Biology

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Biology is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three units of science.. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

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.

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

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 species due to population genetics and gene frequency

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

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

NATURE OF SCIENCE HIGH SCHOOL

Nature of Science One goal of science education is to help students become scientifically literate citizens 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, abilities, 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.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Biology continued

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.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. Ohio's Cognitive Demands relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the Nature of Science.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.H.1: Cellular genetics			
Discuss ways that human genetic information can be used (e.g., ancestry, health) and the ethical implications of using this information.		Using information from the Human Genome Project, show how DNA testing companies have developed and what information is used to show how people are related. Compare the DNA sequences of different cells from the same organism. Explain how all cells, except gametes, in a specific organism have identical genetic information (DNA) but have different functions. Compare the information that is provided by various commercial genetic testing companies and determine how it can be used.	Describe the central dogma (DNA to RNA to protein) and its relationship to heredity.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.H.2: Structure and function of DNA in cells			
		Discuss and provide evidence that phenotypic variations may result from genetic recombination through meiosis (e.g., sorting, recombination, crossing over) and sexual reproduction.	Given one strand of DNA, construct the complementary strand and/or the mRNA molecule transcribed from it. Describe the process of meiosis in relation to the function of DNA and chromosomes in coding the instructions for traits passed from parents to offspring.
B.H.3: Genetic mechanisms and inheritance			
	Propose hypotheses, design experiments and analyze a population (e.g., dog breeds, fruit flies, Fast Plants, virtual simulations) to identify the genotypes of one or more individuals with unknown genotypes. Use Punnett Squares and pedigrees based on their phenotypes and the phenotypes of their offspring. Use the principles of statistics to compare real-world data to predicted outcomes.	Explain the outcomes of a series of genetic crosses from a population (e.g., fruit flies, virtual simulation, Fast Plants) using Mendelian and non-Mendelian genetics (e.g., incomplete dominance, sex-linked traits, dihybrid crosses). Include a discussion of gene interactions, gene linkage and the source of phenotypic variation.	Use a model of meiosis to demonstrate crossing over and independent assortment during gamete formation. Explain how this contributes to variation within a population.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	B.H.4: Mutations		
		Given examples of original and mutated DNA segments, analyze the mutation and identify the impact on phenotype. Make a connection to how natural selection might favor, select against or be neutral on the resulting changes in the protein (phenotype).	Recall types of mutations and describe the effects they might have on a protein. Classify mutations as gene mutations (e.g., insertion, deletion, substitution) or chromosomal mutations (e.g., trisomy, monosomy). Evaluate chromosome maps to identify linkage groups.
	B.H.5: Modern genetics		
Research current genetic engineering practices (e.g., Clustered Regularly Interspaced Short Palindromic Repeats [CRISPR], GMO, specially modified bacteria, cloning, epigenetic technology). Evaluate the implications of implementing genetic engineering practices. Using knowledge of genetic technology, create a proposal for the design of a product to solve a current world problem (e.g., golden rice, oil-eating bacteria, insulin-producing bacteria, pigs for producing human organs).	Given a problem (e.g., diseases, hunger, pests, water concerns), propose a solution that uses genetic technology (e.g., specially modified bacteria, GMO, CRISPR, epigenetic technology) and defend your reasoning. Use electrophoresis (actual or virtual) technology to evaluate DNA results (e.g., crime scene analysis, paternity, phylogenetic relationships).	Explain how electrophoresis is used to evaluate DNA results (e.g., crime scene analysis, paternity, phylogenetic relationships).	Create a timeline of the significant discoveries in genetics.

Biology continued

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.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.E.1: Mechanisms			
Genetic drift			
Consider an organic farming operation growing a heritage variety of sweet corn. The operation borders a large, industrial farm producing genetically modified corn. The organic farm's success is threatened by both gene flow from the corporate GMO (genetically modified organism) farm and genetic drift. Propose a solution to minimize the effect of these factors on the organic farm. Design a solution to lessen the impact of genetic drift (e.g., increasing genetic variation in populations of cheetahs or lowland gorillas housed in zoos around the world).	Generate hypotheses to explain real-world examples of apparent genetic drift (e.g., maintaining heritage breeds of crop plants and livestock, hemophilia in Queen Victoria's descendants, polydactylism in the Amish population, inbreeding in isolates, island populations, loss of diversity in artificially fertilized livestock or zoo populations).	Identify and explain a real-world example of genetic drift.	Differentiate between gene flow (e.g., pollen from GM crops blowing to an organic farmer's crop) and genetic drift (e.g., limited variation within corn crops).

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Modeling Hardy Weinberg			
Critique a real-world solution to the arrival of an invasive species and how it changed native populations and/or the invasive population with respect to Hardy-Weinberg assumptions (e.g., Ohio examples: Japanese honeysuckle, zebra and quagga mussels, Emerald Ash Borers, purple loosestrife, white-nose syndrome in bats). Design an engineering or technical solution to keep out or remove an invasive species from a local habitat (e.g., invasive fish out of Lake Michigan, garlic mustard, Zebras mussels, invasive lampreys from Great Lakes tributaries). Construct a program to remove all descendants of invasive species in a habitat (e.g. rats on small Pacific island). Design an engineering/technical solution to help return native species following the intentional removal of all invasive species (e.g. rats on small Pacific islands). Design and construct a habitat that maintains the gene pool of a transplanted population at equilibrium.	Generate hypotheses to predict the ecological changes following the appearance of an invasive species into a new habitat (e.g., fire ants invading Ohio) based on reports of the impact of that species in other habitats in the recent past.	Using a model of Hardy Weinberg, explain the results of a change generated in the model population. Prepare a visual representation to present information. Identify the likely stakeholders (e.g., commercial or sporting groups) affected by the arrival of an invasive species. Prepare a presentation for those stakeholders about predicted changes and the basis for making these predictions.	Use Hardy-Weinberg principles to explain the concept of an individual acting as a "carrier" of a rare genetic disorder. Provide an example of an invasive species and describe the nature of the biological relationship with each native species that is impacted.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.E.2: Speciation			
Natural selection			
Design a medical protocol to discourage the persistence (spread) of antibiotic resistance through natural selection in populations of bacteria. Design an agricultural solution/procedure to discourage the persistence (spread) of herbicide resistance in crop plants or pesticide resistance in insects through natural selection.	For two closely related species such as sibling species, (e.g., tassel-eared squirrels, yellow-rumped and Audubon's warbler, plant examples) propose hypotheses to explain their current distributions.	Given information about the current range and population size of a species, predict the effect of a change in environmental factors (e.g., retreat of the last glaciers, rapid increase in water temperatures in the Gulf of Maine) on the species. Design a public exhibit that attracts tourists by demonstrating convergent evolution of plants on different continents. Compare the work of Lamarck, Darwin and Wallace.	Explain how natural selection has affected a species (e.g., Darwin's finches, peppered moths, Hawaiian honeycreepers, Galapagos tortoises).
Variance within and between populations			
Observe and measure traits within several groups of local species. Propose an engineering solution to block or allow interbreeding between neighboring populations (e.g., tassel-eared squirrels).	Examine neighboring populations of similar species. Propose one or more analyses to determine if they are distinct species.	Present graphically the distribution of a specific trait within and between species in a group (e.g., needle length or number of needles in multiple pine species). Interpret your data through natural selection.	Identify a geographical barrier likely responsible for distinct, yet similar populations in an area (e.g., Lake Erie Water Snakes (LEWS), tassel-eared squirrels) and explain how it might account for the close similarity of multiple forms.
Modern and historical theory			
		Explore modern and historical evidence from various disciplines (e.g., molecular, anatomical, paleontological) that support the theory of evolution through natural selection.	Use molecular, anatomical, and/or paleontological data to explain classic examples of convergent evolution.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Evolutionary relatedness			
Design a technological solution to determine identification in species where visual cues alone cannot determine the identity (e.g., bird species that can only be identified by their song or mating behaviors).	Select a group of organisms and generate an evolutionary hypothesis with a cladogram using researched data (e.g., molecular, anatomical, binomial nomenclature). Evaluate cladograms produced by classmates. Support proposed evolutionary relationships with evidence.	Interpret the degree of evolutionary relatedness (phylogenetic closeness) based on information found in a cladogram. Evaluate two or more cladograms representing different hypotheses of the evolution of a given clade.	Given data in a table (e.g., molecular, anatomical, binomial nomenclature) illustrate evolutionary relatedness (phylogenetic closeness) using a cladogram.

Biology continued

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.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

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B.DI.1: Biodiversity			
Genetic diversity			
Investigate a species of extremely low abundance (e.g., Vaquita porpoise, Sumatran/Javan rhinos or native bees) and propose monitoring or management methods to increase the genetic diversity.	Investigate various agricultural/crop production practices, then propose a hypothesis to explain how these practices might impact a species' genetic diversity. Review data (e.g., recorded by National Center for Biotechnology Information, National Institutes of Health, Centers for Disease Control and Prevention) to examine genetic diversity within populations. Evaluate populations with specific genetic traits and how these are related to the survival abilities of the population (e.g., Irish potato famine, northern white rhino, hemophilia, sickle cell anemia, malaria). Compare and contrast the factors that influence growing/propagating different varieties (e.g., heirloom and genetically modified organisms) of plants of the same species. This could include growing each variety if resources permit. Using this information, advise the stakeholders of a country/community about the trade-offs of growing each type of plant.	Use a model or simulation to analyze the impact of an environmental stressor on the genetic diversity and long-term survival of a population.	Identify organisms with high (e.g., tomatoes, beans) and low (e.g., cheetahs) genetic diversity. Recognize that species with low genetic diversity are more likely to become extinct.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Species diversity			
Propose and justify suggestions to increase diversity and stability of an ecosystem. Design, evaluate, and refine a solution to reduce the impacts of human activities on the environment and biodiversity. Investigate the practice of stocking fish in Ohio to identify potential problems and benefits of this practice. Examine how this practice impacts the environment. Develop a public service announcement (PSA) to inform the community about a specific fish that will be stocked in the community's local waterway. Explore a species that has been removed from the endangered species list (e.g., Lake Erie Water Snakes (LEWS), river otters, bobcats). Evaluate how this action can impact the species and the environment.	Investigate species diversity for local populations, which could include school grounds and/or local wildlife areas, by comparing the number of different species to the abundance of each species. Consider a stream survey or investigate the influence of introducing wolves back into an ecosystem (e.g., Isle Royale, Yellowstone).	Using data on a variety of Ohio species, create a chart comparing the species diversity across the state's ecosystems. Use historical and real-time data (e.g., Ohio Department of Natural Resources (ODNR) historical and current data) to monitor changes in populations of Ohio species and correlate population size to wildlife management policies (e.g., river otters, deer, Canada geese, sturgeons). Examine current lake or stream fish populations in local bodies of water to make predictions of future population numbers. Compare this to past years data from ODNR and project future population numbers. Investigate the species diversity within a biome. Analyze the number of different types of vertebrates, invertebrates and plant species in a biome. Identify patterns in distribution between different biomes and consider the influence latitude and/or altitude plays on species diversity. Correlate the patterns of diversity with energy flow, cycles of matter, and persistence within biological communities.	

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.DI.2: Ecosystems			
Equilibrium and disequilibrium			
Devise a plan to address the ecological and economic impacts of an invasive species. The plan should address lessening the species' impacts. Design, evaluate, and communicate to stakeholders the strategies to restore equilibrium to an ecosystem previously altered by human impact (e.g., dams, channelization, urbanization, nutrient overload/algal blooms in lakes). Select a species that has recently been removed from the endangered species list. Evaluate the current management plan and how this action will impact the species and the environment.	Devise a study to investigate an ecosystem in equilibrium and an ecosystem in disequilibrium (e.g., changing populations of algae species in an aquarium as a function of phosphorus concentration over time). Gather data and analyze the results.	Predict how predator/prey population cycles (e.g., moose/wolf, hare/lynx) will change if there are changes in the numbers of either species. Explain how humans can impact predator/prey relationships (e.g., hunting large predators such as wolves, hunting large herbivores such as bison, Nile Perch). Compare equilibrium and disequilibrium. Give examples of each in real populations. Relate this to Ohio animals and plants. Consider the impact of stocking fish on a native population of the same or similar (able to interbreed) fish (e.g., rainbow trout). Investigate an invasive species in Ohio (e.g., zebra mussels, purple loosestrife, emerald ash borer, sea lamprey, honeysuckle, gobies, Asian carp), analyze its impacts and predict the ecological and economic impacts on communities. Research should include analyzing the factors that contribute to the organism's success as well as various ideas to provide a solution for managing the species.	

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Carrying capacity			
	Investigate how urban sprawl affects carrying capacity for a native population (e.g., loss of native populations from the introduction of kudzu for groundcover, the use of Japanese honeysuckle for ornamentation).	Analyze population data for patterns in population cycles and determine carrying capacities. Identify and explain correlations between variables in population data. Track the effect of varying levels of disturbance (e.g., regulated hunting, poaching, seasonal flooding, volcanic eruption, sea level rise) on ecosystems and create data sets to communicate findings.	Identify and label various features of population growth curves (e.g., fast or slow growth rates, carrying capacity, equilibrium, population boom and bust). Describe the characteristics of exponential and logistical growth.
Population studies			
Design a tracking method to estimate population size and carrying capacity for an organism.	Use real-time data (e.g., from student designed tracking methods or Movebank data) to track and monitor populations. Analyze data to determine population cycles and carrying capacity.		

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.DI.3: Loss of diversity			
Climate change			
Heat retention due to increasing levels of atmospheric greenhouse gases poses challenges for species. Use data-driven models to predict how current rates of change could reshape the range and distribution of species.	Use satellite or buoy temperature data to analyze ocean temperature and evaluate temperature effects on marine life. Investigate a local species (e.g., tree, insect, amphibian, reptile). Use historical and current data to create a profile of the species showing the impact of climate over the past century. Conduct an experiment to measure changes in temperature of an enclosed environment (e.g., terrarium, 2L bottle) by altering variables such as light intensity, CO_2 and humidity. Compare the effect of different factors on the enclosed ecosystem. Plan a project utilizing real-time/authentic data (e.g., community planners, ODNR, interviews with local farmers) to explain strategies (e.g., pest control, water supply, crop rotations, stormwater management) used to adapt to changes in climate.	Given real-world data charts from NASA or NOAA construct graphs to examine how factors involved in climate change impact global biological diversity (e.g., coral reefs, desertification, ocean acidification). Compare historical levels of atmospheric greenhouse gases with levels over the last century. Relate this to climate change and its impact on biodiversity. Identify patterns in local weather conditions (e.g., temperature, precipitation) and changes in the severity or frequency of extreme weather events. Make inferences on how these changes may impact Ohio climate zones in the future.	Describe feedback loops that exist between sunlight, the ocean, the atmosphere and the biosphere. List examples of local environmental impacts caused by climate change (e.g., increased flooding, shoreline erosion, shifting planting zones, drought). Draw and label a biogeochemical cycle (e.g., carbon cycle, water cycle, nitrogen cycle). Identify the factors within this cycle that are influenced by climate change.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Anthropocene effects			
Design, evaluate, or refine a solution for reducing the impacts of human activities (e.g., urbanization, building dams, introduction of invasive species, sinking ships to rebuild coral reefs, creating manmade lakes) on the environment and biodiversity. Research how domestication and selective breeding have impacted animal and plant genetic biodiversity (e.g., apples, dogs). Analyze the impacts of the changes. Predict how biodiversity will be impacted in the future.	Design a study to examine how Earth system interactions are modified by human activities (e.g., an increase in atmospheric carbon dioxide results in an increase in ocean acidification that impacts marine populations).	Provide examples of GMOs and examine their possible impact on the environment. Use principles of evolution through natural selection to explain the rise in the occurrence of herbicide-resistant weeds in areas using herbicide-resistant GMO corn and soy seeds. Compare this process with the rise of antibiotic-resistant microbes.	Identify and describe anthropogenic factors (e.g., acid rain, ozone depletion, landfill leaching, thermal pollution, light pollution) and correlate these influences with their impacts on the environment. Graph the global growth of the human population over the last 10,000 years.
Extinction			
Research the role zoos are playing in the conservation of endangered or threatened species. Analyze the impact of these efforts to address the potential loss of diversity within the species or within the ecosystem. Identify the limitations of zoo-based captive breeding programs (e.g., inbreeding) and propose solutions to minimize such problems. Investigate a species of extremely low abundance (e.g., Vaquita porpoise, Sumatran/Javan rhinos) and propose monitoring or management methods to improve the genetic diversity. Research the possibility of bringing back extinct species. Examine species restoration methods and techniques. Explore the possibility of de-extinction of a species, its ecological impacts, moral implications and economic values.	Given a factor that may impact the ecosystem (e.g., weather event, pesticide, climate change) predict the influence of the impact on the ecosystem. Predict which species would be most vulnerable to extinction and which species would be most resilient. Defend your reasoning. Examine the established programs to repopulate endangered animal species. Pick a species involved in the restoration and describe current methodology and costs of these programs. Project the benefits to society and why these species are critical to their ecosystem. Examine the role of social media, national economy, politics, energy use, commercial interests, and local traditions in the decision-making process.	Explore a region of the world that is experiencing high rates of extinction and examine the cause. Analyze the impact of extinction on keystone species, food webs, niches and cycling of matter. Discuss the limitations of zoos, arboretums and botanical gardens as defenses against global biodiversity loss.	List historical events that have that resulted in species extinction. Categorize recent causes of extinction of species (e.g., overharvesting, habitat loss). Identify possible impacts species extinction has on biological communities.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Invasive species	
Research an invasive species in Ohio, analyze its ecological and economic impacts on biological and human communities. Identify factors that contribute to the species' success and propose solutions to reduce the ecological and economic impacts of the species.	Investigate the prevalence of invasive species in the local area and the impact these species have on native species.	Explain the impact of various invasive species control methods on invasive and native species populations (e.g., LEWS). Investigate the increase of human disease due to invasion and range expansion of disease vectors (e.g., mosquitoes, ticks). Examine both human and natural means for vector movement (e.g., severe acute respiratory syndrome [SARS], West Nile, Bird Flu, Tsetse fly, nematodes).	Describe common ways invasive species are introduced to a new habitat. Describe the characteristics of successful invasive species. Create a list of invasive species for your local area and identify the native species with which they compete. Relate this to the ecological controls of native species in the area and how the invasive species escapes those (e.g., invasive starlings are more aggressive at defending nest sites than native bluebirds).

Biology continued

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.*

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.C.1: Cell structure and function			
Building a cell membrane			
	Develop an investigation to observe how materials transport across a selectively permeable membrane and how various cells respond to different environmental conditions to maintain a dynamic equilibrium. Construct a model of the phospholipid bilayer and predict the movement of various materials across the membrane.	Use a model of the phospholipid bilayer and demonstrate transport of various materials across a semipermeable membrane that maintains homeostasis. Provide a survival advantage explanation for why some organelles have double membranes.	Identify different types of transport. Determine how materials move across a selectively permeable membrane.
Cell tour			
		Within a cell, model the synthesis of a hormone such as insulin, including modifications, from start to finish.	Identify the interactivity of organelles resulting in cellular processes such as protein synthesis and metabolism.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Microscopy			
	Collect and analyze microscopic organisms from a local pond or stream. Infer evolutionary relationships between organisms according to ancestral traits and derived characteristics like cell parts and multicellularity.	Create a graphic organizer consisting of various cells and cell structures. Organize them according to size. Investigate how each would appear under different types of microscopes.	
Homeostasis and feedback loop			
Research the cause and effect of various homeostatic diseases (e.g., Type 2 diabetes, high blood pressure, gout) and develop solutions to achieve homeostatic balance for patients that suffer from this disease. Suggest an explanation for the increased incidence of diabetes worldwide.	Plan and conduct an investigation that identifies or manipulates feedback mechanisms to maintain homeostasis. Investigations could include heart rate response to exercise, stomate response to moisture and temperature and root development in response to water levels.	Illustrate a model of negative or positive feedback including a sensor, a control center, effectors and variables being regulated.	Compare negative and positive feedback mechanisms.
B.C.2: Cellular Processes			
Fermentation			
Refine a product such as yogurt so that it better addresses dietary concerns, restraints and restrictions (e.g. diabetics, infants, bodybuilders).	Design a lab studying yeast and adjust variables such as temperature, pH and food sources. Use probes or other methods to measure gas exchange.	Provide data from fermentation activities (e.g., Kombucha, sauerkraut) and evaluate variables and outcomes.	Identify the cellular organelles involved in fermentation. Include inputs and outputs required for the process.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Biosynthesis of macromolecules	
Plan and design an investigation using algae, fungi or other microorganisms to biosynthesize a natural product that has commercial applications.	Research various biomolecules found in food. Investigate a food source and identify its biomolecule components. Evaluate and critique popular food options on the market and determine if the nutritional analysis is factual. Using nutritional data create a new marketing promotion for healthier food choices and present findings.	Research various techniques to extract oil or hormones from algae. Infer the structural changes (e.g., cellular inclusions, smooth endoplasmic reticulum proliferation) to the algal cells that these techniques may cause. Which strains of algae utilize the most cost-efficient metabolic pathways for oil or hormone production?	Construct models of various biomolecules. Identify basic building blocks, functions, and location of biomolecules in food and/or the environment.
		Enzymes	
	Plan and design an investigation to determine the factors (e.g., temperature, pH, substrate concentration) that affect the activity of enzymes on their substrates (e.g., peroxidase). Research diseases caused by enzymatic deficiencies and propose possible solutions or evaluate how medical breakthroughs have solved the problem (e.g., lactase persistence, adrenoleukodystrophy, mitochondrial disorders).	Using a simulation or data predict the effects of different variables (e.g., temperature, pH, salinity) on enzyme structure and function. Given a graph, interpret and analyze activation energy with optimal pH and temperature.	Identify the structure and function of enzymes and substrates applying models such as lock and key or induced fit.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Photosynthesis and respiration			
Promote awareness of photosynthetic processes as a component of the Earth's CO_2 recycling system. Design a "green" environment (e.g., school, house, microenvironment) that demonstrates sustainable environmental practices, such as vegetated green roof systems to improve air quality. The design should encompass the efficient use of fuel resources and building materials to lower carbon footprint and reduce greenhouse gas emissions. Generate an argument and present data justifying how the design improves sustainability.	Design experiments to study gas exchange in photosynthetic organisms. Analyze the data generated to justify which environmental conditions are the most efficient for the photosynthetic organisms. Probes could be used to measure gas exchange.	Generate a model to depict the role of photosynthesis and cellular respiration in the cycling of matter and energy through biogeochemical cycles.[1]	Identify key organelles, as well as the inputs and outputs of matter and energy, utilized by photosynthesis and cellular respiration.

[1] National Geographic Website-The Earth Has Lungs This website uses satellite imagery to demonstrate the vast planetary breathing system—a giant green machine that pulls enormous quantities of carbon dioxide out of the air, especially in the warmer months. This site is useful for demonstrating the effect of photosynthesis on the Earth's CO_2 recycling system.