecosystem;
- Predicting the effect of geological, biological, or environmental changes on a population within an ecosystem (e.g., climate change, deforestation, human development);
- Predicting the effect of geological, biological, or environmental changes on a population within an ecosystem (e.g., climate change, deforestation, human development);

- Discussing the implications of technology or engineering on an ecosystem (e.g., power plant increasing water temperature);
- Using mathematical models to explain carrying capacity and homeostasis within ecosystems;
- Given a scenario, designing an experiment to predict the effect of several possible factors on the carrying capacity;

Distractors may include, but are not limited to, the following common misconceptions:

- Carrying capacity never changes;
- Environmental change is always responsible for genetic variation;
- Environmental changes are always detrimental;
- A stable ecosystem is graphically represented by a static horizontal line;
- All usable energy is conserved and passed on in a usable form in an ecosystem.

B.C: CELLS

B.C.1: Cell structure and function

- Structure, function and interrelatedness of cell organelles
- Eukaryotic cells and prokaryotic cells

B.C.2: Cellular processes

- Characteristics of life regulated by cellular processes
- Photosynthesis, chemosynthesis, cellular respiration, biosynthesis of macromolecules

CONTENT ELABORATION: CELLS

Building on knowledge from middle school (cell theory, cell division and differentiation), this topic focuses on the cell as a system itself (single-celled organism) and as part of larger systems (multicellular organism), sometimes as part of a multicellular organism, always as part of an ecosystem. The cell is a system that conducts a variety of functions associated with life. Details of cellular processes such as photosynthesis, chemosynthesis, cellular respiration and biosynthesis of macromolecules are addressed at this grade level. The concept of the cell and its parts as a functioning biochemical system is more important than just memorizing the parts of the cell.

B.C.1: Cell structure and function

Every cell produces a membrane through which substances pass differentially, maintaining homeostasis. Molecular properties and concentration of the substances determine which molecules pass freely and which molecules require the input of energy. In all but quite primitive cells, a complex network of proteins provides organization and shape. Within the cell are specialized parts that transport materials, transform energy, build proteins, dispose of waste and provide information feedback and movement. Many chemical reactions that occur in some cells of multicellular organisms do not occur in most of the other cells of the organism. Prokaryotes, simple single-celled organisms, are first found in the fossil record about 3.8 billion years ago. Cells with nuclei, eukaryotes, developed one billion years ago and from these increasingly complex multicellular organisms descended.

B.C.2: Cellular processes

Living cells interact with, and can have an impact on, their environment. Carbon is a necessary element that cells acquire from their environment. Cells use carbon, along with hydrogen, oxygen, nitrogen, phosphorous and sulfur, during essential processes like respiration, photosynthesis, chemosynthesis and biosynthesis of macromolecules (e.g., proteins, lipids, carbohydrates). Chemical reactions that occur within a cell can cause the storage or release of energy by forming or breaking chemical bonds. Specialized proteins called enzymes lower the activation energy required for chemical reactions, increasing the reaction rate. Positive and negative feedback mechanisms regulate internal cell functions as external conditions vary. Most cells function within a narrow range of temperature and pH. Variations in external conditions that exceed the optimal range for a cell can affect the rate at which essential chemical reactions occur in that cell. At very low temperatures, reaction rates are slow. High temperatures can irreversibly change the structure of most protein molecules. Changes in pH beyond the optimal range of the cell can alter the structure of most protein molecules and change how molecules within the cell interact.

The sequence of DNA bases on a chromosome determines the sequence of amino acids in a protein. Enzymatic proteins catalyze most chemical reactions in cells. Protein molecules are long, folded chains made from combinations of 20 common amino-acids. The activity of each protein molecule results from its sequence of amino acids and the shape the chain takes as a result of that sequence.

Note 1: *The idea that protein molecules assembled by cells conduct the work that goes on inside and outside the cells in an organism can be learned without going into the biochemical details. It is sufficient for students to know that the molecules involved are different configurations of a few amino acids and that the different shapes of the molecules influence what they do.*

Note 2: *Emphasis is on inputs and outputs of matter and the transfer and transformation of energy in biological processes. Specific steps, names of enzymes, and intermediates of the pathways for these processes are beyond the scope of the standards.*

Content Limits:

- The cell is a functioning system (e.g., regulation, homeostasis, cell cycle, and transport);
- The cell has specialized parts for the transport of materials, energy transformation, protein building, waste disposal, and movement;
- Role of water and organic molecules in cells (lipids, carbohydrates, nucleic acids, proteins);
- Properties of the cellular environment that affect shape and function of enzymes (e.g., pH, temperature, concentration);
- Transformation of energy through ATP and cycling of carbon through cellular processes in cells (e.g., photosynthesis, cellular respiration).
- Nature of Science skills and attributes related to this content.

Do Not Assess:

- Steps of protein synthesis;
- Names of specific enzymes;
- Memorization of formulas and detailed chemical reactions associated with cellular functions;
- Memorization of cell parts and their functions (basic cell parts and functions are assessed at Grade 6);
- Electron transport chains.
- Memorization of the steps of feedback loops

Stimulus Attributes:

- Investigative scenarios that explore abiotic effects on the cell cycle;
- Investigative scenarios that determine factors that affect the activity of enzymes on their substrates;
- Environmental and industrial application of cells (e.g., fermentation, medicine, plastics, oil spills)
- Diagrams of photosynthesis, cellular respiration, and/or chemosynthesis connected to a real-world scenario;
- Diagrams of cells from a variety of organisms (e.g., plant vs. animal cells, prokaryotic vs. eukaryotic cells);
- Diagrams or simulations of cellular transport (e.g., cells with or without a potassium pump, osmosis, facilitated diffusion).

Response Attributes: Response options may include, but are not limited to, the following:

- Interpreting graphs or data (e.g., temperature, pH, light, concentration) to explain the rate of enzyme activity in a cell;
- Explaining how the structure of cellular parts facilitates their function;
- Describing regulation of the cellular environment (e.g., homeostasis);
- Comparing organic molecules and their role in cells;
- Describing how photosynthesis and cellular respiration impact the concentration of chemicals in a system;
- Using a diagram of the basic stages of photosynthesis (light and dark reactions) identify the major reactants/products (CO_2, H_2O, ATP, O_2, glucose) involved in each stage;
- Explaining how cell components work together to perform the functions of the cell;
- Analyzing graphs displaying data about enzyme activity and how that impacts a cell;
- Designing an experiment to determine the effect of external factors (e.g., pH, temperature, concentration) on the cellular function (e.g., transport, enzyme rate, photosynthesis, cellular respiration);
- Evaluating or improving the design of an industrial application of cellular processes (e.g., optimal environment for fermentation, genetically modified organisms).

Distractors may include, but are not limited to, the following common misconceptions:

- Plant cells only produce oxygen;
- Only animal cells perform cellular respiration;
- Most of plants mass is from water or soil (gases have no mass);
- Oxygen is produced from the carbon dioxide in photosynthesis;
- Energy can be created by cellular processes;
- Equilibrium means no movement of molecules;
- Prokaryotic cells lack membranes;
- Only plant cells have cell walls;
- Plants are prokaryotic and animals are eukaryotic;
- All lipids are “bad.”