Cedar Grove School District

Cedar Grove, NJ

2017 | Grade 10

Biology Honors

Approved by the Cedar Grove Board of Education

Superintendent of Schools
Mr. Michael J. Fetherman

Biology Honors
Course Description

This course is laboratory based with an emphasis on students being able to construct and conduct scientific investigations to determine relationships between variables. There is also a focus on students being able to construct scientific arguments from gathered evidence. Biology is designed to encourage students to increase their understanding of concepts and topics within the realm of biology.

Units of instruction include Interdependent Relationships in Ecosystems, Matter and Energy Transformations in Ecosystems, Cell Specialization and Homeostasis, DNA and Inheritance, Natural Selection, Evolution, Human Activity and Climate, and Human Activity and Biodiversity. The process of scientific inquiry and the integration of concepts within life experiences are stressed throughout the course. Students will gain the knowledge through their experiences in biology to understand topics relevant to their life as well as current events. They will learn to use evidence to make educated decisions helping them to maintain healthy lifestyles and to become better citizens.

The course is centered on the New Jersey Student Learning Standards for Science/Next Generation Science Standards. Students will engage in science and engineering practices in order to understand conceptual progression which is reinforced in the disciplinary core ideas. Students will make connections to prior learning through the infusion of cross cutting concepts that demonstrate the connections between scientific disciplines. Students will demonstrate their mastery of the content through assessment activities that are based on the NJSLS/NGSS performance expectation statements. In order to provide students a challenging rigorous course certain assessment boundaries have been removed to incorporate a deeper level of knowledge.

This curriculum was written in accordance with the
NEW JERSEY STUDENT LEARNING STANDARDS
for SCIENCE

The standards can be viewed at http://www.state.nj.us/education/aps/cccs/science/.

Biology Honors

Unit 1: Matter and Energy in the Biosphere — Instructional Days: 20

Unit Description

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. Students utilize the crosscutting concepts of *matter and energy* and *systems, and system models* to make sense of ecosystem dynamics. Students are expected to use 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* as they demonstrate their understanding of the disciplinary core ideas.

New Jersey Student Learning Standards for Science/NGSS

Student Learning Objectives

HS-LS1-5	Use a model to illustrate how photosynthesis transforms light energy into stored chemical 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.

Enduring Understandings

- Students will understand how photosynthesis and cellular respiration drive cellular function at the molecular level.
- Students will be able to explain how materials are cycled through various cellular processes.
- Students will be able to describe the flow of energy through living systems in various food webs.
- Understand how the world is interconnected and interdependent upon one another to survive

Essential Questions

- How is energy converted within the process of both photosynthesis and cellular respiration?
- What is the relationship between photosynthesis and cell respiration in terms of the cycling of material and flow of energy?
- How is the process of energy conversion different depending on the presence of oxygen?
- How do matter and energy cycle through ecosystems?

Part A: *Why do astrobiologists look for water on planets and not oxygen when they search for life on other planets?*

Concepts

- Energy drives the cycling of matter within and between systems.
- Energy drives the cycling of matter within and between systems in aerobic and anaerobic conditions.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.

Formative Assessment

Students who understand the concepts are 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.

Part B: *Why is there no such thing as a food chain?*

Concepts

- Energy cannot be created or destroyed—it only moves

Formative Assessment

Students who understand the concepts are able to:

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.	• 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.
Part C: ***How can the process of photosynthesis and respiration in a cell impact ALL of Earth's systems?***	
Concepts	**Formative Assessment**
• 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.	*Students who understand the concepts are able to:* • 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.
Suggested Learning Activities and Educational Resources	

- Students reinforce their understanding of the concept that energy drives the cycling of matter within and between systems by applying this concept directly to ecosystem processes and biogeochemical cycles. A variety of models, including computer simulations, diagrams, and drawings, could be used to enhance visual, verbal, and/or written understanding of the various ecological cycles (e.g., carbon, nitrogen, water, phosphorus).
- Energy flows within an ecosystem; therefore, a pattern of transfer is predictable and observable based on historical ecological data, since energy moves through trophic levels. Student-generated pyramids of biomass and food webs could illustrate this. Plants, algae, and chemosynthetic organisms form the lowest level of a food web. Students will learn that energy transfer from producer to multiple consumer levels is inefficient. Emphasize that 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.
- Because energy cannot be created or destroyed and can move only between objects, fields, or systems, students must understand that 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. Models of an ecological system, such as energy pyramids or biogeochemical cycles, could be used to illustrate this concept.
- The reactants and products of photosynthesis and cellular respiration (aerobic and anaerobic) will be used to explain energy transfer and cycling of matter. The carbon cycle can be used as a reference for this. Students must understand that photosynthesis and cellular respiration (including aerobic and anaerobic conditions) provide most of the energy for life processes. Students will also learn specific key Biochemical steps in cellular respiration and photosynthesis.

- Students must also construct and revise an explanation of matter cycling and energy flowing in aerobic and anaerobic conditions based on valid and reliable evidence. Students might engage in their own investigations, simulations, and peer reviews, and/or generate models to validate theories.
- The assumption is 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. To demonstrate that most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence, students should conduct an investigation of previous experiments that contributed to our understanding of photosynthesis and/or cellular respiration. Using mathematical representations (e.g., pyramids of biomass, numbers, and energy amounts) and/or population size, students can manipulate proportions and calculations based on input and output of systems. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much matter is discarded. Atoms and molecules—such as carbon, oxygen, hydrogen and nitrogen, which make up biotic and abiotic parts of the biosphere (atmosphere and soil)—are combined and recombined, demonstrating the conservation of matter and flow of energy.
- To understand energy conservation, students use proportional reasoning to demonstrate that on average, regardless of scale, 10% of energy is transferred up from one trophic level to another. Students might use various pyramids (e.g., energy, biomass) and calculate the amount of available energy at each trophic level.
- Students can also analyze diagrams of chemical cycles (carbon, nitrogen, water, etc.) to identify the movement of matter within ecosystems.
- Through the use of diagrams, concept maps, or computer models, students will examine how energy is cycled within systems. Students will examine how energy drives the cycling of matter, using diagrams of ecosystems to map the flow of energy and the simultaneous changes in matter. Students could construct two systems, including autotrophs and heterotrophs, to model the transfer of energy. Emphasis is on the construction of student-based theories and explanations based on the interaction of the system. Students will then revise their primary explanation based on new evidence. Student explanations should demonstrate an understanding of the relationship between photosynthesis and cellular respiration.

Suggested Activity Resources

- **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.
- **Surviving Winter in the Dust Bowl (Food Chains and Trophic Levels):** This is one of 30 lessons from the NSTA Press book Scientific Argumentation in Biology. The lesson engages students in an argumentation cycle based on an engaging scenario in which their group is a farm family trying to survive a dust bowl winter with limited food and water resources. The family has a bull, a cow, and limited amounts of water and wheat. Students are presented with four options that include various combinations of eating or keeping the animals alive and eating the wheat. Within this scenario, the lesson provides data on nutritional requirements of cows and humans, along with nutritional contents of wheat, milk, and beef. Students then use this data to construct an argument for the best strategy to allow their family to survive. As they construct this argument, students build and apply knowledge of food chains, trophic levels, interdependence among organisms, and energy transfers within ecosystems. This lesson is intended for middle or high school students. Teachers are encouraged to refer to the preface, introduction, student assessment samples, and appendix provided in the full book for important background on the practice of argumentation and resources for classroom implementation.
- **Of Microbes and Men:** Students will 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.

Performance Expectations

Science and Engineering Practices	DCI	Crosscutting Concepts
Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer	**LS1.C: Organization for Matter and Energy Flow in Organisms** • The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-1)	**Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-1) • Energy drives the cycling of matter within and between

review) and the assumption that theories and laws that describe the natural world operate as they did in the past and will continue to do so in the future. (HS-LS2-3) **<u>Using Mathematics and Computational Thinking</u>** • Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4) • Developing and Using Models • Develop models based on evidence to illustrate the relationship between system components or a system. (HS-LS1-5), (LS-LS2-5)	**<u>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems</u>** • Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3) • 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. At each link in an ecosystem, matter and energy are conserved. (HS-LS2-4) 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. (HS-LS2-5)	systems. (HS-LS2-3) • Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS2-4) **<u>Systems and System Models</u>** 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. (HS-LS2-5) - ***Connections to Nature of Science*** **Scientific Knowledge is Open to Revision in Light of New Evidence** • Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS-LS2-3)

Cross-Curricular Connections	
New Jersey Student Learning Standards for Language Arts Literacy	**New Jersey Student Learning Standards for Mathematics**
• Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **<u>RST.11-12.1</u>** (HS-LS2-3) • Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. **SL.11-12.5** (HS-LS1-5),	• Reason abstractly and quantitatively. **MP.2** (HS-LS2-4) • Model with mathematics. **MP.4** (HS-LS2-4) • Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN-Q.A.1** (HS-LS2-4) • Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.2** (HS-LS2-4)

	• HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HSLS2-4)

21st Century Career Ready Practices

- **CRP1**. Act as a responsible and contributing citizen and employee.
- **CRP2.** Apply appropriate academic and technical skills.
- **CRP3.** Attend to personal health and financial well-being.
- **CRP4.** Communicate clearly and effectively and with reason.
- **CRP5.** Consider the environmental, social and economic impacts of decisions.
- **CRP6.** Demonstrate creativity and innovation.
- **CRP7.** Employ valid and reliable research strategies.
- **CRP8.** Utilize critical thinking to make sense of problems and persevere in solving them.
- **CRP9.** Model integrity, ethical leadership and effective management.
- **CRP10.** Plan education and career paths aligned to personal goals.
  CRP11. Use technology to enhance productivity.
  CRP12. Work productively in teams while using cultural global competence.

- **Suggested Resources**

Biology Honors

Unit 2: Ecosystem Interactions — Instructional Days: 20

Unit Description

In this unit of study, students formulate answers to the question “how and why do organisms interact with each other (biotic factors) and their environment (abiotic factors), and what affects these interactions?” Secondary ideas include the interdependent relationships in ecosystems; dynamics of ecosystems; and functioning, resilience, and social interactions, including group behavior. Students use mathematical reasoning and models to make sense of carrying capacity, factors affecting biodiversity and populations, the cycling of matter and flow of energy through systems. The crosscutting concepts of scale, proportion, and quantity and stability and change are called out as organizing concepts for the disciplinary core ideas. Students are expected to use mathematical reasoning and models to demonstrate proficiency with the disciplinary core ideas.

New Jersey Student Learning Standards for Science/NGSS

Student Learning Objectives

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.
LS2.A	Illustrate how interactions among living systems and with their environment result in the movement of matter and energy.
LS2.A	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.
LS2.A	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.

Enduring Understandings

- Scientific inquiry involves asking scientifically oriented questions, collecting evidence, forming explanations, connecting explanations to scientific knowledge and theory, and communicating and justifying explanations.
- Thinking systematically means looking for the relationships between parts.
- Organisms and their environments are interconnected. Changes in one part of the system will affect other parts of the system.
- Matter needed to sustain life is continually recycled among and between organisms and the environment. Energy from the sun flows irreversibly through ecosystems and is conserved as organisms use and transform it.
- Humans can alter the living and non-living factors within an ecosystem, thereby creating changes to the overall system.

Essential Questions

- How can change in one part of an ecosystem affect change in other parts of the ecosystem?
- How do organisms interact with the living and nonliving environments to obtain matter and energy? Why is sunlight essential to life on Earth?
- How do humans have an impact on the diversity and stability of ecosystems?

Part A: *When they relocate bears, wolves, or other predators, how do they know that they will survive?*

Concepts

- 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

Formative Assessment

Students who understand the concepts are able to:

- Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

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- 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.

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- Use quantitative analysis to compare relationships among interdependent factors and represent their effects on the carrying capacity of ecosystems at different scales.

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<tr><td colspan="2">Part B: What limits the number and types of different organisms that live in one place?</td></tr>
<tr><th>Concepts</th><th>Formative Assessment</th></tr>
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- 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.

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Students who understand the concepts are able to:

- 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.

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<tr><td colspan="2">Part C: How can small changes over short periods of time in ecosystems ultimately have devastating effects on biotic components?</td></tr>
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- 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.

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Students who understand the concepts are able to:

- 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.

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- 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.

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- Construct explanations of how modest biological or physical changes versus extreme changes affect stability and change in ecosystems.

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<tr><th colspan="2">Suggested Learning Activities</th></tr>
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- Emphasis should be on having students make quantitative analysis and comparisons of the relationships among interdependent factors, including boundaries, resources, climate, and competition. When choosing materials for analysis, data should be presented at different scales, and students should use units as a way to understand the factors that affect carrying capacity of ecosystems at different scales. Students might also generate charts, graphs, and histograms from data sets. When reporting quantities representing the factors that affect carrying capacity of ecosystems, students should consider any limitations on measurement.
- Mathematical and computational representations can be used to show that 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.
- Students can use quantitative analysis (e.g., graphs and other data displays with appropriate units and scale) to compare and determine how relationships among interdependent factors such as famine, disease, competition, predation, and shelter affect the carrying capacity of ecosystems at different scales. Examples of different scales could be data sets showing the population dynamics of an ecosystem in a jar, predator–prey oscillation studies, introduction of invasive species into an ecosystem, or changes as a result of the natural process of succession.
- Through relevant reading experiences, students might also develop and write explanations, citing textual evidence, for factors that affect carrying capacity of ecosystems. In their explanations, students should select the most significant and relevant facts, extended definitions, concrete details, and quotations to support their explanations.
- The availability of current technology allows for more sophisticated observations and more accurate data collection and analysis. These data represent the most recent explanations for phenomena. Students might study existing data on factors that affect biodiversity and write explanatory texts, citing evidence and noting gaps or inconsistencies. In their own investigations, students might model how bacterial populations respond to exposure to antibacterial gel over time, illustrating community biodiversity. Community diversity at a microscopic scale, illustrating logistic, exponential growth, and carrying capacity, can be used to better model similar patterns on a larger scale (e.g., habitat, ecosystem, biome, biosphere) using data sets. Students should identify important factors affecting biodiversity and populations in ecosystems, quantify those factors using appropriate units, and draw conclusions based on any noted relationships. Ex. Reintroduction of Wolf populations to Yellow Stone National Park
- Students should have an overall understanding of the significance of carrying capacity and its dependence upon the relationships among interdependent factors including boundaries, resources, climate, and competition. Quantitative data from simulations of modest biological or physical disturbances can demonstrate how ecosystems can return to original status, more or less. Examples of data showing modest disturbances might include changes in weather patterns (e.g., drought), clearing of land for development, or forest fires. In order to understand this phenomenon, students might also analyze data from old-field succession, abandoned urban parking lots, or transect studies in order to make claims, using evidence, about effects on biodiversity and populations. Students should also examine evidence of extreme fluctuations, such as from natural disasters, and how the functioning of ecosystems can be challenged in terms of resources and habitat availability.
- Mathematical representations to support explanations should include finding averages, determining trends, and using graphical comparisons of multiple sets of data.
- Using food webs and ecological models/states, students can observe that the numbers and types of organisms are relatively constant over long periods of time under stable conditions. In order to make mathematical representations to support claims, students need to examine data showing the complex set of interactions that occur in ecosystems. Students should examine data illustrating the quantitative fluctuations in populations that

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occur because of factors such as predator–prey relationships, availability of resources, and habitat availability.

- To support claims about complex interactions in ecosystems and changes in numbers of organisms in stable and changing conditions, students should be able to cite specific textual evidence and integrate and evaluate multiple sources of information presented in diverse formats. Students could develop an understanding of orders of magnitude that exist within the ecosystem concept through experiences such as microscopic examination of pond water producers and consumers (phytoplankton and zooplankton), construction of jar ecosystems, or visits to local terrestrial and/or aquatic ecosystems (forest, pond). Their study of ecosystem scale could then extend to models of regional ecosystems and global ecosystem types (biomes). Through activities such as these, students learn that ecological processes and interactions present at the microscopic level are the same as those found in the biosphere.

Suggested Activity Resources

- **Bunny Population Growth Activity:** Students collect data during a simulation and use it to support their explanation of natural selection in a rabbit population and how populations change over time when biotic or abiotic factors change.
- **African Lions Activity:** Students using the data presented to make a prediction regarding the zebra population during the periods of increase rainfall. Students will create a representation of the data that illustrates both the lion population and zebra population during the same time period
- **Animal Behavior:** Students will make detailed observations of an organism's behavior and then design and execute a controlled experiment to test a hypothesis about a specific case of animal behavior. Students will record observations, make sketches, collect and analyze data, make conclusions, and prepare a formal report.
- **Biodiversity:** Students use this lab to represent how biodiversity stops a disease from spreading.

Performance Expectations

Science and Engineering Practices	DCI	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HS-LS2-1) • Use mathematical representations of phenomena or design solutions to support and revise explanations. (HS-LS2-2) **Engaging in Argument from Evidence** • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)	**LS2.A: Interdependent Relationships in Ecosystems** • Ecosystems have carrying capacities, which are limits to the numbers 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, competition, 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. (HS-LS2-1),(HS-LS2-2) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** • 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	**Scale, Proportion, and Quantity** • The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1) • Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2) **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6)

	fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2),(HS-LS2-6)	

Cross-Curricular Connections	
New Jersey Student Learning Standards for Language Arts Literacy	**New Jersey Student Learning Standards for Mathematics**
• Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. RST.11-12.1 (HS-LS2-1),(HS-LS2-2),(HS-LS2-6) • Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. RST.11-12.7 (HS-LS2-6) • Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. RST.11-12.8 (HS-LS2-6) • Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. WHST.9-12.2 (HS-LS2-1),(HS-LS2-2)	• Reason abstractly and quantitatively. MP.2 (HS-LS2-1),(HS-LS2-2),(HS-LS2-6) • Model with mathematics. MP.4 (HS-LS2-1),(HS-LS2-2) • Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. HSN.Q.A.1 (HS-LS2-1),(HS-LS2-2) • Define appropriate quantities for the purpose of descriptive modeling. HSN.Q.A.2 (HS-LS2-1),(HS-LS2-2) • Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. HSN.Q.A.3 (HS-LS2-1),(HS-LS2-2) • Represent data with plots on the real number line. HSS-ID.A.1 (HS-LS2-6) • Understand statistics as a process for making inferences about population parameters based on a random sample from that population. HSS-IC.A.1 (HS-LS2-6)

21st Century Career Ready Practices

- **CRP1**. Act as a responsible and contributing citizen and employee.
- **CRP2.** Apply appropriate academic and technical skills.
- **CRP3.** Attend to personal health and financial well-being.
- **CRP4.** Communicate clearly and effectively and with reason.
- **CRP5.** Consider the environmental, social and economic impacts of decisions.
- **CRP6.** Demonstrate creativity and innovation.
- **CRP7.** Employ valid and reliable research strategies.
- **CRP8.** Utilize critical thinking to make sense of problems and persevere in solving them.
- **CRP9.** Model integrity, ethical leadership and effective management.
- **CRP10.** Plan education and career paths aligned to personal goals.

CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

Suggested Resources

Biology Honors

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<tr><td colspan="3">Unit 3: Human Impact on Ecosystems</td><td>Instructional Days: 20</td></tr>
<tr><th colspan="4">Unit Description</th></tr>
<tr><td colspan="4">In this unit of study, students examine factors that have influenced the distribution and development of human society; these factors include climate, natural resource availability, and natural disasters. Students use computational representations to analyze how earth systems and their relationships are being modified by human activity. Students also develop an understanding of how human activities affect natural resources and of the interdependence between humans and Earth's systems, which affect the availability of natural resources. Students will apply their engineering capabilities to reduce human impacts on earth systems and improve social and environmental cost–benefit ratios. The crosscutting concepts of cause and effect, systems and systems models, stability and change, and the influence of engineering, technology, and science on society and the natural world are called out as organizing concepts for the disciplinary core ideas. Students will analyze and interpret data, use mathematical and computational thinking, and construct explanations as they demonstrate understanding of the disciplinary core ideas.</td></tr>
<tr><th colspan="4">New Jersey Student Learning Standards for Science/NGSS</th></tr>
<tr><th colspan="4">Student Learning Objectives</th></tr>
<tr><td>HS-ESS3-1</td><td colspan="3">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.</td></tr>
<tr><td>HS-ESS3-6</td><td colspan="3">Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.</td></tr>
<tr><td>HS-ESS3-5</td><td colspan="3">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.</td></tr>
<tr><td>HS-ESS3-4</td><td colspan="3">Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*</td></tr>
<tr><td>HT-ETS1-3</td><td colspan="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.</td></tr>
<tr><th colspan="2">Enduring Understandings</th><th colspan="2">Essential Questions (3 or 4)</th></tr>
<tr><td colspan="2">• Understand the impact humans have on the planet.
• Understand what is being done today to help stop extinction and pollution on earth.
• Understand an impact anywhere (ecosystem) can influence another elsewhere.</td><td colspan="2">• How do humans depend on Earth's resources?
• How and why do humans interact with their environment and what are the effects of these interactions?
• How are all species connected?
• Where do we go from here (conservation biology)?</td></tr>
<tr><th colspan="4" align="left">Part A: How are human activities influence the global ecosystem?</th></tr>
<tr><th colspan="2">Concepts</th><th colspan="2">Formative Assessment</th></tr>
<tr><td colspan="2">• 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.</td><td colspan="2">Students who understand the concepts are able to:
• Construct an explanation based on valid and reliable evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
• Use empirical evidence to differentiate between how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.</td></tr>
<tr><th colspan="4" align="left">Part B: What are the relationships among earth's systems and how are those relationships being modified due to human activity?</th></tr>
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Concepts	Formative Assessment
• 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.	*Students who understand the concepts are 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. • Calculate ecological foot prints
Part C: What is the current rate of global or regional climate change and what are the associated future impacts to Earth's systems?	
Concepts	**Formative Assessment**
• 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.	*Students who understand the concepts are able to:* • 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.
Part D: How can the impacts of human activities on natural systems be reduced?	
Concepts	**Formative Assessment**
• 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.	*Students who understand the concepts are able to:* • 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.

• Analysis of costs and benefits is a critical aspect of decisions about technology.	

Suggested Learning Activities

- Students will use their understanding of photosynthesis, cellular respiration, and the carbon cycle from prior units and examine their relationship to climate change and human impact on climate. They will develop an understanding of how human activity can influence the complex set of interactions within an ecosystem, causing changes in the number of different types of species.
- Students will also build on the idea that 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. All of these concepts support students' understanding of human dependence on Earth's resources, human interactions with the environment, and human impacts on Earth's systems. Students will research a superfund site in NJ
- Environmental factors have affected human populations over the course of history. Resource availability, natural disasters, and other geologic events have driven global development of societies, sizes of human populations, and human migrations. Student understanding of these relationships could be enhanced by examining and citing evidence from text or other investigations that show correlations between human population distribution and regional availability of resources such as fresh water, fertile soils, and fossils fuels.
- Students should look for cause-and-effect relationships between human population distribution and resource availability and distinguish between causality and correlation. In developing an explanation for how the availability of natural resources has influenced human activity, students might consider, for example, the dependence of large urban populations on the technology required to deliver potable water. An example of the role that technology plays could include the impounding of the Colorado River by the Hoover Dam and the formation of Lake Mead, which provides the water required to support large human populations in an otherwise arid and desert habitat.
- Historical accounts of natural disasters (e.g., Krakatoa eruption, American Dust Bowl, Superstorm Sandy, and Hurricane Katrina) resulting human suffering and loss of life could provide empirical evidence of past impacts on human population size and distribution. Previous climate change events (sea level fall and rise, desertification of the Sahara) could be studied as examples of natural events that can drive human migrations. Students should use evidence from data analysis to make inferences and predictions about the impacts of future climate change and global warming on displacement or migration of humans.
- When examining and reporting data, students should represent resource availability, natural disasters, and human activity symbolically and determine what quantitative relationships exist. Students might map these relationships in graphs, charts, or other descriptive models, while considering any limitations on measurement when reporting quantities.
- Through computer simulations and other studies, important discoveries are still being made about how the ocean, atmosphere, and biosphere interact and are modified in response to human activities. Students should describe the boundaries of Earth's systems by looking at models, data sets, or graphics showing temperatures and currents of the ocean and atmosphere. They should identify evidence to support the claim that human activity can modify Earth's systems. When students are 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. Students will analyze and describe the inputs and outputs of Earth's systems by researching and investigating the amount of carbon dioxide produced by human activities. In their research, students should integrate and evaluate multiple sources of information and verify data when possible. Students will design a solution to decrease the amount of carbon dioxide added by human activity. The design process may need to be broken down into logical steps that can be approached systematically, and decisions about the priority of certain criteria over others should be considered throughout the process.
- Current global models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models depend on the amount of human-generated greenhouse gases added to the atmosphere each year and on the ways in which these gases are absorbed by the ocean and biosphere. Students can use computational representations of geoscience data to illustrate these relationships and make forecasts about Earth's systems. Students might illustrate how relationships are being modified due to human activity by graphing temperature changes over a period of time. Rates of change should be quantified and modeled at different time scales. In symbolic representations of relationships between Earth's systems and human activity, students should consider appropriate quantities and limitations on

measurement when reporting data.

- When evaluating or refining a technological solution that reduces impacts of human activities on natural systems, such as use of alternative energy sources, students should read and integrate multiple sources of information to create a coherent understanding of the problem. In their evaluation, they should consider costs, benefits, and risks of systems created by engineers. When evaluating solutions, students should take into account a range of constraints, including costs, safety, and reliability, as well as any social, cultural, and environmental impacts. Models created by students should be used to illustrate and analyze positive and negative feedback within natural systems that may lead to stabilization or destabilization.
- Examples of technologies that might limit future impacts of human activity could be small-scale local efforts or large-scale geoengineering solutions for more global issues. Students will* research and analyze data regarding the use of fossil fuels to power machines and the quantities and types of pollutants produced. The analysis of data will be used to investigate how alternative energy machines, such as electric- or hydrogen powered cars, could be used to reduce carbon emissions. Students should consider the availability of infrastructure, trained technicians, economic constraints, reliability, and other trade-offs, like personal aesthetic preference, in their evaluations or design decisions.
- *Integration of engineering-*
- Performance expectation HS-ESS3-4 specifically identifies a connection to HS-ETS1-3. This requires students to evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. To meet this requirement, students will evaluate technological solutions that limit human impacts on natural systems. In their evaluations, students should consider how 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.

Suggested Activity Resources

- **Climate Change Impacts:** NOAA Education Resources that can be used to teach climate science.
- **Digital Library for Earth System Education:** DLESE is the Digital Library for Earth System Education, a free resource that supports teaching and learning about the Earth system. DLESE's development was funded by the National Science Foundation and continues to be built by a distributed community of educators, students, and scientists to support Earth system education at all levels. DLESE is operated by the National Center for Atmospheric Research (NCAR) Computational and Information Systems Laboratory and the NCAR Library on behalf of the education community.

Performance Expectations

Science and Engineering Practices	DCI	Crosscutting Concepts
Constructing Explanations and Designing Solutions • 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. **(HS-ESS3-1)** • Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **(HS-ESS3-4)** **Analyzing and Interpreting Data**	**ESS3.A: Natural Resources** • Resource availability has guided the development of human society. **(HS-ESS3-1)** **ESS3.B: Natural Hazards** • Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. **(HS-ESS3-1)** **ESS2.D: Weather and Climate** • Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **(HS-ESS3-1)** **Systems and System Models** • 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. **(HS-ESS3-6)** **Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. **(HSESS3-4)** - ***Connections to Engineering,***

• Analyze data using computational models in order to make valid and reliable scientific claims. **(HS-ESS3-5)** **<u>Using Mathematics and Computational Thinking</u>** • Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. **(HS-ESS3-6)**	depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary to **HS-ESS3-6)** **<u>ESS3.D: Global Climate Change</u>** • 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. **(HS-ESS3-6)** **<u>ETS1.B: Developing Possible Solutions</u>** • 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. **(HS-ETS1-3)**	***Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • 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. **(HS-ETS1-1) (HS-ETS1-3)**

Cross-Curricular Connections	
New Jersey Student Learning Standards for Language Arts Literacy	**New Jersey Student Learning Standards for Mathematics**
• Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **RST.11-12.1** (HS-ETS1-3) • Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **RST.11-12.7** (HS-ETS1-3) • Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **RST.11-12.8** (HS-ETS1-3) • Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. **RST.11-12.9** (HS-ETS1-3).	• Reason abstractly and quantitatively. **MP.2** (HS-LS2-1),(HS-LS2-2),(HS-LS2-6),(HS-LS2-7) • Model with mathematics. **MP.4** (HS-ETS1-3) • Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN.Q.A.1** (HS-ETS1-3). • Define appropriate quantities for the purpose of descriptive modeling. **HSN.Q.A.2** (HS-ETS1-3). • Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. **HSN.Q.A.3** (HS-ETS1-3).

21st Century Career Ready Practices
• **CRP1**. Act as a responsible and contributing citizen and employee. • **CRP2.** Apply appropriate academic and technical skills. • **CRP3.** Attend to personal health and financial well-being. • **CRP4.** Communicate clearly and effectively and with reason. • **CRP5.** Consider the environmental, social and economic impacts of decisions.

• **CRP6.** Demonstrate creativity and innovation. • **CRP7.** Employ valid and reliable research strategies. • **CRP8.** Utilize critical thinking to make sense of problems and persevere in solving them. • **CRP9.** Model integrity, ethical leadership and effective management. • **CRP10.** Plan education and career paths aligned to personal goals. **CRP11.** Use technology to enhance productivity. **CRP12.** Work productively in teams while using cultural global competence.
Suggested Resources

<table>
<tr><td colspan="2">Biology Honors</td></tr>
<tr><td>Unit 4: Ecosystem Solutions</td><td>Instructional Days: 20</td></tr>
<tr><td colspan="2">Unit Description</td></tr>
<tr><td colspan="2">In this unit of study, mathematical models provide support for students’ conceptual understanding of systems and students’ ability to design, evaluate, and refine solutions for reducing the impact of human activities on the environment and maintaining biodiversity. Students create or revise a simulation to test solutions for mitigating adverse impacts of human activity on biodiversity. Crosscutting concepts of systems and system models play a central role in students' understanding of science and engineering practices and core ideas of ecosystems. Mathematical models also provide support for students' conceptual understanding of systems and their ability to develop design solutions for reducing the impact of human activities on the environment and maintaining biodiversity.</td></tr>
<tr><td colspan="2">New Jersey Student learning Standards for Science/NGSS</td></tr>
<tr><td colspan="2">Student Learning Objectives</td></tr>
<tr><td>HS-ESS3-3</td><td>Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.</td></tr>
<tr><td>HS-LS2-7</td><td>Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.</td></tr>
<tr><td>HS-LS4-6</td><td>Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.</td></tr>
<tr><td>HS-ETS1-1</td><td>Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants</td></tr>
<tr><td>HS-ETS1-2</td><td>Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</td></tr>
<tr><td>HS-ETS1-3</td><td>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.</td></tr>
<tr><td>HS-ETS1-4</td><td>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.</td></tr>
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<tr><th>Enduring Understandings</th><th>Essential Questions</th></tr>
<tr><td>The sustainability of human societies and the biodiversity that supports them require responsible management of natural resources.
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.
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.</td><td>Would we treat our resources and life support system if we were on a rocket headed for Mars as we do in our community right now?
How can humans manage earth’s resources with the least impact to sustainable ecosystems?
How do human actions impact ecosystem negatively?
How can the improper management of resources lead to change and the imbalance of ecosystem?</td></tr>
<tr><td colspan="2">Part A: How might we change habits if we replaced the word “environment” with the word “life support system”?</td></tr>
<tr><th>Concepts</th><th>Formative Assessment</th></tr>
<tr><td>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</td><td>Students who understand the concepts are 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</td></tr>
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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.	resources, the sustainability of human populations, and biodiversity.
Part B: ***Does reducing human impacts on our global life support system require social engineering or mechanical engineering?***	
Concepts	**Formative Assessment**
• 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 where not anticipated. Analysis of cost and benefits is a critical.	Students who understand the concepts are able to: • 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.
Part C: ***Is the damage done to the global life support system permanent?***	
Concepts	**Formative Assessment**
• 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,	Students who understand the concepts are able to: • 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

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<td>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.</td>
<td>can be approached systematically based on consideration of trade-offs.
• 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.</td>
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<tr>
<td colspan="2">Suggested Learning Activities</td>
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<td colspan="2">• In this unit we turn our attention to how humans depend on the living world for resources and other benefits provided by biodiversity. Students must know that the sustainability of human societies and the biodiversity that supports them require responsible management of natural resources. Change and rates of change in biodiversity and environmental conditions should be quantified and modeled by students over short and long periods of time. Students should keep in mind that some system changes are irreversible. Deforestation of tropical rain forests and desertification of grasslands are examples of changes students might research. In their research, students should synthesize information from multiple sources and evaluate claims about the impacts of human activity on biodiversity based on analysis of evidence.
• Modern civilization depends on major technological systems. New technologies can have deep impacts on society and the environment, both anticipated and unanticipated. Examples of impacts include extinction of species and loss of habitat. These changes can lead to a decrease in biodiversity. To address these concepts, students should create a computational simulation or mathematical model illustrating the relationships among management of natural resources, the sustainability of human populations, and biodiversity. Simulations should model change and rates of change in those relationships. When possible, students should symbolically and quantitatively represent natural resource management, sustainability of human populations, and biodiversity. Students should also map relationships discovered, considering limitations on measurement when reporting quantities or data.
• Students will learn that natural and anthropogenic changes in the physical environment contribute to changes in biodiversity. Changes may include species expansion, invasive species, and extinction. Because humans depend on the living world for resources and other benefits provided by biodiversity, adverse human activities such as overpopulation, exploitation of resources, habitat destruction, pollution, introduction of invasive species, and human impact on climate change must be addressed. Students should understand that sustaining biodiversity is critical to maintaining functional ecosystems. Students might collect data on growth patterns (exponential, logistic) and carrying capacity using bacterial populations in a petri dish, status of local fish and mollusk populations in</td>
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Narragansett Bay, erosion of eel grass beds, or continued Quonset Point dredging. Data could also be collected on Asian Shore Crab infestation and competition with local crabs, or the negative effect of warming coastal estuary water temperature on flounder reproduction rates. Students could use data to make informed decisions about how environmental issues affect their communities politically, economically, and ecologically.

- Students should connect scientific knowledge to human endeavors, imagination, and creativity using conceptual simulations that illustrate relationships such as those between the management of natural resources in local New England fisheries or the lobster-harvesting industry, the needs of the human population, and the effect on marine diversity. Students can use data collected to model changes in marine animal populations to better understand the relationship between management of natural resources, biodiversity, and the sustainability of human populations. Students can also investigate and research major contributions of scientists and engineers who have developed technologies to produce less pollution and waste in order to prevent ecosystem degradation. Students should synthesize information from multiple sources to construct explanations and verify claims about how the environment and biodiversity change and stay the same when affected by human activity.
- In this unit, students are tasked with designing and evaluating a solution for a proposed problem related to threatened or endangered species or to genetic variation of organisms for multiple species. As they consider a design solution, they should know that technological advances by modern civilizations have solved, and sometimes caused, problems related to human interactions with the environment. This relationship could be studied by examining impacts of past technological advances such as electricity generation/distribution, antibiotic production, advanced farming practices, and damming of rivers. This may set the context for a discussion of limits of technological solutions. 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. Students may need to determine long- and short-terms goals of a potential solution, while considering that new technologies can have deep impacts on society and the environment, including some that were not anticipated. For instance, students might consider solutions that address the unanticipated negative impact wind farms have on birds, bats, and offshore fishing grounds.
- Students might use empirical evidence of decreasing bird populations to differentiate between specific causes and effects. Students could choose an adverse practice and research solutions to associated problems. They might consider wind turbines, deforestation, waste management, noise pollution, or automobile fuel (hydrogen, electricity, water). Solutions for minimizing adverse effects should account for a range of constraints such as cost, safety, reliability, and aesthetics, as well as social, cultural, and environmental impacts, since practical solutions are more likely to be implemented by society. Students can use physical models and computer simulations to aid in the engineering process, test potential solutions, and refine designs.
- As they work, project criteria should be broken down and approached systematically. By evaluating or refining a technological solution, such as alternative energy, that reduces impacts of humans on biodiversity, students should consider the cost, benefits, and risks of systems created by engineers. An example might be modeling a solution for addressing the melting of permafrost and the release of previously trapped methane. Students should analyze data for positive and negative feedback within natural systems to predict if there would be stabilization or destabilization of greenhouse gas concentrations. When evaluating solutions, students need to take into account a range of constraints, including costs, safety, and reliability, as well as social, cultural, and environmental impacts.

Integration of Engineering

- In this unit, there are two related performance expectations, HS-LS2-7 and HS-LS4-6, that each identify a connection to HS-ETS1-3. Students will be examining solutions for reducing or mitigating impacts of human activity on the environment and biodiversity. Because they are asked to design, evaluate, refine or revise, and finally test a solution, this unit has been identified as an opportunity for students to experience the complete engineering cycle. All HS-ETS1 performance expectations have been included here.

Suggested Activity Resources

- **Cost-Benefit Analysis Primer**: Students read this explanation about how cost-benefit analysis is derived and applied in order to apply this model to design solutions related to human sustainability. Students then read the application of CBA to water sanitation.
- **Carbon Stabilization Wedge:** Students play this game in order to evaluate competing design solutions for developing, managing, and utilizing energy resources based on cost-benefit ratios.
- **One For All: A Natural Resources Game:** Identify a strategy that would produce a sustainable use of resources in a

simulation game. Draw parallels between the chips used in the game and renewable resources upon which people depend. Draw parallels between the actions of participants in the game and the actions of people or governments in real-world situations.

- **Building Biodiversity** and the **PREDICTS project** and **GLOBIO project:** Students explore this website to develop an understanding of how computational models of the impacts on biodiversity are created. Next, they explore **Conservation Maps** for a global perspective of land use and conservation efforts.
- **Rainforest carbon cycling and biodiversity:** Students apply this model to simulate how atmospheric CO2 concentrations, which influence global climate, increase with
- **I=P*A*T Equation and Its Variants:** Students read this article to learn how ecological economics models are developed and applied to further understand human impacts on our environment.
- **National Climate Assessment:** Students explore the simulations found at this website in order to create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- **Stormwater Calculator** or the **Water Erosion Prediction Project:** Students apply the stormwater runoff calculator to determine the impacts of land use change, precipitation variations, and other parameters on runoff. Alternatively, **Catch It If You Can:** students are scaffolded through the process of calculating stormwater runoff by exploring and applying this case study.
- **The Bean Game: Exploring Human Interactions with Natural Resources:** This activity explores the various influences of human consumption of natural resources over time. (use this as a primer for making a computational model).
- **NSA Challenge: Recycling for a Cleaner World:** Students will develop a strategy to increase recycling and waste diversion for their school.
- **Land and People: Finding a Balance:** This environmental study project allows a group of students to consider real environmental dilemmas concerning water use and provide solutions to these dilemmas.
- **Reefs at Risk:** and **NOAA Coral Reefs at Risk:** Students access and explore a series of interactive maps displaying coral reef data from around the globe and develop hypotheses related to the impacts of climate change (i.e. increased levels of carbon dioxide in our atmosphere) on coral reef health.
- **GLOBE Carbon Cycle:** Students collect data about their school field site through existing GLOBE protocols of phenology, land cover and soils as well as through new protocols focused on biomass and carbon stocks in vegetation. Students participate in classroom activities to understand carbon cycling at local and global scales. Students expand their scientific thinking through the use of systems models.
- **Know Your Energy Costs:** The goal of this activity is to become aware of how much energy you use at school — and the financial and environmental costs.
- **Earth: Planet of Altered States:** Watch a segment of a NASA video and discuss how the earth is constantly changing.
- **Climate Reanalyzer:** Students use the Environmental Change Model of the Climate Reanlyzer to study the feedbacks in the climate system.

Performance Expectations

Science and Engineering Practices	DCI	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. **(HS-ESS3-6), (HS-LS4-6), (HS-LS4-7), (HS-ETS1-4)** **Asking Questions and Defining Problems** • Analyze complex real-world problems by specifying criteria and constraints for successful solutions. **(HS-ETS1-1)**	**ESS3.C: Human Impacts on Earth Systems** • The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. **(HS-ESS3-3)** **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** • 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	**Systems and System Models** • 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. **(HS-ETS1-4)** **Stability and Change** Feedback (negative or positive) can stabilize or destabilize a system. **(HS-ESS3-3),(HS-LS2-7), (HS-LS4-6)**

	and threaten the survival of some species**. (HS-LS2-7)** **<u>LS4.C: Adaptation</u>** • Changes in the physical environment, whether naturally occurring or human induced, have thus 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. (HS-LS4-6) **<u>LS4.D: Biodiversity and Humans</u>** • Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary to HS**-LS2-7)** • 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. (*secondary to* ***HS-LS2-7*****)** • Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (*secondary to* ***HS-LS2-7***) **<u>ETS1.B: Developing Possible Solutions</u>** • 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. (*secondary to* ***HS-LS4-6*****), (HS-ETS1-2**) • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test	

	different 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. (*secondary to* ***HS-LS4-6***),**(HS-ETS1-2)** **<u>ETS1.C: Optimizing the Design Solution</u>** • 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 (tradeoffs) may be needed. **(HS-ETS1-2)**	

Cross-Curricular Connections	
New Jersey Student Learning Standards for Language Arts Literacy	**New Jersey Student Learning Standards for Mathematics**
• Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **RST.11-12.7** (HS-LS2-7) • Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **RST.11-12.8** (HS-ETS1-3) • Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. **RST.11-12.9** (HS-ETS1-3). • Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. WHST.9-12.5 (HSLS4-6).	• Reason abstractly and quantitatively. **MP.2** (HS-LS2-7), (HS-ETS1-3) • Model with mathematics. **MP.4** (HS-ETS1-3) • Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. **HSN.Q.A.1** (HS-LS2-7) • Define appropriate quantities for the purpose of descriptive modeling. **HSN.Q.A.2** (HS-ETS1-3) • Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. **HSN.Q.A.3** (HS-ETS1-3)

21st Century Career Ready Practices
• **CRP1**. Act as a responsible and contributing citizen and employee. • **CRP2.** Apply appropriate academic and technical skills. • **CRP3.** Attend to personal health and financial well-being. • **CRP4.** Communicate clearly and effectively and with reason. • **CRP5.** Consider the environmental, social and economic impacts of decisions. • **CRP6.** Demonstrate creativity and innovation. • **CRP7.** Employ valid and reliable research strategies. • **CRP8.** Utilize critical thinking to make sense of problems and persevere in solving them. • **CRP9.** Model integrity, ethical leadership and effective management. • **CRP10.** Plan education and career paths aligned to personal goals. **CRP11.** Use technology to enhance productivity. **CRP12.** Work productively in teams while using cultural global competence.
Suggested Resources

Biology Honors

Unit 5	Instructional Days: 20

Unit Description
Students formulate an answer to the question "*How do the structures of organisms enable life's functions?" S*tudents 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. The crosscutting concepts of *structure and function*, *matter and energy*, and *systems and system models* are called out as organizing concepts for the disciplinary core ideas. Students use *critical reading*, *modeling*, and *conducting investigations*. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

New Jersey Student Learning Standards for Science/NGSS

Student Learning Objectives

LS1.A	Explain the connection between the sequence and the subcomponents of a biomolecule and its properties.
LS1-A	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.
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.
LS1.1	Construct models that explain the movement of molecules across membranes with membrane structure and function.
HS-LS1-2	Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
LS1.1	Provide examples and explain how organisms use feedback systems to maintain their internal environments.
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.

Enduring Understandings	Essential Questions
• Life and cells are composed of 4 major macromolecules, where there biochemical structure provides them with specific functions and abilities. • Students will understand the mechanisms behind cell transport and how cell organelles interact with one another. • Students will learn about the forefathers that discovered the first cells which helped shape the cell theory • Students will understand the importance of cell replication and the cell cycle • Students will investigate when the cell cycle becomes interrupted/stalled, the prerequisite of cancer	• How does the structure and composition of the 4 major macromolecules contribute to their function in living systems? • How does DNA code for life? • How do molecules move into and out of cells? • What are biological systems? How are they organized to bring order within living things? How do they maintain homeostasis?

Part A: *How does the structure of DNA determine the structure of proteins, and what is the function of proteins?*

Concepts	Formative Assessment
• 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.	*Students who understand the concepts are 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.
Part B: ***What do you mean they say that people are made of a system of systems?***	
Concepts	**Formative Assessment**
• 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.	*Students who understand the concepts are able to:* • 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.
Part C: ***How do feedback mechanisms maintain homeostasis?***	
Concepts	**Formative Assessment**
• 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.	*Students who understand the concepts are able to:* • 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.
Part D: What is the importance of division and differentiation of cells in producing and maintaining complex organisms*?*	
Concepts	**Formative Assessment**
• 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 who understand the concepts are able to:* • 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.

Suggested Learning Activities
• Students must learn that systems of specialized cells within organisms help the organisms perform the essential functions of life. All cells contain genetic information in the form of DNA molecules. Genes are regions of DNA that contain the instructions that code (transcription and translation) for the formation of proteins, which carry out most of the work of cells. Students should conduct a detailed examination of the structure and function of DNA by building a model of DNA to demonstrate their knowledge of Chargaff's Rule. Models can also be used to illustrate the processes of transcription and translation to clarify the function of DNA in terms of protein synthesis. Students should also draw and cite evidence from informational texts to support an explanation for how the structure of DNA determines the structure of proteins. • Multicellular organisms have a hierarchical structural organization in which one system is made of numerous parts and is itself a component of the next level. Models (e.g. physical, mathematical, and computer models) could be used by students to simulate systems and interactions. Students will create presentations, using digital media, to enhance their understanding of the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. • Students should develop an understanding of how systems of cells, tissues, and organs work together to meet the needs of the whole organism. Students should use models and oral presentations to simulate maintenance and development within complex organisms by mitosis and cell differentiation. For example, students might develop models of kidney function using dialysis tubing to illustrate the filtration of particular solutes. The same materials can be used to connect the specialized cells of the kidney to the rest of the organ, organ system, and organism in relation to excretion. Other system models that represent the hierarchical levels of organization that perform necessary life functions maintaining homeostasis could be used. Some examples include gas exchange, secretion, absorption, transport, and communication. • Students need an understanding of how external conditions affect the internal conditions of an organism. Feedback mechanisms maintain the internal conditions of living systems within a limited range, in part due to mediated behaviors such as basking, use of shade, mud baths, and burrowing. These feedback mechanisms can encourage or discourage physiological responses in living systems. Students can investigate sugar, oxygen, and temperature regulations, individually and collaboratively, to produce evidence that feedback mechanisms maintain homeostasis. Because feedback can stabilize or destabilize a system, the planning of investigations should address decisions about the type, quantity, accuracy, reliability, and limitations of the data. Design of investigations should be adjusted accordingly. In planning their investigations, students should conduct research and synthesize information from multiple reliable sources to support claims about how feedback mechanisms maintain homeostasis. • Students should investigate and model the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. In multicellular organisms, individual cells grow and then divide in the process called mitosis. At the earliest stage of life, a single cell, or zygote, divides successively to produce many cells (stem cells). These cells pass identical genetic material (two variants of each chromosome pair) in the form of homologous chromosome pairs to both daughter cells. Complex multicellular organisms maintain themselves by growing and developing through cellular divisions (mitosis) and differentiation of cells. Students should identify important quantities in the role of cellular division and differentiation and use mathematical models to illustrate how these processes produce and maintain complex organisms. Models might include data showing numbers of cells at different stages of development. Data could be collected from observing the different stages of mitosis using a microscope or virtual/computer simulation. Graphs and functions could be used to show growth rate in terms of cell division.
Suggested Activity Resources
• **Membrane Channels Simulation:** Students begin by asking questions that arise from demonstrations with aromatic sprays and they will articulate the movement of particles from areas of high concentrations to lower concentrations. The students will then ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. Students will develop, revise, and /or use a model based on evidence to illustrate and/or predict the relationship between systems or between components of a system using a computer simulation. Students will then communicate scientific and/or technical information or ideas in multiple formats (including orally, graphically, and textually). • **Membrane Diffusion:** Collaboratively, students will analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal design solution. Students can then work either collaboratively or independently to use mathematical, computational, and/or algorithmic representations of

phenomena or design solutions to describe and/or support claims and/or explanations.

Performance Expectations

Science and Engineering Practices	DCI	Crosscutting Concepts
Constructing Explanations and Designing Solutions • 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. **(HS-LS1-1)** **Developing and Using Models** • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. **(HS-LS1-2)** **Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. **(HS-LS1-3)**	**LS1.A: Structure and Function** • 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. **(HS-LS1-2)** • Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it 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. **(HS-LS1-3)** • Regions of DNA called genes determine the structure of proteins, which carry out the essential functions of life through systems of specialized cells. The sequence of genes contains instructions that code for proteins. **(LS1.A)** • Systems of specialized cells within organisms help them perform the essential functions of life. **(HS-LS1-1)** • Groups of specialized cells (tissues) use proteins to carry out functions that are essential to the organism. **(LS1.A)**	**Systems and System Models** • 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. **(HS-LS1-2)** **Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system. **(HS-LS1-3)**

Cross-Curricular Connections

New Jersey Student Learning Standards for Language Arts Literacy	New Jersey Student Learning Standards for Mathematics
• Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. **WHST.9-12.7** (HS-LS1-3) • Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and	**N/A**

overreliance on any one source and following a standard format for citation. **WHST.11-12.8** (HS-LS1-3) • Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. **SL.11-12.5** (HS-LS1-2)	

21st Century Career Ready Practices
• **CRP1**. Act as a responsible and contributing citizen and employee. • **CRP2.** Apply appropriate academic and technical skills. • **CRP3.** Attend to personal health and financial well-being. • **CRP4.** Communicate clearly and effectively and with reason. • **CRP5.** Consider the environmental, social and economic impacts of decisions. • **CRP6.** Demonstrate creativity and innovation. • **CRP7.** Employ valid and reliable research strategies. • **CRP8.** Utilize critical thinking to make sense of problems and persevere in solving them. • **CRP9.** Model integrity, ethical leadership and effective management. • **CRP10.** Plan education and career paths aligned to personal goals. **CRP11.** Use technology to enhance productivity. **CRP12.** Work productively in teams while using cultural global competence.
Suggested Resources

Biology Honors

Unit 6: Molecular Genetics/Inheritance	Instructional Days: 20

Description

Students analyze data develop models to make sense of the relationship between DNA and chromosomes in the process of cellular division, which passes traits from one generation to the next. Students determine why individuals of the same species vary in how they look, function, and behave. Students develop *conceptual models* of the role of DNA in the unity of life on Earth and *use statistical models* to explain the importance of variation within populations for the survival and evolution of species. Ethical issues related to genetic modification of organisms and the nature of science are described. Students explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expressions. The crosscutting concepts of *structure and function*, *patterns*, and *cause and effect* are used as organizing concepts for the disciplinary core ideas. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

New Jersey Student Learning Standards for Science/NGSS

Student Learning Objectives

HS-LS1-4	Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.
LS1.B	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.
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.
LS3.B	Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced.
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.
HS-LS3-3	Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Enduring Understandings	Essential Questions (3 or 4)
• Understand how DNA is copied. • Understand the impact of mutations on a cell(s) • Understand that there are different patterns of and • Understand how genetic syndromes/diseases are passed down, and have the ability to utilize tools to track such syndromes • Understand the effect the environment has on the expression of genetic traits	• What is the central dogma of DNA? • How can a mutation impact any portion of the central dogma? • What is the purpose of knowing there are many patterns of inheritance? • How are characteristics from one generation related to the previous generation? • What are the latest scientific techniques used in the field of genetics?

Part A: *What can't two roses ever be identical?*

Concepts	Formative Assessment
• 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.	*Students who understand the concepts are able 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.

• 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.	
Part B: ***How does inheritable genetic variation occur?***	
Concepts	**Formative Assessment**
• 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.	*Students who understand the concepts are able to:* • 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.
Part C: ***Can a zoologist predict the distribution of expressed traits in a population?***	
Concepts	**Formative Assessment**
• 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 who understand the concepts are able to:* • 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.
Suggested Learning Activities	
• In this unit, students should identify the terms genes, chromosomes, and histones to develop an understanding that genes are contain the instructions that code for the formation of proteins. In addition, students should know that each chromosome cor molecule, and that each gene on the chromosome is a particular segment of that DNA. • Students might demonstrate that all cells in an organism have the same genetic content by using paper models, manipulatives simulate DNA replication. Students could examine the concept that genes used (expressed) by the cell may be regulated in dif changes that occur during puberty, such as development of secondary sexual characteristics and the influence that hormones	

process. Focus should be on student questions that arise from examination of models.

- Students should synthesize information and cite specific evidence from texts, experiments, or simulations to gain a coherent u explanations about the relationship between the role of DNA and chromosomes in coding instructions for characteristic traits offspring. Students should also research and investigate types of DNA, including DNA that codes for proteins, hemoglobin, acti in regulatory or structural functions (cell membrane proteins, cyclins) and DNA that has no known function (introns).
- To understand environmental influence on gene expression, a study and evaluation of the Lac Operon will be used. Students s the relationship between the role of DNA and chromosomes in coding for characteristic traits passed from parent to offspring. research on examples of genetic engineering, such as post-HIV infection treatment using the genetically engineered CCR5delta about the role of DNA and chromosomes.
- New genetic combinations are the result of sexual reproduction, crossing over during meiosis, mutations due to errors in DNA influences. Students should make and defend claims, citing evidence from text, about how inheritable genetic variations may r combinations. Using data from these or other experiments, students can support arguments for the ways inheritable genetic v should make and defend claims about the ways variation occurs using this empirical evidence. Students must understand that tightly regulated, mutation can occur and can result in genetic variations.
- Environmental factors affect the expression of the inherited traits. To illustrate this, students might collect empirical data on p might then focus on the role that temperature plays in influencing coat color and density in response to cold and warm air. Ot temperature in gene expression might address the development of sexual organs among reptiles. Additional organisms, includ damselfish and some frog species, may illustrate how environmental triggers, such as gender density, can influence gene expre
- Students should be provided with the opportunity to determine the probability of occurrence of traits in a population using m these activities, students will observe and predict the variation and distributions of traits and connect their expression to both factors. In developing mathematical models to represent the variation and distribution of expressed traits, students should ma relationships in order to make predictions about the expression of traits. Punnett squares and Mendelian Genetics,
- The variation and distribution of traits depend on both genetic and environmental factors. Students should understand how en expression of traits and the probability of trait occurrences in populations. Data showing the relationship between environme of traits can be used to examine trait variation within a population. Students should be able make predictions as they relate to populations affected by both genetic and environmental factors. Punnett Squares, graphing, Chi square analysis, and Hardy W used to apply concepts of statistics and probability to gene expression and frequency. Algebraic thinking should be used to exa predict the distribution of traits in a population. Through the use of graphs, linear growth can be compared to exponential gro relate to traits within the population.
- Students should be aware that technology and science are related and that technological advances have influenced the progre influences advances in technology, such as in the development of gene therapies. Students should have an understanding of h influenced by society (e.g., need for cures for genetic diseases), and how society is influenced by science and technology (e.g., of genetically modified foods). Previously, students learned how environmental factors influence changes in population. They physical environment (whether naturally occurring or human induced) contribute to the expansion of some species. These con understanding in the current unit, because environmental factors and mutagens can cause mutations resulting in new genetic

Suggested Activity Resources

- **<u>Structure and Function: Stem Cell</u>**: Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
- **<u>DNA Transcription and Translation Simulation:</u>** Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- **<u>Growth and Development:</u>** Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- **<u>Mitosis</u>:** Develop and/or use a model to generate data to support explanations, predict phenomena, analyze systems, and/or problems.
- **<u>Embryonic Development</u>:** Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field with available resources and, when appropriate, frame a hypothesis based on a model or theory.
- **<u>Inheritance and Variation: Genetic Variation</u>:** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.
- **<u>Genetics</u>:** Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.

Performance Expectations

Science and Engineering Practices	DCI	Crosscutting Concepts

<u>Asking Questions and Defining Problems</u> • Ask questions that arise from examining models or a theory to clarify relationships. **(HS-LS3-1)** **<u>Constructing Explanations and Designing Solutions</u>** • 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. (**HS-LS1-1)** **<u>Engaging in Argument from Evidence</u>** • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence**. (HS-LS3-2)** • Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon. **(MS-LS1-3)** • Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. **(MS-LS1-4)**	**<u>LS1.A: Structure and Function</u>** • 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. (secondary to H**S-LS3-1)** **<u>LS3.A: Inheritance of Traits</u>** • 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 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 no as-yet known function. **(HS-LS3-1)** **<u>LS3.B: Variation of Traits</u>** • 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. **(HS-LS3-2)** • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. **(HS-LS3-2; HS-LS3-3)**	**<u>Cause and Effect</u>** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **(HSLS3-1; HSLS3-2)** **<u>Scale, Proportion, and Quantity</u>** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **(HS-LS3-3)**

Cross-Curricular Connections	
New Jersey Student Learning Standards for Language Arts Literacy	**New Jersey Student Learning Standards for Mathematics**

<table>
<tr><td>• Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. WHST.9-12.7 (HS-LS1-3)
• Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. WHST.11-12.8 (HS-LS1-3)
• Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. SL.11-12.5 (HS-LS1-2)</td><td>N/A</td></tr>
<tr><th colspan="2">21st Century Career Ready Practices</th></tr>
<tr><td colspan="2">• CRP1. Act as a responsible and contributing citizen and employee.
• CRP2. Apply appropriate academic and technical skills.
• CRP3. Attend to personal health and financial well-being.
• CRP4. Communicate clearly and effectively and with reason.
• CRP5. Consider the environmental, social and economic impacts of decisions.
• CRP6. Demonstrate creativity and innovation.
• CRP7. Employ valid and reliable research strategies.
• CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
• CRP9. Model integrity, ethical leadership and effective management.
• CRP10. Plan education and career paths aligned to personal goals.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.</td></tr>
<tr><th colspan="2">Suggested Resources</th></tr>
<tr><td colspan="2"></td></tr>
</table>

Biology Honors

Unit 7: Genetic Variation and Natural Selection — Instructional Days: 20

Description

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. The crosscutting concepts of *patterns* and *cause and effect* serve as organizing concepts for the disciplinary core ideas. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

New Jersey Student Learning Standards for Science/NGSS

Student Learning Objectives

LS4.C	Make predictions about the effects of artificial selection on the genetic makeup of a population over time.
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.

Enduring Understandings

- Understand why Darwin's theory set the foundation for the concept of evolution and why it is the most excepted by scientists today.
- Understand how traits can influence survival in a population.
- Understand that organisms must adapt to fit their environment, even when it changes.
- Understand that populations behave in a manner that allows for the best chances of survival.

Essential Questions (3 or 4)

- How can there be so many similarities among organisms yet so many different plants, animals, and microorganisms?
- How can specific traits make individuals of a populations more "fit" than others?
- How do changes in the environment lead to changes is populations?
- How does the behavior of a species contribute to its overall success in its ability to survive and reproduce?

Part A: *How does natural selection lead to adaptations of populations?*

Concepts

- 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.
- Empirical evidence is required to differentiate between cause and correlation and make claims about 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

Formative Assessment

Students who understand the concepts are 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), and 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 natural selection leads to adaptation of populations.
- Use data to differentiate between cause and correlation and to make claims about how specific biotic and abiotic differences in ecosystems contribute to change in gene frequency over time, leading to adaptation of populations.

natural laws operate today as they did in the past and will continue to do so in the future.	

Part B: ***Why is it so important to take all of the antibiotics in a prescription if I feel better?***

Concepts	Formative Assessment
• 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.	*Students who understand the concepts are able to:* • 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.

Part C: ***How are species affected by changing environmental conditions?***

Concepts	Formative Assessment
• 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.	*Students who understand the concepts are able to:* • 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.

Part D: Why do some species live in groups and others are solitary?

Concepts	Formative Assessment
• Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.	*Students who understand the concepts are able to:* • Evaluate the evidence for the role of group behavior on individual and species' chances to survive and

• 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.	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.

Suggested Learning Activities

- Students begin this unit by developing an understanding of the way natural selection leads to adaptation in a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. Empirical evidence (including students' own investigations, models, theories, simulations, peer review) should be used to differentiate between cause and correlation and to make claims about how natural selection leads to adaptation of populations. Students should make sense of quantities and relationships between specific biotic and abiotic differences in ecosystems and their contributions to a change in gene frequency over time that leads to adaptation of populations, paying attention to proportional increases in organisms with advantageous heritable traits.
- Students should use 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. To enhance understanding, students should examine scientific text and cite specific textual evidence to support analysis and explanations for how natural selection leads to change in populations over time. Students need to connect current learning to past events to enhance understanding that scientific knowledge is based on natural laws that operate today as they did in the past and will continue to do so in the future.
- Students will build on their knowledge of the factors that contribute to the variations of different traits within a population. Students should examine how individuals possessing certain forms of inherited traits may have a survival advantage over others in the population. Increased survival and reproductive success in these individuals can cause advantageous traits to become more common in the population. In other words, the population adapts to its environment. This process of change over time, as the environment "selects" for advantageous forms of heritable traits, is called natural selection. Many computer simulations are available that allow students to manipulate changes in the environment and observe how the population changes as individuals with advantageous traits survive and reproduce, while those lacking these traits die in greater numbers before reproducing. From experiments such as these, students can collect numerical data and observe that while the total number of individuals in the population may remain relatively constant, the traits represented in that population can change in response to environmental change. As an extension, students may apply the HWE theorem to analyze shifts in allele frequencies over several generations.
- Human influence can cause changes to the physical environment. Naturally occurring or human-induced behaviors can also contribute the expansion of some species such as zebra mussels, fire ants, or Africanized bees. Students might research migratory patterns of Africanized bees or West Nile virus using CDC data. They might also focus on how species decline and sometimes become extinct using data from research. Species extinction can also result from faster or drastic changes limiting the possibilities of species evolution. Students can investigate claims in order to support how environmental conditions may result in an increase in the number of species, emergence of new species over time, or in the extinction of other species.
- Students should determine the cause-and-effect relationships involved in how changes in the environment affect the distribution or disappearance of traits in a specific species. Addressing how changes to the environment affect the distribution or disappearance of traits in a species could be explained from a cause-and-effect perspective. Possible outcomes of human interactions include changes in the number of individuals of some species, emergence of new species over time, and the extinction of other species.
- Group behavior of organisms has evolved because membership can increase the chance of survival for individuals and

their genetic relatives. Students should collect empirical data that differentiates between cause and correlation relating to the survival rate of species and group behaviors. Students should develop logical and reasonable arguments to clarify the strength of the relationship and interactions between ideas and evidence that may be used to explain the role of group behavior on survival rate. Students might use models of schooling and flocking behavior of organisms as a role that increases species survival. Students might also consider the role of behaviors such as herding, cooperative hunting, migrating, and swarming. Individual and group survival behaviors can be studied to determine their survival advantages, (mimicry, camouflage, flocking, swarming, etc.) Evidence supporting the benefits of group behavior such as predation and life expectancy could be used to illustrate concepts.
Suggested Activity Resources
• **HHMI Pocket Mouse Evolution:** This activity serves as an extension to the HHMI short film *The Making of the Fittest: Natural Selection and Adaptation* and a means of reinforcing the concepts of variation and natural selection. Students explain how variation, selection, and time fuel the process of evolution by comparing, integrating, and evaluating sources of information presented in different media or formats. They analyze and organize data, comparing and contrasting various types of data sets (both self-generated and archival). • **Bunny Population Growth:** Students will develop and use models to simulate the growth of a rabbit population in order to support explanations about the role of limiting factors and variation in maintaining or destroying the population.

Performance Expectations

Science and Engineering Practices	DCI	Crosscutting Concepts
Analyzing and Interpreting Data • Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. **(HS-LS4-3)** • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. **(HS-LS4-3)** **Constructing Explanations and Designing Solutions** • 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. **(HS-LS4-4)** **Engaging in Argument from Evidence** • Evaluate the evidence behind currently accepted explanations	**LS1.A: Structure and Function** • 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. **(HS-LS1-2)** **LS4.B: Natural Selection** • 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. (HS-LS4-3) • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. **(HSLS4-3)** • Adaptation also means that the distribution of traits in a population can change when conditions change. **(HS-LS4-3)** **LS4.C: Adaptation** • 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	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **(HS-LS4-4)** **Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena**. (HS-LS4-3)**

or solutions to determine the merits of arguments. **(HS-LS4-5)**	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. **(HS-LS4-4)** **LS2.D: Social Interactions and Group Behavior** • Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. **(HSLS2-8)**	

Cross-Curricular Connections	
New Jersey Student Learning Standards for Language Arts Literacy	**New Jersey Student Learning Standards for Mathematics**
• Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. **WHST.9-12.7** (HS-LS4-5) • Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. **SL.11-12.5** (HS-LS1-2) • Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **RST.11-12.8** (HS-LS4-5) • Draw evidence from informational texts to support analysis, reflection, and research. **WHST.9-12.9** (HS-LS4-5) • Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem **RST.9-10.8**. (HS-LS2-8) • Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **RST.11-12.1** (HS-LS2-8) • Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **RST.11-12.7** (HS-	Reason abstractly and quantitatively. **MP.2** (HS-LS4-5)

LS2-8) • Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **RST.11-12.8** (HS-LS2-8)	

21st Century Career Ready Practices
• **CRP1**. Act as a responsible and contributing citizen and employee. • **CRP2.** Apply appropriate academic and technical skills. • **CRP3.** Attend to personal health and financial well-being. • **CRP4.** Communicate clearly and effectively and with reason. • **CRP5.** Consider the environmental, social and economic impacts of decisions. • **CRP6.** Demonstrate creativity and innovation. • **CRP7.** Employ valid and reliable research strategies. • **CRP8.** Utilize critical thinking to make sense of problems and persevere in solving them. • **CRP9.** Model integrity, ethical leadership and effective management. • **CRP10.** Plan education and career paths aligned to personal goals. **CRP11.** Use technology to enhance productivity. **CRP12.** Work productively in teams while using cultural global competence.
Suggested Resources

Biology Honors

Unit 8: Evidence for Evolution	Instructional Days: 20

Description

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. Students demonstrate an understanding of these concepts by *obtaining, evaluating, and communicating information* and *constructing explanations and designing solutions*. The crosscutting concepts of patterns and cause and effect support the development of a deeper understanding.

New Jersey Student Learning Standards for Science/NGSS

Student Learning Objectives

LS4.A	Examine a group of related organisms using a phylogenic 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.
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.

Enduring Understandings	Essential Questions (3 or 4)
• Understand how we can use anatomical and genomic information to map out how species are related to one another. • Understand that evolution is the result of 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	• How do we compare the evolutionary relationship between different species? • What evidence shows that different species are related? • What are the primary forces that drive organisms to evolve?

Part A: ***How can someone prove that birds and dinosaurs are related?***

Concepts	Formative Assessment
• 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	*Students who understand the concepts are able to:* • 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.

explanations of common ancestry and biological evolution.	

Part B: ***What is the relationship between natural selection and evolution?***

Concepts	Formative Assessment
• 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 who understand the concepts are 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) 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.

Suggested Learning Activities

- This unit develops an evidence-based model of evolution. Evolution is a theory substantiated by explanations of the natural world that are based on facts, observations, experiments, and evidence. The theory can be modified upon the discovery of new evidence validated by the scientific community. In this unit of study, students should communicate scientific information related to the evidence for evolution and evolutionary relationships between organisms. Students should analyze DNA sequences, amino acid sequences in proteins, and homologous structures in organisms using various models. Models might include illustrations of embryonic development, amino acid sequences, and cladograms. Students should be able to identify patterns in multiple lines of empirical evidence in order to develop an understanding of the role each line of evidence has in supporting common ancestry and biological evolution.
- Students will also need to construct and write explanations supported by evidence from text and build on previous experiences to promote a deeper understanding of natural selection. Natural selection posits there is variation among organisms within a population. The variation present in the genetic information generates the phenotypic differences potentially leading to varying performance among individuals as they compete for limited resources. Students should understand that 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 (Directional, Disruptive, Stabilizing).
- Students can construct explanations using quantitative models, such as histograms, that are based on valid and reliable evidence obtained from a variety of sources such as investigations, graphs, tables, and simulations. Students might demonstrate comprehension by drawing evidence from informational text describing common ancestry and biological evolution. Explanations should be supported by analysis, reflection, and research. Students could also

share this information with others by way of oral presentations, written reports, or technology-based presentations.

- Students might research the range of human birth weights illustrating stabilizing selection, in which individuals too small or too large are selected against. The use of antibiotics and pesticides also can be used to further understand directional selection for an extreme phenotype. The result of these investigations reinforces the concept that the natural world operates today as it has in the past and the future.
- Students will learn that within the process of evolution, there is a potential for species to increase in number. Mutation and sexual reproduction can generate genetic variation, and species compete for limited resources. These factors influence survivorship, reproduction, and the proliferation of species with adaptive phenotypes.
- Students can research the relationship between phenotypic variation and survivorship by studying beak size among the Galapagos Island finches, Coral and King snake mimicry.

Suggested Activity Resources

- **Evolution Webquest:** In this Evolution WebQuest, students investigate evidence for evolution. Teams are responsible for learning about fossil evidence, structural evidence, and genetic evidence for evolution and presenting this information to the class.
- **Lizard Evolution Virtual Lab:** In this Evolution WebQuest, students investigate evidence for evolution. Students compare the morphological characteristic of various lizard species.
- **Stickleback Evolution Virtual Lab:** In this Evolution WebQuest, students investigate evidence for evolution. Students use Chi-Square analysis to determine the evolution of populations

Performance Expectations

Science and Engineering Practices	DCI	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information • Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). **(HS-LS4-1)** **Constructing Explanations and Designing Solutions** • 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. **(HS-LS4-2)**	**LS4.A: Evidence of Common Ancestry and Diversity** • 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. **(HS-LS4-1)** **LS4.B: Natural Selection** • 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**. (HS-LS4-2)** **LS4.C: Adaptation** • 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	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **(HS-LS4-1)** **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **(HS-LS4-2)**

	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. **(HS-LS4-2)**	

Cross-Curricular Connections	
New Jersey Student Learning Standards for Language Arts Literacy	**New Jersey Student Learning Standards for Mathematics**
• Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **RST-11.12.1** (HS-LS4-1),(HS-LS4-2) • Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. **WHST.9-12.2** (HS-LS4-1),(HS-LS4-2) • Draw evidence from informational texts to support analysis, reflection, and research. **WHST.9-12.9** (HS-LS4-1),(HS-LS4-2) • Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. **SL.11-12.4** (HS-LS4-1),(HS-LS4-2)	• Reason abstractly and quantitatively. **MP.2** (HS-LS4-1),(HS-LS4-2) • Model with mathematics. **MP.4** (HS-LS4-2)

21st Century Career Ready Practices
• **CRP1**. Act as a responsible and contributing citizen and employee. • **CRP2.** Apply appropriate academic and technical skills. • **CRP3.** Attend to personal health and financial well-being. • **CRP4.** Communicate clearly and effectively and with reason. • **CRP5.** Consider the environmental, social and economic impacts of decisions. • **CRP6.** Demonstrate creativity and innovation. • **CRP7.** Employ valid and reliable research strategies. • **CRP8.** Utilize critical thinking to make sense of problems and persevere in solving them. • **CRP9.** Model integrity, ethical leadership and effective management. • **CRP10.** Plan education and career paths aligned to personal goals. **CRP11.** Use technology to enhance productivity. **CRP12.** Work productively in teams while using cultural global competence.
Suggested Resources