BERKELEY HEIGHTS PUBLIC SCHOOLS
BERKELEY HEIGHTS, NEW JERSEY

GOVERNOR LIVINGSTON HIGH SCHOOL
SCIENCE DEPARTMENT

BIOLOGY/ PC BIOLOGY/ BIOLOGY HONORS
#SCY0910/#SCY0960/#SCY0920

Curriculum Guide

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This curriculum may be modified through varying techniques, strategies, and materials, as per an individual student's Individualized Education Plan (IEP)

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VISION STATEMENT

The science curriculum aims to provide students with authentic and enriching experiences that enhance critical thinking and problem solving skills. Students gain a deeper understanding and appreciation of science and are exposed to real-world technologies. Students are challenged to analyze and evaluate data, construct new ideas, develop arguments and explanations, and apply concepts through engineering tasks.

To achieve this, the curriculum guides are based on the model science curriculum developed by New Jersey Department of Education and are aligned to the Next Generation Science Standards. The Next Generation Science Standards were created based on the work done by the National Research Council and summarized in their publication, *A Framework for K-12 Science Education (NRC, 2011).* The work shifts the focus of science education towards the development of overarching enduring concepts and emphasizes the process of science. The standards are no longer isolated components but rather a three dimensional approach to teaching that focuses equally on ***Disciplinary Core Ideas***, ***Science and Engineering Practices,*** and ***Crosscutting Concepts***.

Disciplinary Core Ideas have the power to focus K–12 science curriculum, instruction, and assessments on the most important aspects of science. These core ideas:

- Have broad importance across multiple sciences or engineering disciplines or be a key organizing concept of a single discipline;
- Provide a key tool for understanding or investigating more complex ideas and solving problems;
- Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge;
- Are teachable and learnable over multiple grades at increasing levels of depth and sophistication.

The ***Science and Engineering Practices*** describe behaviors that scientists engage in as they investigate and build models about the natural world. Additionally, they emphasize the key set of engineering practices that engineers use as they design and build models and systems. Scientific investigation requires not only skill but also knowledge that is specific to each practice.

Crosscutting Concepts have application across all domains of science. As such, they are a way of linking the different domains of science. They include patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change. These concepts need to be made explicit for students because they provide an organizational schema for interrelating knowledge from various science fields into a coherent and scientifically based view of the world (NSTA, 2014).

Throughout the curriculum, engineering tasks have been embedded, which engage students in the design cycle, encourage the development of 21st century skills, and incorporate college and career ready practices.

MISSION STATEMENT

Biology is a full year, required course at Governor Livingston High School and meets one of the New Jersey state science requirements for graduation. This lab-based course is offered in three formats, a standard format, an honors level, and Project Connect. All of the formats are designed to create scientifically literate individuals that can make informed decisions based on their knowledge of biology. The honors level is intended to prepare students for college/AP level biology, if they so choose.

While the Biology progression is designed to emphasize the life science domain, the course does incorporate Earth and Space Science and Engineering where appropriate. The students begin by examining how matter and energy flow between the environment and individual organisms, allowing cellular processes to occur. The students then take a bigger look at how these organisms interact with each other within their ecosystem. The students extend this examination to determine the specific impact that humans have on the environment, Earth, and other organisms. The unit then spiral back to the cell to develop a richer understanding of cellular processes. This becomes the jumping off point for the students' exploration of Inheritance, Natural Selection, and Evolution, which culminates the curriculum.

The objective in both the standard, PC, and Honors classes is for the students to demonstrate mastery of the course standards by meeting the performance expectations. PC Biology students follow the same overall curriculum as the standard biology course, but the units are grouped thematically to create an interdisciplinary connection between other subject areas. The Honors course does this at a faster rate than the standard course. The students also engage in extension activities that allow them to drive deeper into the content . At times these students will progress beyond the assessment boundary outlined by the state. By doing this, students are better prepared for advanced courses like AP Biology. The extension objectives are outlined in each unit breakdown.

A state competency exam is administered to all Biology students at the end of May. The exam is composed of two parts, a multiple choice section and a written response section. Students are required to take the exam but are not current held accountable for attaining a passing score. The exam data is used to identify weaknesses and improve instruction across all science courses.

COURSE PROFICIENCIES

COURSE OBJECTIVES

The Biology course consists of eight units reflective of the NJDOE Model Curriculum. Each unit is structured to emphasize a three dimensional learning environment and therefore incorporates science and engineering processes, disciplinary core ideas, and crosscutting concepts. The standards, which encompass these three components, are addressed throughout these units are presented below and sorted based on domain.

LS: Life Science

LS1: From Molecules to Organisms: Structures and Processes
- HS-LS1-1
- HS-LS1-2
- HS-LS1-3
- HS-LS1-4
- HS-LS1-5
- HS-LS1-6
- HS-LS1-7

LS2: Ecosystems: Interactions, Energy, and Dynamics
- HS-LS2-1
- HS-LS2-2
- HS-LS2-3
- HS-LS2-4
- HS-LS2-5
- HS-LS2-6
- HS-LS2-7
- HS-LS2-8

LS3: Heredity: Inheritance and Variation of Traits
- HS-LS3-1
- HS-LS3-2
- HS-LS3-3

LS4: Biological Evolution: Unity and Diversity
- HS-LS4-1
- HS-LS4-2
- HS-LS4-3
- HS-LS4-4
- HS-LS4-5
- HS-LS4-6

ESS: Earth and Space Science

ESS3: Earth and Human Activity
- HS-ESS3-1
- HS-ESS3-3
- HS-ESS3-4
- HS-ESS3-5

COURSE PROFICIENCIES (continued)

- HS-ESS3-6

ETS: Engineering, Technology and the Application of Science

ETS1: Engineering Design

- MS-ETS1-1
- MS-ETS1-2
- MS-ETS1-3
- MS-ETS1-4

STUDENT PROFICIENCIES

The student proficiencies represent the broad skills that students will gain by completing the course. These skills spiral throughout the K-12 science progression and are leveled appropriately according to grade level and science domain.

Science and Engineer Practice

- Asking Questions and Defining Problems - A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.
- Developing and Using Models - A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.
- Planning and Carrying Out Investigations - Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.
- Analyzing and Interpreting Data - Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.
- Using Mathematics and Computational Thinking - In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships.
- Constructing Explanations and Designing Solutions - The products of science are explanations and the products of engineering are solutions.
- Engaging in Argument from Evidence -Argumentation is the process by which explanations and solutions are reached.
- Obtaining, Evaluating, and Communicating Information -Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

Crosscutting Concepts

- Patterns - Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.
- Cause and Effect - Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

STUDENT PROFICIENCIES (continued)

- Scale, Proportion, and Quantity - In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.
- Systems and System Models - A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.
- Energy and Matter - Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.
- Structure and Function - The way an object is shaped or structured determines many of its properties and functions.
- Stability and Change - For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Nature of Science

- Scientific Investigations Use a Variety of Methods
- Science Knowledge Is Based on Empirical Evidence
- Scientific Knowledge Is Open to Revision in Light of New Evidence
- Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- Science Is a Way of Knowing
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science Is a Human Endeavor
- Science Addresses Questions About the Natural and Material World

College and Career Ready Practices

- Apply appropriate academic and technical skills.
- Communicate clearly and effectively and with reason.
- Consider the environmental, social and economic impacts of decisions.
- Demonstrate creativity and innovation.
- Employ valid and reliable research strategies.
- Utilize critical thinking to make sense of problems and persevere in solving them.
- Model integrity, ethical leadership and effective management.
- Use technology to enhance productivity.
- Work productively in teams while using cultural global competence.

METHODS OF EVALUATION

1. Homework and classwork
2. Class participation
3. Tests and quizzes
4. Unit Benchmark Assessments
5. Performance Tasks
6. Lab Reports
7. Cooperative learning assignments
8. Final exam, projects and/or reports

SCOPE AND SEQUENCE
COURSE OUTLINE/STUDENT OBJECTIVES

Each unit in the Biology curriculum is listed below with the associated performance expectations students with master. The units are then broken down further in the subsequent sections. The unit provides detailed objectives, clarification statements, possible activities, and suggested timelines.

Unit 1: Matter and Energy Transformations in Ecosystems

- HS-LS1-5: Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
- HS-LS1-7: Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
- HS-LS2-3: Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
- HS-LS2-4: Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
- HS-LS2-5: Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Unit 2: Interdependent Relationships

- HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

Unit 3: Human Activity and Climate

- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
- HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.
- HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
- HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* *

SCOPE AND SEQUENCE (continued)

Unit 4: Human Activity and Biodiversity

- HS-ESS3-3: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-6: Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
- HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
- HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Unit 5: Cell Specialization and Homeostasis

- HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
- HS-LS1-6: Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
- HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
- HS-LS1-4: Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Unit 6: DNA and Inheritance

- HS-LS1-4: Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.
- HS-LS3-1: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
- HS-LS3-2: Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

SCOPE AND SEQUENCE (continued)

Unit 7: Natural Selection

- HS-LS4-4: Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
- HS-LS4-3: Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
- HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
- HS-LS2-8: Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.

Unit 8: Evolution

- HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
- HS-LS4-2: Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- HS-LS3-3: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Unit 1: Matter and Energy Transformations in Ecosystems

Duration: Honors - 20 days / Regular - 26 days

Overview: In this unit of study, students construct explanations for the role of energy in the cycling of matter in organisms and ecosystems. They apply mathematical concepts to develop evidence to support explanations of the interactions of photosynthesis and cellular respiration, and they will develop models to communicate these explanations. Students also understand organisms' interactions with each other and their physical environment and how organisms obtain resources.

Standards:

- **HS-LS1-5** - Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. [Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]
- **HS-LS1-7** - Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [*Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.*]
- **HS-LS2-3** - Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.] [Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]
- **HS-LS2-4** - Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.]
- **HS-LS2-5** - Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. [Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]

Essential Questions:

- Why do astrobiologists look for water and not oxygen when they search for life on other planets?

- Why is a food web a better description of an ecosystem than a food chain?
- How can the process of photosynthesis and respiration in a cell impact ALL of Earth's systems?
- How do the two laws of thermodynamics relate to the amount of energy available at each trophic level?

Students Learning Objectives:

Students will know...

- Energy drives the cycling of matter within and between all systems and in aerobic and anaerobic conditions.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.
- At each link in an ecosystem, matter and energy are conserved.
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level.
- Given this inefficiency, there are generally fewer organisms at higher levels of a food web.
- Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded.
- The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways.
- Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis
- An ecological system is a self-regulating accumulation of biotic and abiotic factors influenced by size, time, and available energy driving the cycling of matter based on the idea that energy cannot be created or destroyed and can move only between objects, fields, or systems

Students will be able to

- Construct and revise an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- Construct and revise an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, considering that most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.

- Support claims for the cycling of matter and flow of energy among organisms in an ecosystem using conceptual thinking and mathematical representations of phenomena.
- Use a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and to show how matter and energy are conserved as matter cycles and energy flows through ecosystems.
- Use a mathematical model to describe the conservation of atoms and molecules as they move through an ecosystem.
- Use proportional reasoning to describe the cycling of matter and flow of energy through an ecosystem.
- Develop a model, based on evidence, to illustrate the roles of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere, showing the relationships among variables in systems and their components in the natural and designed world.
- Develop a model, based on evidence, to illustrate the roles of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere at different scales.

Possible Activities:

- Food webs, energy flow, carbon cycle, and trophic pyramids
  - Students analyze the production and utilization of organic molecules in ecosystems.
  - Students construct a food web for Yellowstone National park, including producers, primary consumers, secondary consumers, decomposers, and trophic omnivores.
  - Students analyze a trophic cascade that resulted when wolves were reintroduced to Yellowstones.
  - Students learn how carbon atoms and energy move in ecosystems as a result of the trophic relationships in food webs, photosynthesis, biosynthesis and cellular respiration.
  - Students use these concepts for quantitative reasoning to understand trophic pyramids.
  - http://serendip.brynmawr.edu/exchange/bioactivities/foodweb
- Building Ecological Pyramids
  - This activity complements WildCam Lab, where students can explore trail camera data from WildCam Gorongosa, an online citizen science platform for identifying animals photographed by motion-detecting trail cameras located throughout Gorongosa National Park.
  - In this activity, students will build biomass pyramids depicting trophic levels of various habitat types using data from the WildCam database.
  - http://www.hhmi.org/biointeractive/building-ecological-pyramids
- The Lynx Eats the Hare Lab
  - The student will simulate the interspecific interactions between a predator population and that of its primary prey
  - The student will discover the link between populations, and use ecosystem vocabulary to identify roles of organisms as well as what is occurring as populations change.
- How do biological organisms use energy?

    - This analysis and discussion activity helps students understand the basic principles of how biological organisms use energy, with a focus on the roles of ATP and cellular respiration.
    - Students apply the principles of conservation of energy and conservation of matter to avoid common errors and correct common misconceptions.
    - http://serendip.brynmawr.edu/exchange/bioactivities/energy
- Using Models to Understand Photosynthesis
    - In this analysis and discussion activity, students develop their understanding of the basic process of photosynthesis and also analyze the advantages and disadvantages of different types of models of photosynthesis, including chemical equations, a chart and a diagram.
    - Students analyze how photosynthesis and cellular respiration work together to provide the ATP that plants need to carry out their molecular and cellular processes.
    - http://serendip.brynmawr.edu/exchange/bioactivities/modelphoto
- Paper Chromatography of Photosynthetic Pigments
    - Students extract pigments from plants, identifying that there are multiple types of pigments that are involved in photosynthesis.
    - Students explain why some pigments separate more rapidly than others.
- Photosynthesis Investigation (Leaf Disk Lab)
    - Students learn how to use the floating leaf disk method to measure the rate of net photosynthesis (i.e. the rate of photosynthesis minus the rate of cellular respiration).
    - They compare the rate of net photosynthesis in water vs. a solution of sodium bicarbonate. The questions in this section guide students in reviewing the relevant biology and interpreting their results.
    - Student groups develop hypotheses about factors that influence the rate of net photosynthesis
    - Student groups design and carry out an investigation to test the effects of one of these factors.
    - http://serendip.brynmawr.edu/exchange/waldron/photosynthesis
- Where does a plant's mass come from?
    - This analysis and discussion activity helps students to understand that a large part of a plant's mass consists of water, most of the biomass comes from carbon dioxide, and minerals from the soil contribute only a tiny amount of the plant's mass.
    - Students engage in analyzing and interpreting data and arguing from evidence.
    - http://serendip.brynmawr.edu/exchange/bioactivities/plantmass
- Alcoholic Fermentation in Yeast -- Bioengineering Design Challenge
    - Students learn about the fundamentals of alcoholic fermentation and test for alcoholic fermentation by assessing CO_2 production by live yeast cells in sugar water vs. two controls.
    - Students work to find the optimum sucrose concentration and temperature to maximize rapid CO_2 production, using no more sucrose than needed for maximum CO_2 production.
    - Structured questions guide the students through the basic engineering steps of applying the relevant scientific background, developing and systematically testing

proposed design solutions, and then using initial results to develop and test improved design solutions.
    - http://serendip.brynmawr.edu/exchange/waldron/fermentation
- How do muscles get the energy they need for athletic activity?
    - Students learn about the similarities and differences between aerobic cellular respiration and anaerobic fermentation and learn how these processes contribute to ATP production in muscle cells during different types of athletic activity.
    - Students gain understanding of general principles such as the conservation of energy and conservation of matter, the constant dynamic activity in cells, and the importance of interactions between body systems to accomplish functions such as supplying the energy that muscles need for physical activity.
    - http://serendip.brynmawr.edu/exchange/waldron/fermentation
- V-Cell App
    - Photosynthesis - Movie - Pictures - Quiz
    - Cellular Respiration - Movie -Pictures - Quiz
    - Aerobic Respiration - Movie -Pictures - Quiz
- Leaf Photosynthesis NetLogo Model
    - This Java-based NetLogo model allows students to investigate the chemical and energy inputs and outputs of photosynthesis through an interactive simulation.
    - https://concord.org/stem-resources/leaf-photosynthesis

Unit 2: Interdependent Relationships

Duration: Honors - 20 days / Regular - 22 days

Overview: In this unit students will be introduced to ecosystem ecology as it relates to populations and biodiversity. They will be encouraged to explain how different environmental factors influence interactions and interdependencies in specific biomes. Students will use graphs and models to explore limits organisms face in their niches.

Standards:

- **HS-LS2-1**- Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. [Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [*Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.*]
- **HS-LS2-2** - Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [*Assessment Boundary: Assessment is limited to provided data.*]
- **HS-LS2-6** - Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. [Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.]

Essential Questions:

- When they relocate bears, wolves, or other predators, how do they know that they will survive?
- What limits the number and types of different organisms that live in one place?
- How can a one or two inch rise in sea level devastate an ecosystem?

Student Objectives

Students Will be Able to

- Ecosystems have carrying capacities, which are limits to the number of organisms and populations they can support.
- These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, completion, and disease.
- Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (the number of individuals) of species in any given ecosystem.

- The significance of carrying capacity in ecosystems is dependent on the scale proportion and quantity at which it occurs.
- Quantitative analysis can be used to compare and determine relationships among interdependent factors that affect the carrying capacity of ecosystems at different scales.
- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.
- Ecosystems have carrying capacities, which are limits to the number of organisms and populations they can support.
- These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, completion, and disease.
- Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite.
- This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions.
- If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem.
- Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability
- Using the concept of orders of magnitude allows one to understand how a model of factors affecting biodiversity and populations in ecosystems at one scale relates to a model at another scale.
- Much of science deals with constructing explanations of how things change and how they remain stable.
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions.
- If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem) as opposed to becoming a very different ecosystem.
- Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.

Students will be able to

- Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- Use quantitative analysis to compare relationships among interdependent factors and represent their effects on the carrying capacity of ecosystems at different scales.
- Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- Use the concept of orders of magnitude to represent how factors affecting biodiversity and populations in ecosystems at one scale relate to those factors at another scale.

- Evaluate the claims, evidence, and reasoning that support the contention that complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- Construct explanations of how modest biological or physical changes versus extreme changes affect stability and change in ecosystems.
- Illustrate how interactions among living systems and with their environment result in the movement of matter and energy.
- Graph real or simulated populations and analyze the trends to understand consumption patterns and resource availability, and make predictions as to what will happen to the population in the future.
- Provide evidence that the growth of populations are limited by access to resources, and how selective pressures may reduce the number of organisms or eliminate whole populations of organisms.

Possible Activities:

- Population Growth -- Exponential and Logistic Models vs. Complex Reality
    - This analysis and discussion activity is designed to help students develop a solid understanding of the exponential and logistic models of population growth, including the biological processes that result in exponential or logistic population growth.
    - Students learn about the simplifying assumptions built into the exponential and logistic models and explore how deviations from these assumptions can result in discrepancies between the predictions of these models and the actual trends in population size for natural populations.
    - Students engage in understanding the equations for the exponential and logistic models of population growth and evaluating the relative advantages of equations vs. graphs as models of population growth.
    - http://serendip.brynmawr.edu/exchange/bioactivities/pop
- The Ecology of Lyme Disease
    - This analysis and discussion activity engages students in understanding the lifecycle and adaptations of black-legged ticks and the relationships between these ticks, their vertebrate hosts, and the bacteria that cause Lyme disease.
    - Students use this background to analyze when and where human risk of Lyme disease is greatest, why rates of Lyme disease have increased in recent decades in the US, and ecological approaches to preventing Lyme disease.
    - http://serendip.brynmawr.edu/exchange/bioactivities/LymeDisease
- Exploring Biomes in Gorongosa National Park
    - As students complete the activity, they will analyze climate and vegetation data to draw conclusions about the characteristics of specific biomes.
    - They will also explore the connections between temperature, precipitation, and vegetation in the biomes of Gorongosa National Park and their own region.
    - This activity encourages students to draw upon prior knowledge about climate, make predictions, and then explore those predictions using the Gorongosa National Park Interactive Map click and learn.
    - http://www.hhmi.org/biointeractive/exploring-biomes-gorongosa-national-park
- Hungry Birds App

Unit 3: Human Activities and Climate

Duration: Honors - 26 days / Regular - 18 days

Overview: Students will be given the opportunity to examine, explore and experiment as the discover how human activities affect the global climate. Global Climate Shift (global warming), Acid deposition and natural resource management will be used to relate ideas to real world problems. Natural and artificial succession will be explained so that connections can be made between natural and human influenced.

Standards:

- **HS-ESS3-1** - Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]
- **HS-ESS3-6** - Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]
- **HS-ESS3-5** - Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]
- **HS-ESS3-4** - Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* * [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

- **HS-ETS1-3** - Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Essential Questions:

- How are human activities influence the global ecosystem?
- What are the relationships among earth's systems and how are those relationships being modified due to human activity?
- What is the current rate of global or regional climate change and what are the associated future impacts to Earth's systems?
- How can the impacts of human activities on natural systems be reduced?

Student Objectives:

Students will know

- Resource vitality has guided the development of human society.
  Natural hazards and other geologic events have shaped the course of human history.
- Natural hazards and other geologic events have significantly altered the sizes of human populations and have driven human migration.
- Empirical evidence is required to differentiate between cause and correlation and make claims about how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activities.
- Modern civilization depends on major technological systems.
- Changes in climate can affect population or drive mass migration.
- Current models predict that, although future regional climate changes will be complex and will vary, average global temperatures will continue to rise.
- The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases are added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.
- Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.
- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Criteria may need to be broken down into similar ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.
- Human activities can modify the relationships among Earth systems.
- Although the magnitude of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
- Change in rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Science investigations use diverse methods and do not always use the same set of procedures to obtain data.
- Science knowledge is based on empirical evidence.
- Scientist and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

- Engineers continuously modify these systems to increase benefits while decreasing costs and risks.
- Feedback (negative or positive) can stabilize or destabilize natural systems.
- When evaluating solutions, it is important to take into account a range of constraints, including costs, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.
- New technologies can have deep impacts on society and the environment, including some that are not anticipated.
- Analysis of costs and benefits is a critical aspect of decisions about technology.

Students will be able to

- Use a computational representation to illustrate the relationships among Earth systems and how these relationships are being modified due to human activity.
- Describe the boundaries of Earth systems.
- Analyze and describe the inputs and outputs of Earth systems.
- Analyze geosciences data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
- Quantify and model change and rates of change in geosciences data and rates of global or regional climate change and associated impacts to Earth systems.
- Evaluate or refine a technological solution that reduces impacts of human activities on natural systems based on scientific knowledge and student generated sources of evidence; prioritize criteria and tradeoff considerations.

Possible Activities:

- Changing Biological Communities -- Disturbance and Succession
    - This analysis and discussion activity helps students to understand how biological communities change during succession after a disturbance.
    - Students analyze research evidence and explore how the interactions between different types of plants and animals influence succession.
    - Students use their understanding of the processes involved in succession to construct and evaluate models of succession in abandoned farm fields.
    - Students also analyze the effects on succession of climate and non-native invasive plants.
    - http://serendip.brynmawr.edu/exchange/bioactivities/succession

Unit 4: Human Activity and Biodiversity

Duration: Honors - 24 days / 24 days

Overview: Human interactions with the environment have long term problems and effects on the global community. Sustainability is a pervasive concept through environmental science and helps guide restoration ecology. Students will research and explore how human impacts have caused changes and how those changes may be reversed.

Standards:

- **HS-ESS3-3** - Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]
- **HS-LS2-7** - Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]
- **HS-LS4-6** - Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity. [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]
- **HS-ETS1-1** - Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- **HS-ETS1-2** - Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- **HS-ETS1-3** - Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
- **HS-ETS1-4** - Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Essential Questions:

- How might we change habits if we replaced the word “environment” with the word “life support system”?
- Does reducing human impacts on our global life support system require social engineering or mechanical engineering?
- Is the damage done to the global life support system permanent?

Student Objectives:

Students will know

- The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources.
- Change and rates of change can be quantified and modeled over very short or very long periods.
- Some system changes are irreversible.
- Modern civilization depends on major technological systems.
- New technologies can have deep impacts on society and the environment including some that are not anticipated.
- Scientific knowledge is a result of human endeavors imagination and creativity.
- Anthropogenic changes (induced by human activity) in the environment— including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.
- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change.
- Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth.
- Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.
- Much of science deals with constructing explanations of how things change and how they remain stable.
- When evaluating solutions, it is important to take into account a range of constraints—including costs, safety, reliability, and aesthetics—and to consider social, cultural, and environmental impacts.
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of cost and benefits is a critical.
- Changes in the physical environment, whether naturally occurring or human induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species.
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change.
- Thus sustaining biodiversity so that ecosystems’ functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.
- Both physical models and computers can be used in various ways to aid the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test ways of solving a problem or to see which one is most efficient or economical, and in making a persuasive presentation to a client about how a given design will meet his or her needs.
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.
- New technologies can have deep impacts on society and the environment, including some that were not anticipated.
- Analysis of costs and benefits is a critical aspect of decisions about technology. endangered species or to genetic variation of organisms for multiple species.
- Analyze costs and benefits of a solution to mitigate adverse impacts of human activity on biodiversity.

Students will be able to

- Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- Quantify and model change and rates of change in the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
- Construct explanations for how the environment and biodiversity change and stay the same when affected by human activity.
- Evaluate a solution for reducing the impacts of human activities on the environment and biodiversity based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoff considerations.
- Analyze costs and benefits of a solution for reducing the impacts of human activities on the environment and biodiversity based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
- Create or revise a simulation based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoff considerations to test a solution to mitigate adverse impacts of human activity on biodiversity.
- Use empirical evidence to make claims about the impacts of human activity on biodiversity.
- Break down the criteria for the design of a simulation to test a solution for mitigating adverse impacts of human activity on biodiversity into simpler ones that can be approached systematically based on consideration of tradeoffs.
- Design a solution for a proposed problem related to threatened or endangered species or to genetic variation of organisms for multiple species.
- Analyze costs and benefits of a solution to mitigate adverse impacts of human activity on biodiversity.

Possible Activities:

- Of Microbes and Men
    - To develop a model to show the relationships among nitrogen and the ecosystem including parts that are not observable but predict observable phenomena. They will then construct an explanation of the effects of the environmental and human factors on this cycle.
    - http://www.science-live.org/teachers/NitrogenGame.html
- Students will be examining solutions for reducing or mitigating impacts of human activity on the environment and biodiversity. They will design, evaluate, refine or revise, and finally test a solution, utilizing the complete engineering cycle.

Unit 5: Cell Specialization and Homeostasis

Duration: Honors - 24 days / Regular - 20 days

Overview: Cells are the basic unit of life. As we allow students to examine this we need to explore how structure determines use. In biochemistry, individual molecules interact in specifically with each other and with the environment. Cell specialization and differentiation in multicellular systems can be seen as the extension of different genes found on chromosomes. The movement of molecules into, out of and through cells determine what those cells may be able to do. Honors students dive deeper into this and related topics

Standards:

- **HS-LS1-1** - Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. [Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]
- **HS-LS1-6** - Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [*Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.*]
- **HS-LS1-2** - Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. [Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]
- **HS-LS1-3** - Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. [Clarification Statement: Examples of investigations could include heart rate response to exercise, stomatal response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]
- **HS-LS1-4** - Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. [Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]

Essential Questions:

- How do the structures of organisms enable life's functions?
- How does the structure of DNA determine the structure of proteins, and what is the function of proteins?
- What do people mean when they say that humans are made of a system of systems?

- How do feedback mechanisms maintain homeostasis?
- Why aren't all elephants the same size?

Student Objectives

Students will know

- Systems of specialized cells within organisms help them perform the essential functions of life.
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.
- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal their functions and/or solve a problem.Investigate explanations for the structure and functions of cells as the basic unit of life, of hierarchical organization of interacting organ systems, and of the role of specialized cells for maintenance and growth.
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales.
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.
- Feedback mechanisms maintain a living system's internal conditions within certain limits, and they mediate behaviors, allowing the system to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.
- Feedback (negative or positive) can stabilize or destabilize a system.
- In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow.
- The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells.
- Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.
- Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions, including energy, matter, and information flows, within and between systems at different scales.

Students will be able to

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Construct an explanation, based on the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, for

how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.

- Conduct a detailed examination of the structure and function of DNA.
- Develop and use a model based on evidence to illustrate hierarchical organization of interacting systems that provide specific functions within multicellular organism.
- Develop and use a model based on evidence to illustrate the interaction of functions at the organism system level.
- Develop and use a model based on evidence to illustrate the flow of matter and energy within and between systems of an organism at different scales.
- Plan and conduct an investigation individually and collaboratively to produce evidence that feedback mechanisms (negative and positive) maintain homeostasis.
- In the planning of the investigation, decide on the types, amount, and accuracy of the data needed to produce reliable measurements, consider limitations on the precision of the data, and refine the design accordingly.
- Use a model based on evidence to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.
- Use a model to illustrate the role of cellular division and differentiation in terms of energy, matter, and information flows within and between systems of cells/organisms.
- Explain the connection between the sequence and the subcomponents of a biomolecule and its properties. [Clarification Statement: Emphasis is on the general structural properties that define molecules. Examples include r-groups of amino acids, protein shapes, the nucleotide monomers of DNA and RNA, hydrophilic and hydrophobic regions.] [Assessment Boundary: Assessment does not include identification or the molecular sequence and structure of specific molecules]
- Create representations that explain how genetic information flows from a sequence of nucleotides in a gene to a sequence of amino acids in a protein.
- Provide examples and explain how organisms use feedback systems to maintain their internal environments.
- Construct models that explain the movement of molecules across membranes with membrane structure and function. [Clarification Statement: Emphasis is on the structure of cell membranes, which results in selective permeability; the movement of molecules across them via osmosis, diffusion and active transport maintains dynamic homeostasis.]

Possible Activities:

- Water Properties & pH Lab
    - Students will test and observe the properties of water including cohesion, adhesion, water temperature, density, and water as a solvent, explaining why these properties of water are important for life
    - Students will buffer a solution, and explain how buffers are used in the blood
    - Students will test the pH of different household products, and will construct a pH scale
- Acid Rain: The Invisible Threat Video
    - Students will view a video about acid rain to identify the causes and effects on humans and the ecosystem
- Testing for Life's Molecules Lab
    - Students will recognize that living things are made of organic molecules.

- Students will identify and describe different types of organic molecules.
    - Students will be able to test for the presence of proteins, glucose, starch, and fats using indicators.
- Enzyme Action Activity
    - Students "become an enzyme" to demonstrate the functions and properties of enzymes.
- Viruses Scavenger Hunt
    - Students will learn about viruses by visiting various stations (include videos, articles, and websites of information) around the classroom while using a worksheet to guide them.
- Bacteria Research
    - Students will jigsaw information about bacteria after researching topics such as bacteria basics, domain archaea, bacteria as pathogens, bacteria as weapons, environmental cleanup, and bacteria vs. viruses.
- A Tour of the Cell
    - Students will watch the Bozeman Video called "A Tour of the cell", and answer questions about the structure and function of cellular parts.
- Structure and Function of Molecules and Cells
    - Students learn how the function of molecules and cells is related to their structure (including shape, constituent components, and relationships between components). Students analyze multiple examples of the relationship between structure and function in diverse proteins and eukaryotic cells.
    - Students learn that cells are dynamic structures with constant activity, students learn about emergent properties, and students engage in argument from evidence to evaluate three alternative claims concerning the relationship between structure and function.
    - http://serendip.brynmawr.edu/exchange/bioactivities/SFMolecCell
- Build a Membrane
    - Students create a model of a small section of the cell membrane, identifying the function of each of the parts
    - http://learn.genetics.utah.edu
- Diffusion across a selectively permeable membrane
    - Students investigate the effects of molecule size on diffusion across a synthetic selectively permeable membrane.
    - This investigation includes a brief introduction to osmosis.
    - Additional questions introduce students to the roles of proteins in transporting polar substances across the cell membrane and guide students in analyzing the relative advantages of two different types of model of the cell membrane.
    - http://serendip.brynmawr.edu/exchange/waldron/diffusion
- Lego Protein Building
    - Students will use lego kits to construct models.
    - Students identify that the same parts can be used in different ways to construct different types of models, and relate this principle to protein synthesis and the central dogma.
- From Gene to Protein -- Transcription and Translation

    - Students learn how a gene provides the instructions for making a protein and how genes influence our characteristics.
    - To help students understand transcription, translation, and how genes can result in albinism or sickle cell anemia, this activity includes multiple figures, brief explanations and questions, together with three recommended animations.
    - http://serendip.brynmawr.edu/exchange/bioactivities/trans
- From Gene to Polypeptide -- The Roles of the Base-Pairing Rules and the Genetic Code
    - Students complete this discussion/worksheet activity to review the information flow from a gene to a polypeptide, with an emphasis on understanding the roles of the base-pairing rules and the genetic code chart.
    - http://serendip.brynmawr.edu/exchange/bioactivities/basepair
- The Molecular Biology of Mutations and Muscular Dystrophy
    - Students complete this discussion/worksheet activity to review the information flow from a gene to a polypeptide, with an emphasis on understanding the roles of the base-pairing rules and the genetic code chart.
    - http://serendip.brynmawr.edu/exchange/bioactivities/basepair
- Activities for Understanding Gene Regulation
    - Students play the role of parts of operons in this activity to understand their structure and function.
    - Students identify why organisms must regulate gene expression.
- Diffusion Lab
    - Calculate effect of concentration on rate of diffusion.
    - Define concentration gradient
    - Explain experimental data concerning different concentration gradients
    - Create and complete a data table and prepare a graph to illustrate data.
    - Apply information from this experiment to other related problems.
- Students will create a model or written analogy for a cell as it relates to specialized parts working together for the synthesis of a product.
- Osmosis Lab
    - Recognize the direction of water through semipermeable membranes.
    - Distinguish differences between hypotonic and hypertonic solutions.
    - Predict impact of changing concentration gradients based on experimental data.
- Kingdom Exploration Lab - Observing organisms with a microscope.
    - Calibrate and calculate measurements for organisms under a microscope.
    - Observe different types of cells and organisms under a microscope.
- Carbohydrate Testing Lab
    - Create a reference for identifying different saccharides using iodine and benedict's solution.
    - Test and identify unknown saccharides.
- Construct a model of DNA
- Construct a model of DNA replication.
- DNA Extraction Lab
    - Isolate different macromolecules from cell debri
    - Extract DNA.
- NOVA Elements

- http://learn.genetics.utah.edu/content/labs/- Tour the Basics
- http://learn.genetics.utah.edu/content/labs/- From Gene to Protein
- http://learn.genetics.utah.edu/content/labs/- DNA Extraction
- http://learn.genetics.utah.edu/content/labs/ - Gel Electrophoresis
- http://learn.genetics.utah.edu/content/labs/ - Polymerase Chain Reaction
- http://learn.genetics.utah.edu/content/labs/ - Cloning the Basics
- Let's Clone a Mouse, Mouse, Mouse Lab
- Modeling Gene Transfer with a Plasmid
    - Students will explain function of a restriction enzyme.
    - Students will model process of making a recombinant DNA plasmid from a desired gene and the plasmid.
- V-Cell App
    - Protein Expression - Movie -Pictures - Quiz
    - RNA Expression - Movie -Pictures - Quiz

Unit 6 - DNA and Inheritance

Duration: Honors - 18 days / Regular - 20 days

Overview: Students in this unit will discover how reproduction both cellular and sexual are responsible for both maintenance and change. The cell cycle, mitosis and meiosis are involved in the processes. Genetic variation and mutations will be examined and experimented with to support the idea of heritability of traits.

Standards:

- **HS-LS1-4** - Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. [Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]
- **HS-LS3-1** - Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]
- **HS-LS3-2** - Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]

Essential Questions:

- What can't two roses ever be identical?
- How does inheritable genetic variation occur?
- Can a zoologist predict the distribution of expressed traits in a population?

Student Objective:

Students will know

- All cells contain genetic information in the form of DNA molecules.
- Genes are regions in the DNA that contain the instructions that code for the formation of proteins.
- Each chromosome consists of a single, very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA.
- The instructions for forming species' characteristics are carried in the DNA.
- All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways.
- Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have, as yet, no known function.
- Empirical evidence is required to differentiate between cause and correlation and to make claims about the role of DNA and chromosomes in coding the instructions for the characteristic traits passed from parents to offspring.

- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation.
- Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation.
- Environmental factors can also cause mutations in genes, and viable mutations are inherited.
- Environmental factors also affect expression of traits, and hence affect the probability of occurrence of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.
- Empirical evidence is required to differentiate between cause and correlation and to make claims about inheritable genetic variations resulting from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.
- Environmental factors affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variations and distributions of traits observed depend on both genetic and environmental factors.
- Algebraic thinking is used to examine scientific data and predict the distribution of traits in a population as they relate to the genetic and environmental factors (e.g., linear growth vs. exponential growth).
- Technological advances have influenced the progress of science, and science has influenced advances in technology.
- Science and engineering are influenced by society, and society is influenced by science and engineering.

Students will be be to

- Ask questions that arise from examining models or a theory to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parent to offspring.
- Use empirical evidence to differentiate between cause and correlation and make claims about the role of DNA and chromosomes in coding the instructions for characteristics passed from parents to offspring.
- Make and defend a claim based on evidence that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.
- Use data to support arguments for the ways inheritable genetic variation occurs.
- Use empirical evidence to differentiate between cause and correlation and make claims about the ways inheritable genetic variation occurs
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercepts, and correlation coefficient for linear fits) to explain the variation and distribution of expressed traits in a population.
- Use mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.
- Use algebraic thinking to examine scientific data on the variation and distribution of traits in a population and predict the effect of a change in probability of traits as it relates to genetic and environmental factors.

- Explain how the process of meiosis results in the passage of traits from parent to offspring, and how that results in increased genetic diversity necessary for evolution. [Clarification Statement: The emphasis is on how meiosis results in genetic diversity, not the rote memorization of the steps of meiosis.]
- Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced.

Possible Activities:

- Bozeman Video: DNA & RNA
    - Students view the bozeman science video on DNA and RNA, and answer questions about the scientists who played a role in discovering the structure and function of DNA.
    - http://www.bozemanscience.com/027-part-1-dna-rna/
- DNA Structure, Function, and Replication
    - This analysis and discussion activity can be used to introduce your students to key concepts about the structure, function and replication of DNA or to review these topics.
    - This activity includes hands-on modeling of DNA replication.
    - http://serendip.brynmawr.edu/exchange/bioactivities/DNA
- Engineering Design Challenge: Making duplicate cells
    - Students will make models of the cell, analyze what happens to it if it is cut, brainstorm solutions for design flaws when the cell is cut, adapt their model, and conduct research on how actual cells behave prior to division, as well as how they stop dividing and what types of cells they become.
- Mitosis -- How each new cell gets a complete set of genes
    - This minds-on, hands-on activity helps students to understand how mitosis ensures that each new cell gets a complete set of genes.
    - This mitosis activity begins with an introduction to chromosomes, genes and alleles, and the effects of genes on phenotypic characteristics.
    - Students learn about the basic process of mitosis and use model chromosomes to simulate mitosis.
    - Students respond to analysis and discussion questions to further develop their understanding of mitosis.
    - http://serendip.brynmawr.edu/exchange/waldron/mitosis
- Cell Cycle iMovie Project
    - Students will make an iMovie to model the stages and events of the cell cycle
    - Students will brainstorm a plan, create models and labels, create a script, perform the stages required, synthesize the iMovie, view drafts and take notes on what needs to be edited, edit, submit final draft, and watch videos evaluating the movie based on the student-generated rubric.
- The Eukaryotic Cell Cycle and Cancer
    - Students can toggle between two different views. The first view describes the cell cycle phases and checkpoints, including illustrations of the cell's chromosomes. The second view explains the protein regulators, their roles in cell cycle progression, and how mutated versions of these proteins can lead to cancer.

- http://www.hhmi.org/biointeractive/eukaryotic-cell-cycle-and-cancer
- Meiosis and Fertilization -- Understanding how genes are inherited
    - Students learn how the function of molecules and cells is related to their structure (including shape, constituent components, and relationships between components).
    - Students analyze multiple examples of the relationship between structure and function in diverse proteins and eukaryotic cells.
    - Students learn that cells are dynamic structures with constant activity, students learn about emergent properties, and students engage in argument from evidence to evaluate three alternative claims concerning the relationship between structure and function.
    - http://serendip.brynmawr.edu/exchange/bioactivities/SFMolecCell
- Chromosomal Disorders Project
    - Students create a presentation that informs the class about a particular chromosomal disorder.
    - Student presentations include causes, symptoms, frequency, treatments and or preventions, and other descriptive information.
- Dragon Genetics
    - Students cross two adult dragons to create a dragon offspring, and express the traits of the offspring on a dragon model.
    - Students determine whether they are dominant or recessive for some common genetic traits.
- Genetics
    - This activity helps students to understand basic genetics concepts, including how genotype influences phenotype and how understanding meiosis and fertilization provides the basis for understanding inheritance.
    - Modules include (1) an introductory module that uses the example of albinism to help students understand all of the basic concepts and introduces students to the Punnett square as a summary of how genes are transmitted from parents to offspring through the processes of meiosis and fertilization, (2) a Coin Toss Genetics activity and an analysis of student data on the sex makeup of sibships, both of which help students understand the probabilistic nature of inheritance and Punnett square predictions, (3) an analysis of the inheritance of sickle cell anemia that reinforces basic concepts and introduces the important points that a single gene often has multiple phenotypic effects and alleles often are neither completely dominant nor completely recessive, and (4) pedigree analyses for recessive and dominant alleles, including challenge questions that introduce the role of new mutations and engage students in evaluating the relative advantages and disadvantages of Punnett squares and pedigrees as models of inheritance.
    - http://serendip.brynmawr.edu/exchange/waldron/genetics
- Pedigrees
    - Students interpret and create pedigrees for different genetic traits.
    - Students identify specific individuals in a pedigree, determine the genotype of the individuals, and determine the pattern of inheritance of the given trait.
- Mendelian genetics, probability, pedigrees, and chi-square statistics

- This classroom activity uses the information presented in the short film *The Making of the Fittest: Natural Selection in Humans* to take students through a series of questions pertaining to the genetics of sickle cell disease and its relationship to malaria resistance.
    - The questions are divided into sections: Mendelian Genetics and Probability, Pedigrees, and Chi-Square Statistics. Within each section, the questions sequentially move from a basic level to a more advanced level in order to develop the skills of the students.
    - Students will use Punnett squares to predict the frequencies of genotypes in the next generation based on the genotypes of the parents.
    - Students understand the rules of probability as they relate to genetics problems
    - Students analyze pedigrees to deduce genotypes, phenotypes, and probabilities
    - Students use the chi-square statistical analysis test to determine the significance of genetics data.
    - http://www.hhmi.org/biointeractive/mendelian-genetics-probability-pedigree-and-chi-square-statistics
- Colorblindness Lab
    - Students will cross two adults 20 times to identify how colorblindness is inherited.
- Mitosis in Onion Root Tip Lab
    - Students will observe the stages of mitosis.
    - Students will calculate the relative and actual length of time for some of the stages of mitosis.
- Cell Size and Surface Area-to-Volume Ratios
    - Students will calculate how a cell's surface area-to-volume ration limits its size.
- Mitosis Animation
    - Students will create model drawings animating the progression of mitosis.
- Investigating the Results of Inherited Traits.
    - Students will see how traits are inherited based on dominance.
- Gene Linkage Lab
    - Students will observe the inheritance of linked genes.
    - Students will defend why linked genes challenged independent assortment.
- Genetic Probability Lab.
    - Students will predict the genotypic and phenotypic ratios of offspring resulting from the random pairing of gametes.
    - Students will model the random pairing of alleles.
- Finding Phenotypes and Genotypes for Two Traits Lab
    - Students will substitute marked coins for gamete cells and toss the coins to represent offspring.
    - Students will determine the expected offspring and compare it to observed offspring obtained through coin tossing.
    - Students will write a report based on data that explains the similarity or dissimilarity of expected and observed results and how sample size affects results.

Unit 7: Natural Selection

Duration: Honors - 20 days / Regular - 22 days

Overview: Students constructing explanations and designing solutions, analyzing and interpreting data, and engaging in argument from evidence investigate to make sense of the relationship between the environment and natural selection. Students also develop an understanding of the factors causing natural selection of species over time. They also demonstrate and understandings of how multiple lines of evidence contribute to the strength of scientific theories of natural selection.

Standards:

- **HS-LS4-4** - Construct an explanation based on evidence for how natural selection leads to adaptation of populations. [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]
- **HS-LS4-3** - Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]
- **HS-LS4-5** - Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]
- **HS-LS2-8** - Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. [Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]

Essential Questions:

- How does natural selection lead to adaptations of populations?
- Why is it so important to take all of the antibiotics in a prescription if I feel better?
- How are species affected by changing environmental conditions?
- Why do some species live in groups and others solitarily?

Student Objectives:

Students will know

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
- Empirical evidence is required to differentiate between cause and correlation and make claims about how natural selection leads to adaptation of populations and how specific biotic and abiotic differences in ecosystems contribute to change in gene frequency over time, leading to adaptation of populations.
- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and will continue to do so in the future.
- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
- Adaptation also means that the distribution of traits in a population can change when conditions change.
- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
- Changes in the physical environment, whether naturally occurring or human induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline, and sometimes the extinction, of some species.
- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.
- Empirical evidence is required to differentiate between cause and correlation and make claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
- Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.
- Empirical evidence is required to differentiate between cause and correlation and to make claims about the role of group behavior in individual and species' chances to survive and reproduce.

- Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in the revision of an explanation about the role of group behavior on individual and species' chances to survive and reproduce.

Students will be able to

- Make predictions about the effects of artificial selection on the genetic makeup of a population over time.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
- Analyze shifts in numerical distribution of traits and, using these shifts as evidence, support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
- Observe patterns at each of the scales at which a system is studied to provide evidence for causality in explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
- Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
- Determine cause-and-effect relationships for how changes to the environment affect distribution or disappearance of traits in species.
- Use empirical evidence to differentiate between cause and correlation and to make claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
- Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.
- Distinguish between group and individual behavior.
- Identify evidence supporting the outcome of group behavior.
- Develop logical and reasonable arguments based on evidence to evaluate the role of group behavior on individual and species' chances to survive and reproduce.
- Use empirical evidence to differentiate between cause and correlation and to make claims about the role of group behavior on individual and species' chances to survive and reproduce

Possible Activities:

- Human Genetic Traits using the Hardy-Weinberg Equation.
  - Students will determine how many classmates display certain inherited traits.
  - Students will discover whether a dominant trait is always found in a majority of a population.
  - Students will measure the occurrence of three pairs of genetics traits.
  - Students will analyze data by comparing them with data for larger populations.
- Modeling Adaptation Lab
  - Students will model how organisms survive in new habitats.
- Peppered Moth Simulation Lab

    - Students will describe the importance of natural variation in avoiding predation.
    - Students will relate environmental change to changes in organisms.
    - Students will explain how natural selection causes populations to change.
- Design a Lab Demonstrating Natural Selection
    - Students will research and design a lab demonstrating natural selection.
    - Students will develop analysis questions based on experimental data.
    - Students will complete classmates labs.

Unit 8: Evolution

Duration: Honors - 20 days / Regular - 20 days

Overview: Students construct explanations for the processes of natural selection and evolution and then communicate how multiple lines of evidence support these explanations. Students evaluate evidence of the conditions that may result in new species and understand the role of genetic variation in natural selection. Additionally, students can apply concepts of probability to explain trends in population as those trends relate to advantageous heritable traits in a specific environment.

Standards:

- **HS-LS4-1** - Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]
- **HS-LS4-2** - Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]
- **HS-LS3-3** - Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.[Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [*Assessment Boundary: Assessment include Hardy-Weinberg calculations only for Honors.*]

Essential Questions:

- How can someone support that birds and dinosaurs are related?
- What is the relationship between natural selection and evolution?

Student Objectives:

Students will know

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

- Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.
- Different patterns in multiple lines of empirical evidence may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of common ancestry and biological evolution.
- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.
- Empirical evidence is required to differentiate between cause and correlation and make claims about the process of evolution.

Students will be able to

- Examine a group of related organisms using a phylogenetic tree or cladogram in order to (1) identify shared characteristics, (2) make inferences about the evolutionary history of the group, and (3) identify character data that could extend or improve the phylogenetic tree.
- Communicate scientific information in multiple forms that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
- Understand the role each line of evidence has relating to common ancestry and biological evolution.
- Observe patterns in multiple lines of empirical evidence at different scales and provide evidence for causality in explanations of common ancestry and biological evolution.
- Construct an explanation, based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- Use empirical evidence to explain the influences of: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment, on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species.

Possible Activities:

- Bird Beak Adaptation Lab
    - To see how certain adaptations can increase the bird's chances of acquiring food
    - To use utensils to represent a type of bird beak to pick up "food"
    - To explain how a bird's beak is adapted to the type of food they eat
    - To explain how and why organisms become adapted for their environment through natural selection
- How Do Fossils Show Change?
    - To examine diagrams of fossil horses and present day horses shown in their surroundings
    - To examine diagrams of the structure of the front foot of fossil horses and present day horses
    - To explain changes in horses that have taken place over time
- Human Skin Color: Evidence for Selection
    - To make predictions and propose hypotheses based on available information
    - To use real data presented in scientific figures and information from the film to make evidence based claims
    - http://www.hhmi.org/biointeractive/human-skin-color-evidence-selection
- Origin of Birds video with quiz
    - To view the film which illustrates many of the practices of science, including asking important questions, formulating and testing hypotheses, analyzing and interpreting evidence, and revising explanations as new evidence becomes available.
    - http://www.hhmi.org/biointeractive/origin-birds-quiz
- How did dinosaurs regulate their body temperature
    - To analyze, interpret, and draw conclusions from authentic data
    - To participate in a collaborative discussion of the evidence with their classmates
    - http://www.hhmi.org/biointeractive/how-did-dinosaurs-regulate-their-body-temperature
- Evolution and Adaptation
    - To understand natural selection by explicitly recognizing that in common experience, the term "adapting" usually refers to changes during an organism's lifetime,but in discussing natural selection biologists use the term "adaptation" for a heritable trait that increases fitness.
    - To help students reconcile their everyday experience with an understanding of natural selection, this activity discusses phenotypic plasticity (the ability of an organism to adapt to different environments within its lifetime)
    - To analyze how the balance between the advantages and disadvantages of a given trait can change as the environment changes, how phenotypic plasticity can be one way to optimize fitness in a variable environment, and how natural selection can influence the amount of phenotypic plasticity in a population.
    - http://serendip.brynmawr.edu/exchange/bioactivities/evoadapt
- How eyes evolved
    - To analyze evidence from comparative anatomy, mathematical modeling, and molecular biology.

    - to interpret this evidence including natural selection, fitness, and the difference between homology (similarity due to common descent) and analogy (similarity due to convergent evolution).
    - http://serendip.brynmawr.edu/exchange/bioactivities/evoleye
- Examining Variation in a Population
    - To measure and record the length of one of your shoes to the nearest centimeter
    - To record your measurement and your gender in the class data table
    - To make a graph showing the distribution of length of shoes in the class, and analyze the data to explain why there is variation among shoe length
- Comparing Limb Structure and Function
    - To observe and describe the limb structure of different organisms
    - To identify relationships between the structures of different organisms
    - To compare and contrast divergent and convergent evolution

SUGGESTED AUDIO VISUAL/COMPUTER AIDS

1. Computer Interface Probe System: PASCO Interfaces and Probes
2. Graphing Calculator
3. iPad apps and peripherals
4. Microscopes, stereoscopes, and viewers
5. Discovery Channel's *Mythbusters*
6. http://video.mit.edu/
7. http://scienceworld.scholastic.com/
8. EdRNA App - Decode Meiosis
9. http://learn.genetics.utah.edu/content/labs/
10. HHMI Biointeractive
11. iCell App
12. Snurfle Mitosis & Meiosis App
13. Cell Defense App
14. Cell Explorer App
15. Infection App
16. Powers of Minus10 App
17. Periodic Table App
18. Nova Elements App

SUGGESTED MATERIALS

Texts

- Nowicki, Stephen. Biology. Holt & McDougal, 2012.
- Campbell, N. A., J. L. Dickey, J. B. Reece, E. J. Simon, and M. R. Taylor. Biology: Concepts and Connections. Benjamin Cummings, 2008

Resources for Students

http://phet.colorado.edu - excellent simulation site. Includes lessons and resources at the bottom of each simulation that follow the NGSS framework.

https://www.khanacademy.org/ - useful videos, practice problems, and quizzes in both math and science.

http://www.bozemanscience.com/ - short explanatory videos on science concepts and pedagogical approaches to teaching science

Resources for Teachers

http://www.state.nj.us/education/modelcurriculum/sci/ - site of the NJ DOe model curriculum project. Contains sample plans, storylines, progressions and more.

Science Engineering Practices Grades 6-8 Quick Reference

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.National Research Council. (2012).Washington, DC: National Academy of Sciences.

Quick Reference Guide to the Framework for K-12 Science Education, NJDOE. (2016). This quick reference document hyperlinks the user to specific sections of the *Framework*.

Next Generation Science Standards. NGSS Lead States. (2013).Washington, DC: The National Academies Press.

Guide to Implementing the Next Generation Science Standards. National Research Council. (2015).Washington, DC: National Academy of Sciences

Primer on Science Instruction: This two-page document highlights some of the essential characteristics of evidence-based teaching practices.

Planning NGSS-Based Instruction: Where Do You Start? (Colson, M. and Colson, R., 2016) This article addresses the question "*So what comprises an authentic classroom science experience?*"

National Science Teachers Association - the *classroom resources* and *curriculum planning* sections provide a plethora of lesson ideas and plans that can be incorporated into the curriculum.

SUGGESTED MATERIALS (continued)

http://assessment.aaas.org/topics - as we develop a learning progression, we should consider misconceptions that students may have as it relates to the content/skills we are teaching.

http://pum.rutgers.edu/index.php - excellent resources for developing physical science ideas