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Biology

SYLLABUS AND MODEL CURRICULUM

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 a three-unit course with 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.

SCIENCE INQUIRY AND APPLICATION

During the years of grades 9 through 12, all students must use the following 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**;
- Use technology and mathematics to improve investigations and communications;
- Formulate and revise explanations and models using logic and evidence (critical thinking);
- Recognize and analyze explanations and models; and
- Communicate and support a scientific argument.

COURSE CONTENT

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

HEREDITY

- Cellular genetics
- Structure and function of DNA in cells
- Genetic mechanisms and inheritance
- Mutations
- Modern genetics

EVOLUTION

- Mechanisms
  - Natural selection
  - Mutation
  - Genetic drift
  - Gene flow (immigration, emigration)
  - Sexual selection
  - History of life on Earth
- Diversity of Life
  - Speciation and biological classification based on molecular evidence
  - Variation of organisms within a species due to population genetics and gene frequency

DIVERSITY AND INTERDEPENDENCE OF LIFE

- Classification systems are frameworks created by scientists for describing the vast diversity of organisms indicating the degree of relatedness between organisms.
- Ecosystems
  - Homeostasis
    - Carrying capacity
    - Equilibrium and disequilibrium

CELLS

- Cell structure and function
  - Structure, function and interrelatedness of cell organelles
  - Eukaryotic cells and prokaryotic cells
- Cellular processes
  - Characteristics of life regulated by cellular processes o Photosynthesis, chemosynthesis, cellular respiration o Cell division and differentiation

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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), this topic 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 on to the next generation through both asexual and sexual reproduction. In addition, they learn that traits are defined by instructions encoded in many discrete genes and that a gene may come in more than one form called alleles.

At the high school level, the explanation of genes is expanded to include the following concepts:

- Life is specified by genomes. Each organism has a genome that contains all of the biological information needed to build and maintain a living example of 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** 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.
- An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm or have little or no effect on the offspring's success in its environments.
- **Gene mutations** (when they occur in gametes) can be passed on to offspring.
- Genes code for protein. The sequence of DNA bases in a chromosome determines the sequence of amino acids in a protein.
- "**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. Different genes are active in different types of cells, influenced by the cell's environment and past history." (AAAS)

In high school biology, 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. **Sorting** and recombination of genes in sexual reproduction and meiosis specifically result in a variance in traits of the offspring of any two parents and explicitly connect the knowledge to evolution.

The gene interactions described in middle school were limited primarily to dominance and co- dominance traits. In high school genetic mechanisms, both classical and modern including incomplete dominance, sex-linked traits, **goodness of fit test (Chi-square)** and dihybrid crosses are investigated through real-world examples. Dihybrid crosses can be used to explore linkage groups. Gene interactions and phenotypic effects can be introduced using real-world examples (e.g. **polygenic inheritance, epistasis,** and **pleiotrophy**).

It is imperative that the technological developments that lead to the current knowledge of heredity be included in the study of heredity. For example, the development of the model for DNA structure was the result of the use of technology and the studies and ideas of many scientists. Watson and Crick developed the final model, but did not do the original studies.

EXPECTATIONS FOR LEARNING: COGNITIVE DEMANDS

This section provides definitions for Ohio's science cognitive demands, which are intrinsically related to current understandings and research about how people learn. They provide a structure for teachers and assessment developers to reflect on plans for teaching science, to monitor observable evidence of student learning and to develop summative assessment of student learning of science.

VISIONS INTO PRACTICE

This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

- Develop a timeline from Mendel's, Darwin's and Wallace's work to the present day.
- Design and implement an investigation to test the affect of low doses of different common chemicals (e.g., boric acid, acetone or vinegar) on the development of a plant from seed to adult. Represent the data in a way that demonstrates the relationship, if any, between the chemical and changes in the development pattern. Explain how the investigation is similar to or different from the processes that occur in the natural environment.

Note: Only plants should be used in this experiment.

INSTRUCTIONAL STRATEGIES AND RESOURCES

This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on, minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or Web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

- The National Institute of the Health provides a **time line** of the milestones in genetics. Stories, archival images and original scientific publications tell the historical story of genetic discoveries. Students can trace how new understandings about the transmission of traits developed new questions that led to new discoveries. One major milestone is the Human Genome Project. **DNA Learning Center** features an interactive site that provides detailed background knowledge on how genomes are developed and used for research.
- Mendelian Genetics provides clear explanations for basic genetics; this link connects to an explanation and example of **Chi-square**.

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- Cold Spring Harbor Laboratory's **Dolan DNA Learning Center** provides DNA Molecules for models that help to illustrate some of the more abstract concepts associated with DNA. Scroll down the page to the *More 3-D Animation Library*.

COMMON MISCONCEPTIONS

- **The Genetic Science Learning Center** provides information about misconceptions related to cloning.

DIVERSE LEARNERS

Strategies for meeting the needs of all learners including **gifted students, English Language Learners** (ELL) and students with **disabilities** can be found at the **Ohio Department of Education site**. Resources based on the Universal Design for Learning principles are available at **www.cast.org**.

CLASSROOM PORTALS

The Annenberg Media series "**Teaching High School Science**" is a six-video program that highlights a variety of classroom activities that foster inquiry-based learning.

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CONTENT ELABORATION: EVOLUTION

At the elementary school level, evolution concepts include the relationship between organisms and the environment, parent 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 history, changing environmental conditions (abiotic factors), natural selection and biological evolution.

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. The study of evolution must include Modern Synthesis, the unification of genetics and evolution and historical perspectives of evolutionary theory. The study of evolution must include gene flow, mutation, speciation, natural selection, genetic drift, sexual selection and Hardy Weinberg's law.

The basic concept of biological evolution is that the Earth's present-day species descended from earlier, common ancestral species. At the high school level, the term natural selection is used to describe the process by which traits become more or less common in a population due to consistent environmental effects upon the survival or reproduction of the individual with the trait. Mathematical reasoning must be applied to solve problems, (e.g., use Hardy Weinberg's law to explain gene frequency patterns in a population).

Modern ideas about evolution provide a natural explanation for the diversity of life on Earth as represented in the fossil record, in the similarities of existing species and in modern molecular evidence. From a long-term perspective, evolution is the descent with modification of different lineages from common ancestors.

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 explanation of the internal structure and function of chromosomes. Natural selection works on the phenotype.

Populations evolve over time. Evolution 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 with the specific phenotype.

Mutations are described in the content elaboration for Heredity. Apply the knowledge of mutation and genetic drift to real-world examples.

Recent molecular-sequence data generally, but not always, support earlier hypotheses regarding lineages of organisms based upon morphological comparisons.

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. Formulate and revise explanations for gene flow and sexual selection based on real-world problems.

EXPECTATIONS FOR LEARNING: COGNITIVE DEMANDS

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VISIONS INTO PRACTICE

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- Manipulate variables (e.g., distribution of traits, number of organisms and change in environmental conditions) in a simulation that represents natural selection in terms of how changes in environmental conditions can result in selective pressure on a population of organisms. Analyze the data to determine the relationship, if any, between the environmental changes and the population. Explain how each part of the simulation is similar to or different from the process of natural selection.

INSTRUCTIONAL STRATEGIES AND RESOURCES

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- **University of Colorado's PhET** provides an interactive simulation of natural selection for a population of rabbits. Environmental factors can be altered and mutations introduced to show how the population would change over time.
- Annenberg's Rediscovering Biology: **Molecular to Global Perspectives, Session 3,** Evolution and Phylogenetics is a tutorial for teachers on some of the current advances in biology.
- The National Science Teachers Association offers a position paper on the **Teaching of Evolution**.
- Online course in evolutionary biology for teachers is provided by the Public

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Broadcasting System: **Evolution**.

COMMON MISCONCEPTIONS

- The University of California Museum of Paleontology with support provided by the National Science Foundation and the Howard Hughes Medical Institute provides **common misconceptions about evolution**.

DIVERSE LEARNERS

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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 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 great diversity of organisms and ecological niches they occupy result from more than 3.5 billion years of evolution. Some ecosystems can be reasonably persistent over hundreds or thousands of years. Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change as geological or biological conditions vary. Misconceptions about population growth capacity, interspecies and intra-species competition for resources, and what occurs when a species immigrates to or emigrates from ecosystems are included in this topic. Technology must be used to access real-time/authentic data to study population changes and growth in specific locations.

Classification systems are frameworks developed by scientists for describing the diversity of organisms, indicating the degree of relatedness between organisms. **Recent molecular**-sequence data generally support earlier hypotheses regarding lineages of organisms based upon morphological comparisons. Both morphological comparisons and molecular evidence must be used to describe biodiversity (cladograms can be used to address this).

Organisms transform energy (flow of energy) and matter (cycles of matter) as they survive and reproduce. The cycling of matter and flow of energy occurs at all levels of biological organization, from molecules to ecosystems. At the high school level, the concept of energy flow as unidirectional in ecosystems is explored.

Mathematical graphing and algebraic knowledge (at the high school level) must be used to explain concepts of carrying capacity and homeostasis within biomes. Use real-time data to investigate population changes that occur locally or regionally. Mathematical models can include exponential growth model and the logistic growth model. The simplest version of the logistic growth model is **Population Growth Rate = rN (K-N) / K**; the only new variable added to the exponential model is K for carrying capacity.

Note 1: Exponential growth equation in simplest form, change in population size *N* per unit time *t* is a product of *r* (the per capita reproductive rate) and *N* (population size.

Note 2: Carrying capacity is defined as the population equilibrium sized when births and deaths are equal; hence Population Growth Rate = zero.

Note 3: Constructing food webs/food chains to show interactions between organisms within ecosystems was covered in upper elementary school and middle school; constructing them as a way to demonstrate content knowledge is not appropriate for this grade. Students may use these diagrams to help explain real-world relationships or events within an ecosystem, but not to identify simple trophic levels, consumers, producers, predator-prey and symbiotic relations.

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- Construct a model to exemplify biomagnification in an ecosystem such as mercury in Lake Erie. Include a quantification of the distribution and buildup of the potentially damaging molecule that was introduced into the ecosystem. Within the model, predict and explain why the consequences occur at each trophic level as the relative concentration of the chemical increases. Include in your justification the changes in the number of organisms at each trophic level, matter cycling and energy transfer from one level to another.

INSTRUCTIONAL STRATEGIES AND RESOURCES

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- Examine **wildlife populations** in Ohio like bald eagles, beavers or white-tailed deer. The Ohio Department of Natural Resources provides population data over the years. Examine the factors that have impacted the carrying capacity.
- **The Southern Nevada Regional Professional Development Center** provides a tutorial, which explains the links between classification systems and evolution.

COMMON MISCONCEPTIONS

- Binghamton University provides a general list for of naïve concepts for life science called **Overcoming Ecological Misconceptions**.

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CONTENT ELABORATION: CELLS

Building on knowledge from middle school (cell theory), 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, cell division and differentiation are studied at this grade level. Additionally, cellular organelles studied are cytoskeleton, Golgi complex and endoplasmic reticulum.

From about 4 billion years ago to about 2 billion years ago, only simple, single-celled microorganisms are found in the fossil record. Once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved.

Every cell is covered by a membrane that controls what can enter and leave the cell. In all but quite primitive cells, a complex network of proteins provides organization and shape. **Within the cell** are specialized parts for the transport of materials, energy transformation, protein building, waste disposal, information feedback and movement. In addition to these basic cellular functions, most cells in multicellular organisms perform some specific functions that others do not.

A living cell is composed of a small number of elements, mainly carbon, hydrogen, nitrogen, oxygen, phosphorous and sulfur. Carbon, because of its small size and four available bonding electrons, can join to other carbon atoms in chains and rings to form large and complex molecules. The essential functions of cells involve chemical reactions that involve water and carbohydrates, proteins, lipids and nucleic acids. A special group of proteins, enzymes, enables chemical reactions to occur within living systems.

Cell functions are regulated. **Complex interactions** among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. **Most cells function** within a narrow range of temperature and pH. At very low temperatures, reaction rates are slow. High temperatures and/or extremes of pH can irreversibly change the structure of most protein molecules. Even small changes in pH can alter how molecules interact.

The sequence of DNA bases on a chromosome determines the sequence of amino acids in a protein. **Proteins catalyze** most chemical reactions in cells. Protein molecules are long, usually folded chains made from combinations of the 20 typical amino-acid sub-units found in the cell. The function of each protein molecule depends on its specific 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: The concept of the cell and its parts as a functioning system is more important than memorizing parts of the cell.

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- Investigate the effect of different chemicals on the growth of algal colonies. Use mathematics to explain why even under ideal situations the colonies cannot continue exponential growth.
- Plan and design an investigation to determine the factors that affect the activity of enzymes on their substrates.
- Research and provide a written explanation of how unicellular organisms are used for industrial purposes.

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- **Optical enhancements** can be used to alter the image produced by a light microscope to show greater detail. Compare cells using unaltered Compound Light Microscopes with the same cells using Darkfield, Rheinberg and Polarization techniques.
- Examine the role of bacteria in food production. Determine what types of bacteria are used and how it impacts (pH levels, gases produced, impact on proteins) the production of the product (yogurt, cheese).

Career Connection

Students can research careers in the field of food production relative to the role of bacteria across quality control, the **U.S. Food and Drug Administration**, agriculture, and research and development of food production (e.g., biologists; chemists; agricultural scientists; science technician; food processors, inspectors, and preparers). Through their research, they will identify applications of this classroom

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content to the workplace. Students can conduct career interviews, workplace visits, and navigate company or agency websites.

COMMON MISCONCEPTIONS

- The Annenberg Media series *Minds of Our Own* offers *Lessons From Thin Air,* which illustrates the misconceptions that students have about photosynthesis and plant growth, at **http://www.learner.org/resources/series26.html**.

DIVERSE LEARNERS

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