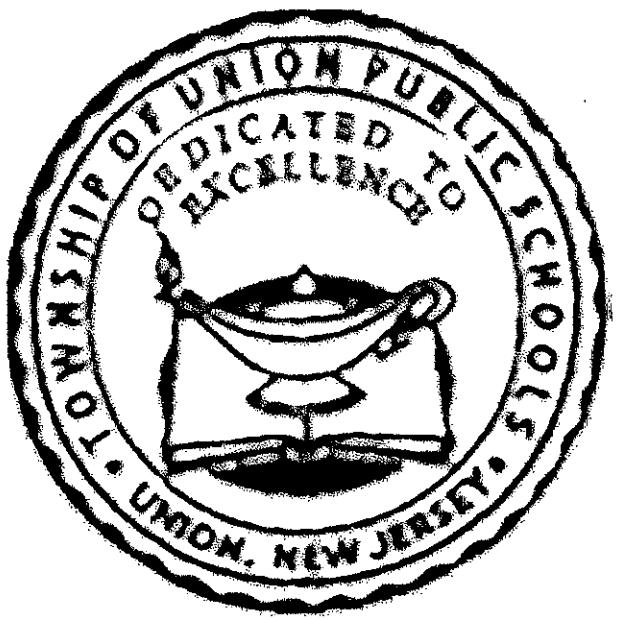
TOWNSHIP OF UNION PUBLIC SCHOOLS



SC 211 Honors Biology

Curriculum Guide 2016

Curriculum Committee

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Academic Area

Honors Biology

References

The following curriculum guide was adapted from the Next Generation Science Standards and the State of New Jersey Department of Education High School Biology Model Curriculum.

"Model Curriculum: HS Biology." *Model Curriculum: HS Biology*. State of New Jersey. 2014. Web. 22 Apr. 2016.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press. Web. 22 Apr. 2016.

Curriculum Unit Overview

Unit 1- Interdependent Relationships in Ecosystems & Population Dynamics

Unit 2- Structure & Function

Unit 3- Matter and Energy in Organisms and Ecosystems

Unit 4- Inheritance and Variation of Traits

Unit 5- Natural Selection and Mechanisms of Evolution

Unit 6- Evidence of Evolution, Relationships and Common Ancestry

Curriculum Pacing Guide – Honors Biology

Unit Name	Estimated Number of Days
Unit 1- Interdependent Relationships in Ecosystems & Population Dynamics	30
Unit 2- Structure & Function	30
Unit 3- Matter and Energy in Organisms and Ecosystems	30
Unit 4- Inheritance and Variation of Traits	45
Unit 5- Natural Selection and Mechanisms of Evolution	20
Unit 6- Evidence of Evolution, Relationships and Common Ancestry	25

Honors Biology Course Description

The Honors Biology course is specifically designed for the student who has demonstrated exceptional ability in the sciences. The course challenges the student with a rigorous, in-depth study of Biology, stressing higher-level learning skills and critical thinking. Emphasis is on developing skills such as: designing experiments and investigative procedures, hypothesizing, observing, interpreting, data analysis, graphing, and inferring. Extensive open-ended laboratory and computer-based investigations are utilized, to foster inquiry and discovery skills.

Course Proficiencies

For all units, students will understand and follow all laboratory and safety rules, understand scientific explanations, generate scientific evidence through active investigations, reflect on scientific knowledge and participate productively in science.

The honors biology student will explore the following unit topics that are aligned with the NGSS Disciplinary Core Ideas/ NJ Biology Model Curriculum Standards:

Unit 1- Interdependent Relationships in Ecosystems & Population Dynamics

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. Additionally, 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. 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.

Unit 2- Structure & Function

Students formulate an answer to the question "*How do the structures of organisms enable life's functions?*" Students 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.

Unit 3- Matter and Energy in Organisms and Ecosystems

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.

Unit 4- Inheritance and Variation of Traits

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.

Unit 5- Natural Selection and Mechanisms of Evolution

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 a organizing concepts for the disciplinary core ideas. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

Unit 6- Evidence of Evolution, Relationships and Common Ancestry

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.

Unit 1 Summary

Interdependent Relationships in Ecosystems & Population Dynamics

How do organisms interact with the living and nonliving environments to obtain matter and energy?

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.

Student Learning Objectives

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. LS2.A

Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. *[Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.]* (HS-LS2-1)

Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. *[Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]* (HS-LS2-2)

Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. *[Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.]* (HS-LS2-6)

Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. *[Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]* (HS-LS2-7)

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.[Clarification Statement: Emphasis is on: (1)

distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming. (HS-LS2-8)

Unit Sequence

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

Concepts	Formative Assessment
• Ecosystems have carrying capacities, which are limits to the number of organisms and populations they can support. • These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, completion, and disease. • Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (the number of individuals) of species in any given ecosystem. • The significance of carrying capacity in ecosystems is dependent on the scale proportion and quantity at which it occurs. • Quantitative analysis can be used to compare and determine relationships among interdependent factors that affect the carrying capacity of ecosystems at different scales.	*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. • Use quantitative analysis to compare relationships among interdependent factors and represent their effects on the carrying capacity of ecosystems at different scales.

Unit Sequence

Part B: *What limits the number and types of different organisms that live in one place?*

Concepts	Formative Assessment
• 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	*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.

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.

Unit Sequence

Part C: *How can a one or two inch rise in sea level devastate an ecosystem?*

Concepts	**Formative Assessment**
• Much of science deals with constructing explanations of how things change and how they remain stable. • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. • If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem) as opposed to becoming a very different ecosystem. • Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.	*Students 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. • Construct explanations of how modest biological or physical changes versus extreme changes affect stability and change in ecosystems.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts supporting explanations of factors that affect carrying capacity of ecosystems at

different scales, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

- Develop and write explanations of factors that affect carrying capacity of ecosystems at different scales by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
- Cite specific textual evidence to support how factors affect biodiversity and populations in ecosystems of different scale, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write explanatory texts based on scientific procedures/experiments to explain how different factors affect biodiversity and populations in ecosystems at different scales.
- Assess the extent to which the claim 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, is supported by reasoning and evidence.
- Cite specific textual evidence to support claims 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, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address claims 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.
- Evaluate the validity of evidence and reasoning that support claims 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, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Mathematics

- Represent the factors that affect carrying capacity of ecosystems at different scales symbolically and manipulate the representing symbols. Make sense of quantities and relationships between different factors that affect carrying capacity of ecosystems at different scales.
- Use a mathematical model to describe factors that affect carrying capacity of ecosystems at different scales. Identify important quantities in factors that affect carrying capacity of ecosystems at different scales and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand how factors affect the carrying capacity of ecosystems at different scales. Choose and interpret units consistently in formulas to determine carrying capacity. Choose and interpret the scale and origin in graphs and data displays showing factors that affect carrying capacity of ecosystems at different scales.
- Define appropriate quantities for the purpose of descriptive modeling of factors that affect carrying capacity of ecosystems at different scales.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing factors that affect carrying capacity of ecosystems at different scales.
- Represent the factors that affect biodiversity and populations in ecosystems symbolically and manipulate the representing symbols. Make sense of quantities and relationships between different factors and their effects on biodiversity and populations in ecosystems.
- Use a mathematical model to describe the factors that affect biodiversity and populations in ecosystems. Identify important quantities in factors that affect biodiversity and populations in ecosystems and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting

on the results and improving the model if it has not served its purpose.

- Use units as a way to understand factors that affect biodiversity and populations in ecosystems.
- Choose and interpret units consistently in formulas to determine effects on biodiversity and populations in ecosystems. Choose and interpret the scale and the origin in graphs and data displays representing the factors that affect biodiversity and populations in ecosystems.
- Define appropriate quantities for the purpose of descriptive modeling of the factors that affect biodiversity and populations in ecosystems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the factors that affect biodiversity and populations in ecosystems.
- Represent claims 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 symbolically and manipulate the representing symbols. Make sense of quantities and relationships between complex interactions in ecosystems and ways in which ecosystems remain stable and ways in which they change.
- Represent data relating to complex interactions in ecosystems and their effects on stability and change in ecosystems with plots on the real number line (graph).
- Understand statistics as a process for making inferences about complex interactions in ecosystems and organism population parameters based on a random sample from that population.
- Evaluate reports of complex interactions and their effects on stability and change in ecosystems based on data showing numbers and types of organisms in stable conditions and in changing conditions.

Suggested Learning Activities

Predator/Prey Relationships: Students will construct and interpret graphs to correlate relationships between population sizes of predator and prey.

Infectious Disease Lab: Students will model spread of disease (density dependent factor) and the exponential growth of bacterial populations.

Human Population Age Structure Study: Students will compare age structure histograms to predict future trends for developing and developed countries.

Live and Let Live Group Project: Students will work in cooperative learning groups to develop a plan to accommodate an increase in human population while having a minimal impact on surrounding ecosystem.

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).

World In Balance Film: Students will view film that reviews age structure trends within various countries.

Population Growth – Exponential and Logistic Models vs. Complex Realities: This analysis and discussion activity is designed to help students develop a solid understanding of the exponential and logistic models of population growth, including the biological processes that result in exponential or logistic population growth. Students learn about the simplifying assumptions built into the exponential and logistic models and explore how deviations from these assumptions can result in

discrepancies between the predictions of these models and the actual trends in population size for natural populations.

Changing Biological Communities – Disturbance and Succession: Students use their understanding of the processes involved in succession to construct and evaluate models of succession in abandoned farm fields. Students also analyze the effects on succession of climate and non-native invasive plants.

Bye Bye Birdie: Students will develop criteria that ecologists, wildlife managers, and public officials might use to make decisions about protecting endangered species, conduct research on an endangered species through the Internet and other sources, and then present their findings, showing how their species measures up against the chosen decision criteria.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. *[Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.]* (HS-LS2-1)

Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. *[Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]* (HS-LS2-2)

Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. *[Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.]* (HS-LS2-6)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	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	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	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

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)	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 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)	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)

Unit 2 Summary
Structure and Function

How do the structures of organisms enable life's functions?

Students formulate an answer to the question *"How do the structures of organisms enable life's functions?"* Students 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.

Student Learning Objectives

Explain the connection between the sequence and the subcomponents of a biomolecule and its properties. *[Clarification Statement: Emphasis is on the general structural properties that define molecules. Examples include r-groups of amino acids, protein shapes, the nucleotide monomers of DNA and RNA, hydrophilic and hydrophobic regions.] [Assessment Boundary: Assessment does not include identification or the molecular sequence and structure of specific molecules]* (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. (LS1.A)

Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. *[Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]* **(HS-LS1-1)**

Construct models that explain the movement of molecules across membranes with membrane structure and function. *[Clarification Statement: Emphasis is on the structure of cell membranes, which results in selective permeability; the movement of molecules across them via osmosis, diffusion and active transport maintains dynamic homeostasis.]* (LS1.A)

Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. *[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]* **(HS-LS1-2)**

Provide examples and explain how organisms use feedback systems to maintain their internal environments. (LS1.A)

Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. *[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]* **(HS-LS1-3)**

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. *[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]* **(HS-LS1-4)**

Unit Sequence	
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.

Unit Sequence	
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.

Unit Sequence
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.

Unit Sequence

Part D: *Why aren't all elephants the same size?*

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.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Write an explanation that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Draw evidence from informational texts to support how the structure of DNA determines the structure of proteins, which carry out the essential functions of life

through systems of specialized cells.

- Make strategic use of digital media in presentations to enhance understanding of the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- Conduct short as well as more sustained research to determine how feedback mechanisms maintain homeostasis. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- Gather applicable information from multiple reliable sources to support claims that feedback mechanisms maintain homeostasis. Use 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.
- Make strategic use of digital media in presentations to enhance understanding of the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Mathematics

- Use a mathematical model to illustrate the role of cellular division and differentiation in producing and maintaining complex organisms. Identify important quantities in the role of cellular division and differentiation in producing and maintaining complex organisms and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Graph functions expressed symbolically showing the role of cellular division and differentiation in producing and maintaining complex organisms and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
- Write a function that describes a relationship between the role of cellular division and differentiation and the production and maintenance of complex organisms.

Suggested Learning Activities

Building Macromolecules from Monomers: Students will combine paper models of monomers for various macromolecules using knowledge of dehydration synthesis to create macromolecules.

Understanding the Functions of Proteins and DNA: Students learn about the functions of proteins and how different versions of a protein can result in a characteristic such as albinism or sickle cell anemia.

Model of phospholipid bilayer: Students will recognize structural components of fluid mosaic model.

Introduction to Osmosis- **Osmosis Egg Demonstration:** Students will predict cell response to a change in osmotic conditions.

Osmosis in Onion Cell Lab: Students will utilize microscope techniques to observe cell structures that regulate osmotic pressure to maintain homeostasis.

Design your own dialysis diffusion lab?/ **Diffusion Across a Selectively Permeable Membrane:** Students will design their own investigation using dialysis tubing, sugar and starch solutions to predict and observe the diffusion of water and other substances through the a selectively permeable membrane.

Osmosis & Diffusion "In and Out of Cells" Web quest: Students will use internet simulations to study active and passive transport.

Modeling endocytosis and exocytosis: Students will investigate the types of active transport in cells.

Enzyme Liver Lab (Chemical Reactions and Catalysts in Living Organisms): Students will observe the impact of temperature and pH on enzyme activity via. analysis

of data.

Enzymes Help Us Digest Food: Students also analyze how lactase functions in the digestive system and how the digestive and circulatory systems cooperate to provide cells all over the body with molecules that provide the energy for cellular processes

Structure and Function of Molecules and Cells: Students analyze multiple examples of the relationship between structure and function in diverse proteins and eukaryotic cells. In addition, students learn that cells are dynamic structures with constant activity, students learn about emergent properties, and students engage in argument from evidence to evaluate three alternative claims concerning the relationship between structure and function.

Amylase cracker demonstration: Students will use sense of taste in recognizing specificity of digestive enzymes in the body.

Murder Food Lab (macromolecule identification): Students will apply various chemical tests to determine presence or absence of macromolecules of unknown sample.

Cell Cycle and Mitosis Internet Activity: Students will use an online web quest to identify stages of the cell cycle

Ideal Cell Size Lab Investigation: Students will use potato cubes to predict the rate of diffusion for a small and large cell. Students will measure the depth and rate of diffusion for a small and large cell (potato cube)

Mitosis vs. Meiosis Pipe Cleaner Modeling Activity: Students will use pipe cleaner chromosomes to model the processes of mitosis and meiosis

Structure and Function of Cells, Organs and Organ Systems: Students analyze multiple examples of the relationship between structure and function in diverse eukaryotic cells and in the digestive system. In addition, students learn that cells are dynamic structures with constant activity and they learn how body systems interact to accomplish important functions.

Mitosis – How Each New Cell Gets a Complete Set of Genes: students learn about the basic process of mitosis and use model chromosomes to simulate mitosis. Throughout, students respond to analysis and discussion questions to further develop their understanding of mitosis.

Homeostasis and Negative Feedback – Concepts and Breathing Experiments: Students carry out and analyze an experiment which investigates how rate and depth of breathing are affected by negative feedback regulation of blood levels of CO_2 and O_2. Finally, students formulate a question concerning effects of exercise on breathing, design and carry out a relevant experiment, analyze and interpret their data, and relate their results to homeostasis during exercise

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab

performance and analysis, Classwork & Homework reinforcement techniques, Discussion
Appendix A: NGSS and Foundations for the Unit
Explain the connection between the sequence and the subcomponents of a biomolecule and its properties. *[Clarification Statement: Emphasis is on the general structural properties that define molecules. Examples include r-groups of amino acids, protein shapes, the nucleotide monomers of DNA and RNA, hydrophilic and hydrophobic regions.] [Assessment Boundary: Assessment does not include identification or the molecular sequence and structure of specific molecules]* (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. (LS1.A)
Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. *[Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]* **(HS-LS1-1)**
Construct models that explain the movement of molecules across membranes with membrane structure and function. *[Clarification Statement: Emphasis is on the structure of cell membranes, which results in selective permeability; the movement of molecules across them via osmosis, diffusion and active transport maintains dynamic homeostasis.]* (LS1.A)
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. *[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]* **(HS-LS1-2)**
Provide examples and explain how organisms use feedback systems to maintain their internal environments. (LS1.A)
Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. *[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]* **(HS-LS1-3)**
Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. *[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]* **(HS-LS1-4)**

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices	Disciplinary Core Ideas	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)

Unit 3 Summary
Matter and Energy in Organisms and Ecosystems

How do matter and energy cycle through ecosystems?

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.

This unit is based on HS-LS1-5, HS-LS2-3, HS-LS2-4, and HS-LS2-5.

Student Learning Objectives

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.]* [Assessment Boundary: Assessment does not include specific biochemical steps.] **(HS-LS1-5)**

Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. *[Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.] [Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]* **(HS-LS2-3)**

Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. *[Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.]* **(HS-LS2-4)**

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. *[Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]* **(HS-LS2-5)**

Unit Sequence

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

Concepts	Formative Assessment
• 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)	*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

provide most of the energy for life processes.	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.

Unit Sequence

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

Concepts	**Formative Assessment**
• Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. • At each link in an ecosystem, matter and energy are conserved. • Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level. • Given this inefficiency, there are generally fewer organisms at higher levels of a food web. • Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. • The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways.	*Students who understand the concepts are able to:* • 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.

Unit Sequence

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,	*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

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.	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.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Develop and write an explanation, based on evidence, for the cycling of matter and flow of energy in aerobic and anaerobic conditions by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples.
- Develop and strengthen an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

Mathematics

- Represent the cycling of matter and flow of energy among organisms in an ecosystem symbolically and manipulate the representing symbols. Make sense of quantities of and relationships between matter and energy as they cycle and flow through an ecosystem.
- Use a mathematical model to describe the cycling of matter and flow of energy among organisms in an ecosystem. Identify important quantities in the cycling of matter and flow of energy among organisms in an ecosystem and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the cycling of matter and flow of energy among organisms in an ecosystem. Choose and interpret units consistently in formulas to determine the cycling of matter and flow of energy among organisms in an ecosystem. Choose and interpret the scale and the origin in graphs and data displays representing the cycling of matter and flow of energy among organisms in an ecosystem.
- Define appropriate quantities to represent matter and energy for the purpose of descriptive modeling of their cycling and flow among organisms in ecosystems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing matter cycles and energy flows among organisms in ecosystems.

Suggested Learning Activities

Experiments in Photosynthesis Film: Students will make predictions on plant response to various conditions pertaining to the reactants and products of photosynthesis.

Photosynthesis Web- Quest: Students will utilize internet resources to observe and make predictions on factors that affect the process of photosynthesis including light intensity, water availability and gas exchange.

Photosynthesis Modeling Activity: Students learn the chemical formula for photosynthesis by acting out plant's photosynthetic process including photosystem 2,

photosystem 1, and the Calvin cycle. Great visual and kinesthetic activity.

Where does a plant's mass come from? This analysis and discussion activity helps students to understand that a large part of a plant's mass consists of water, most of the biomass comes from carbon dioxide, and minerals from the soil contribute only a tiny amount of the plant's mass. For example, students engage in analyzing and interpreting data and arguing from evidence.

Plant Growth Puzzle: This analysis and discussion activity presents a structured sequence of questions to challenge students to explain why a plant that sprouts and grows in the light has a greater biomass than the seed it came from, whereas a plant that sprouts and grows in the dark has less biomass than the seed it came from.

Build a Paper Ecosystem: Using biotic and abiotic factors, students will build a food web and energy pyramid using examples of producers, consumers, and decomposers.

Surviving Winter in the Dust Bowl (Food Chains and Trophic Levels): 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.

How does Energy Flow Through an Ecosystem? Virtual lab: Model Ecosystems: **Students** will model the transfer of energy up a food chain via online simulation.

Link: http://www.mhhe.com/biosci/genbio/virtual_labs/BL_02/BL_02.html

Food Webs, Energy Flow, Carbon Cycles and Trophic Pyramids: Students construct a food web for Yellowstone National Park, including producers, primary consumers, secondary consumers, decomposers, and trophic omnivores. Then, students analyze a trophic cascade that resulted when wolves were re-introduced to Yellowstone.

Cellular Respiration Activity: Students will model the biochemistry behind cellular respiration by acting out the steps of cellular respiration.

Exercise & Cellular Respiration Lab: Students will compare rate of aerobic cellular respiration before and after physical activity to confirm the production of CO_2 during aerobic respiration.

Lactic Acid Fermentation in Human Muscle Cells Investigation: Students will investigate the relationship between aerobic respiration, anaerobic respiration and muscle fatigue in living organisms.

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.

How do Biological Organisms Use Energy? This analysis and discussion activity helps students understand the basic principles of how biological organisms use energy, with a focus on the roles of ATP and cellular respiration. In addition, students apply the principles of conservation of energy and conservation of matter to

avoid common errors and correct common misconceptions.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.]* [Assessment Boundary: Assessment does not include specific biochemical steps.] **(HS-LS1-5)**

Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. *[Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.] [Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]* **(HS-LS2-3)**

Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. *[Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.]* **(HS-LS2-4)**

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. *[Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]* **(HS-LS2-5)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	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 review) and the assumption that theories and laws that describe the natural world operate today	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) LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	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 systems. (HS-LS2-3)

as they did in the past and will continue to do so in the future. (HS-LS2-3) **Using Mathematics and Computational Thinking** • Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4) **Developing and Using Models** • Develop a model based on evidence to illustrate the relationships between systems or components of a system. (HS-LS1-5),(HS-LS2-5)	• 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)	• 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) **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-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)

Unit 4 Summary
Inheritance and Variation of Traits

How are characteristics from one generation related to the previous generation?

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.

Student Learning Objectives

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. *[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]* (HS-LS1-4)

Explain *how* the process of meiosis results in the passage of traits from parent to offspring, and how that results in increased genetic diversity necessary for evolution. *[Clarification Statement: The emphasis is on how meiosis results in genetic diversity, not the rote memorization of the steps of meiosis.]* (LS1.B)

Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. *[Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]* (HS-LS3-1)

Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. (LS3.B)

Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. *[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]* (HS-LS3-2)

Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. *[Clarification Statement: Emphasis on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]* (HS-LS3-3)

Unit Sequence

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

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

Unit Sequence

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	*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.

from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.	

Unit Sequence

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.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, resolving conflicting information when possible.
- Cite specific textual evidence to support analysis of science and technical texts describing the ways that inheritable genetic variation occurs, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write arguments, 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.

Mathematics

- Represent symbolically 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, and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict the ways in which inheritable genetic variation occurs.
- Represent the variation and distribution of expressed traits in a population symbolically and manipulate the representing symbols. Make sense of quantities and

relationships to describe and predict the variation and distribution of expressed traits in a population.

Suggested Learning Resources

Structure and Function: Stem Cell: 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.

DNA Structure, Function and Replication: To introduce students to key concepts about the structure, function and replication of DNA or to review these topics. This activity includes hands-on modeling of DNA replication.

Modeling DNA Replication, Transcription and Translation Activities: Model the process of protein synthesis utilizing the genetic codon chart to show how DNA determines the structure of proteins which determine physical characteristics in organisms.

From Gene to Protein – Transcription and Translation: Students also analyze how lactase functions in the digestive system and how the digestive and circulatory systems cooperate to provide cells all over the body with molecules that provide the energy for cellular processes

DNA Mutations and Consequences Activity: Students will witness the change a single point mutation in the DNA can have on a resulting protein.

DNA Extraction Lab: Through active investigation of extraction human cheek cells, students will understand the technique and applications of DNA extraction.

Determining Structure of DNA Investigation: Students will analyze given set of data to construct an argument about the molecular structure of DNA. Students will compare synthesized models to determine the validity of their argument.

Karyotype & Pedigree STEM project: Students will explore, explain, elaborate and evaluate karyotypes and pedigrees of human chromosomal disorder case studies.

Probability Lab: Students will be introduced to concepts of probability and inheritance by applying concepts of statistics to bead models.

Genetics Activity: Students will complete a coin toss genetics activity and an analysis of student data on the sex makeup of sibships, both of which help students understand the probabilistic nature of inheritance and Punnett square predictions

Soap Opera Genetics – Genetics to Resolve Family Arguments: Students explain the relevant biology to answer the probing questions of a skeptical father who wants to know how his baby could be albino when neither he nor his wife are albino. Students also analyze sex-linked inheritance.

Genetic Engineering Challenge - How can scientists develop a type of Rice that could prevent vitamin A deficiency? To challenge students to design a basic plan that could produce a genetically engineered rice plant that makes rice grains that contain pro-vitamin A

Investigating Corn Genetics: Students will collect and analyze data of corn kernel population and apply test cross methods in determining genotypes of P generation. Students will additionally complete a test cross based on two-trait (dihybrid) corn kernel analysis.

Using Blood Tests to Identify Babies and Criminals: Students will use knowledge of non-mendelian genetics and multiple alleles to determine identities of unknown individuals.

Meiosis and Fertilization – Understanding How Genes Are Inherited: Students use model chromosomes to simulate the processes of meiosis and fertilization. As they model meiosis and fertilization, students follow the alleles of three human genes from the parents' body cells through gametes to zygotes.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. [*Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.*] **(HS-LS1-4)**

Explain *how* the process of meiosis results in the passage of traits from parent to offspring, and how that results in increased genetic diversity necessary for evolution. [*Clarification Statement: The emphasis is on how meiosis results in genetic diversity, not the rote memorization of the steps of meiosis.*](LS1.B)

Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*] **(HS-LS3-1)**

Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. (LS3.B)

Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. *[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]* **(HS-LS3-2)**

Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. *[Clarification Statement: Emphasis on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]* **(HS-LS3-3)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems • Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1) **Constructing Explanations and Designing Solutions**	**LS1.A: Structure and Function** • 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 HS-LS3-1)	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HSLS3-1; HSLS3-2)

• 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) **Engaging in Argument from Evidence** • 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)	**LS3.A: Inheritance of Traits** • 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) **LS3.B: Variation of Traits** • 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)	**Scale, Proportion, and Quantity** • 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)

Unit 5 Summary

Natural Selection and Mechanisms of Evolution

How can there be so many similarities among organisms yet so many different plants, animals, and microorganisms?

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.

This unit is based on Disciplinary Core Idea LS4.C (Adaptation), HS-LS4-4, HS-LS4-3, HS-LS4-5, and HS-LS2-8.

Student Learning Objectives

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

Construct an explanation based on evidence for how natural selection leads to adaptation of populations. *[Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]* **(HS-LS4-4)**

Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. *[Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]* **(HS-LS4-3)**

Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. *[Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]* **(HS-LS4-5)**

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. *[Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]* **(HS-LS2-8)**

Unit Sequence

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

Concepts	Formative Assessment
• Natural selection leads to adaptation, that is, to a population dominated by	*Students who understand the concepts are able to:*

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

Unit Sequence

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	*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.

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.	

Unit Sequence

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.

Unit Sequence

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. • Empirical evidence is required to differentiate between cause and correlation and to make claims about the role of group behavior in individual and species' chances to survive and reproduce. • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in the revision of an explanation about the role of group behavior on individual and species' chances to survive and reproduce.	*Students who understand the concepts are able to:* • Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. • Distinguish between group and individual behavior. • Identify evidence supporting the outcome of group behavior. • Develop logical and reasonable arguments based on evidence to evaluate the role of group behavior on individual and species' chances to survive and reproduce. • Use empirical evidence to differentiate between cause and correlation and to make claims about the role of group behavior on individual and species'

	chances to survive and reproduce.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing how natural selection leads to adaptation of populations, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write informative/explanatory texts describing how natural selection leads to adaptation of populations, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Draw evidence from informational texts to support analysis, reflection, and research about how natural selection leads to adaptation of populations.
- Cite specific textual evidence to support analysis of science and technical texts that provide explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write informative/explanatory texts about explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Draw evidence from information texts to support analysis, reflection, and research about organisms with an advantageous heritable trait and their proportional increase as compared to organisms lacking this trait.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text 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, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- Draw evidence from information texts making 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 to support analysis, reflection, and research.
- Assess the extent to which the reasoning and evidence in a text support the author's claim about the role of group behavior on individual and species' chances to survive and reproduce.
- Cite specific textual evidence to support analysis of science and technical texts about the role of group behavior on individual and species' chances to survive and reproduce.
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address the role of group behavior on individual and species' chances to survive and reproduce.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text about the role of group behavior on individual and species' chances to survive and reproduce, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Mathematics

- Represent how natural selection leads to adaptation of populations symbolically, and manipulate the representing symbols. 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.

- Represent symbolically the proportional increase in organisms with an advantageous heritable trait as compared with organisms lacking this trait, and manipulate the representing symbols. Make sense of quantities and relationships between the proportional increase in organisms with an advantageous heritable trait as compared with the numbers of organisms lacking this trait.

Suggested Learning Activities

Peppered Moth Evolution: Students explain how variation, selection, and time drive the process of evolution by collecting and analyzing data within peppered moth population. Students will construct graphical representations to visualize trend of change over time within population of moths.

Evolution by Natural Selection: Students develop their understanding of natural selection by analyzing specific examples and carrying out a simulation

Using Molecular and Evolutionary Biology to Understand HIV/AIDS and Treatment: To challenge students to apply their understanding of basic molecular and cellular biology and natural selection and interpret information presented in prose and diagrams in order to understand multiple aspects of the biology of HIV/AIDS and treatment.

Evolution and Adaptations Lesson: Students will analyze how the balance between the advantages and disadvantages of a characteristic (e.g. an animal's color) can vary in different circumstances, how phenotypic plasticity can be a heritable trait that can optimize fitness in a variable environment, and how natural selection can influence the amount of phenotypic plasticity in a population. This activity is designed to help high school students meet the Next Generation Science Standards and the Common

The Ecology of Lyme Disease: Students will analyze when and where human risk of Lyme disease is greatest, why rates of Lyme disease have increased in recent decades in the US, and ecological approaches to preventing Lyme disease.

Desert Snakes (Mechanics of Evolution): Students will generate argument using multiple lines of evidence presented via. text, data tables and photos to defend claim about physical similarities between snakes. Students will present and justify their claim to classmates.

Monstrous Mutation Lab: Students will simulate how mutations in DNA impact the fitness of an organism due to natural selection.

Modeling the Process of Natural Selection: Class will act as a varied population of living organisms that over time will change due to external and internal factors.

Genetic Drift Activity: Students will analyze shifts in numerical distribution of traits due to density independent factors.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

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

Construct an explanation based on evidence for how natural selection leads to adaptation of populations. *[Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]* **(HS-LS4-4)**

Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. *[Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]* **(HS-LS4-3)**

Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. *[Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]* **(HS-LS4-5)**

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. *[Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]* **(HS-LS2-8)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	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. • 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	**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	**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)

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 or solutions to determine the merits of arguments. (HS-LS4-5)	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 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)	

Unit 6 Summary
Evidence of Evolution, Relationships and Common Ancestry

What evidence shows that different species are related?

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.

Student Learning Objectives

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. (LS4.A)

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. *[Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]* **(HS-LS4-1)**

Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. *[Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]* **(HS-LS4-2)**

Unit Sequence

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	*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

among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. • Different patterns in multiple lines of empirical evidence may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of common ancestry and biological evolution.	and provide evidence for causality in explanations of common ancestry and biological evolution.

Unit Sequence

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.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing common ancestry and biological evolution, attending to important

distinctions the author makes and to any gaps or inconsistencies in the account.

- Write informative/explanatory texts describing common ancestry and biological evolution, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Draw evidence from informational texts describing common ancestry and biological evolution to support analysis, reflection, and research.
- Present claims and findings about common ancestry and biological evolution, 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.

Mathematics

- Represent evidence that common ancestry and biological evolution are supported by multiple lines of empirical evidence symbolically, and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict common ancestry and biological evolution.

Suggested Learning Activities

Anatomical Evidence of Evolution Investigation: Students investigate evidence for evolution by analyzing fossil evidence, structural evidence, and genetic evidence in support of common ancestry among living things.

How could complex eyes have evolved? Students analyze evidence from comparative anatomy, mathematical modeling, and molecular biology. This evidence suggests a likely sequence of steps in the evolution of the human eye and the octopus eye.

Construction of Cladograms: Students will interpret cladograms and synthesize cladograms to identify shared characteristics and make inferences about the evolutionary history of the group.

Geologic Time Web Quest: Students will use various online sources to study the history of life on Earth and major life forms that existed during each era.

Evolutionary Relationships in Mammals: Students will compare amino acid sequences, homologous structures and photographs of various animals to make a claim that incorporates phylogeny between mammal species.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. *[Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of*

evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.] (HS-LS4-1)

Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. *[Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]* (HS-LS4-2)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	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 sexual reproduction, (3) competition for an environment's limited supply of the resources	**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)

	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)	

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Mission Statement

The mission of the Township of Union Public Schools is to build on the foundations of honesty, excellence, integrity, strong family, and community partnerships. We promote a supportive learning environment where every student is challenged, inspired, empowered, and respected as diverse learners. Through cultivation of students' intellectual curiosity, skills and knowledge, our students can achieve academically and socially, and contribute as responsible and productive citizens of our global community.

Philosophy Statement

The Township of Union Public School District, as a societal agency, reflects democratic ideals and concepts through its educational practices. It is the belief of the Board of Education that a primary function of the Township of Union Public School System is formulation of a learning climate conductive to the needs of all students in general, providing therein for individual differences. The school operates as a partner with the home and community.

Statement of District Goals

- Develop reading, writing, speaking, listening, and mathematical skills.
- Develop a pride in work and a feeling of self-worth, self-reliance, and self discipline.
- Acquire and use the skills and habits involved in critical and constructive thinking.
- Develop a code of behavior based on moral and ethical principals.
- To be able to work with others cooperatively.
- Acquire a knowledge and appreciation of the historical record of human achievement and failures and current societal issues.
- Acquire a knowledge and understanding of the physical and biological sciences.
- Efficient and effective participation in economic life and the development of skills to enter a specific field of work.
- Appreciate and understand literature, art, music, and other cultural activities.
- Develop an understanding of the historical and cultural heritage.
- Develop a concern for the proper use and/or preservation of natural resources.
- Develop basic skills in sports and other forms of recreation.

Mission Statement

The Township of Union board of Education believes that every child is entitled to an education, designed to meet his or her individual needs, in an environment that is conductive to learning. State standards, federal and state mandates, and local goals and objectives, along with community input, must be reviewed and evaluated on a regular basis to ensure that an atmosphere of learning is both encouraged and implemented. Furthermore, any disruption to or interference with a healthy and safe educational environment must be addressed, corrected, or when necessary removed in order for the district to maintain the appropriate educational setting.

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Course Description

AP Biology
AP Biology Lab

This is a sequential, full-year, college-level course in Advanced Placement Biology. It is designed to prepare students to take the Advanced Placement examination for college degree credit and/or advanced placement, as well as to offer interested and qualified students the opportunity to pursue the detailed study of a second year of biology. In AP Biology, an emphasis is on students making connections between the Big Ideas within the AP Biology Curriculum Framework, and the NGSS Disciplinary Core Ideas.

This course may be also be taken for Seton Hall University's Project Acceleration Program. The subject matter included will be: the origin of life, basic chemistry and bio-chemistry, cells, enzymes, cell reproduction, molecular genetics, and genetics, evolution, plants, animals, and ecology. The laboratory component involves performing a minimum of eight(8) mandatory A.P. Biology laboratory exercises(two labs within each Big Idea), intended to challenge the student's ability to understand the nature of problems, the developing and testing of hypotheses by designing experiments, collection, analysis, and presentation of data, and drawing conclusions. This lab component represents the 25% of coursework devoted to lab activities, as mandated by the College Board.

The student-directed and inquiry-based laboratory investigations used throughout the course enable students to apply the seven science practices as defined in the Curriculum Framework and NGSS Framework.:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Course Proficiencies

Students will be able to demonstrate his/her knowledge, understanding, and application of the following topics:

- Major themes of biology: Science as a process, evolution, energy transfer, continuity and change, relation of structure to function, homeostasis, interdependence in nature, and science, technology, and society.
- Molecules and cells: biological chemistry, cells, energy transformation/cell energetics.
- Genetics and evolution: molecular genetics, heredity, evolutionary biology, biotechnology.
- Organisms and population: taxonomy, systematics, biodiversity, structure and function of plants and animals, ecology.

Course Proficiencies

By the end of the school year, the learner will be able to:

-develop an independent and responsible attitude towards completing class work and homework assignments

-develop effective study skills and note taking methods

-answer free-response/open-ended questions within a set time limit

-understand and follow all laboratory and safety rules

-demonstrate cooperative learning in a lab environment

-construct a comprehensive lab report including a five paragraph conclusion, based upon a student-designed and performed investigation

-clearly and effectively analyze, interpret, and communicate scientific data (metric system) and conclusions resulting from performing the twelve required AP Laboratory exercises

-understand the eight unifying themes of biology and be able to describe biological concepts in terms of the themes

-understand that biological science is a process of scientific inquiry

-recognize how cells are the structural and functional units of life

-understand that cell processes are based on physical and chemical changes which involve transfer of energy and regulation

-explain the basis of heredity and the role of molecular genetics in reproduction and inheritance

-describe the evidence and mechanisms of biological evolution

-understand the concepts of unity and diversity of organisms

-recognize the dynamic interactions of organisms and their environment

-apply biological knowledge, biotechnology, and critical thinking skills to current environmental and social concerns

Big Idea 1: The process of evolution drives the diversity and unity of life.

Enduring understanding 1.A: Change in the genetic makeup of a population over time is evolution.
Essential knowledge 1.A.1: Natural selection is a major mechanism of evolution.
Essential knowledge 1.A.2: Natural selection acts on phenotypic variations in populations.
Essential knowledge 1.A.3: Evolutionary change is also driven by random processes.
Essential knowledge 1.A.4: Biological evolution is supported by scientific evidence from many disciplines, including mathematics.
Enduring understanding 1.B: Organisms are linked by lines of descent from common ancestry.
Essential knowledge 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.
Essential knowledge 1.B.2: Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested.
Enduring understanding 1.C: Life continues to evolve within a changing environment.
Essential knowledge 1.C.1: Speciation and extinction have occurred throughout the Earth's history.
Essential knowledge 1.C.2: Speciation may occur when two populations become reproductively isolated from each other.
Essential knowledge 1.C.3: Populations of organisms continue to evolve.
Enduring understanding 1.D: The origin of living systems is explained by natural processes.
Essential knowledge 1.D.1: There are several hypotheses about the natural origin of life on Earth, each with

supporting scientific evidence.
Essential knowledge 1.D.2: Scientific evidence from many different disciplines supports models of the origin of life.

Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce, and to maintain dynamic homeostasis.

Enduring understanding 2.A: Growth, reproduction and maintenance of the organization of living systems require free energy and matter.
Essential knowledge 2.A.1: All living systems require constant input of free energy.
Essential knowledge 2.A.2: Organisms capture and store free energy for use in biological processes.
Essential knowledge 2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization.
Enduring understanding 2.B: Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.
Essential knowledge 2.B.1: Cell membranes are selectively permeable due to their structure.
Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.
Essential knowledge 2.B.3: Eukaryotic cells maintain internal membranes that partition the cell into specialized regions.
Enduring understanding 2.C: Organisms use feedback mechanisms to regulate growth and reproduction, and to maintain dynamic homeostasis.
Essential knowledge 2.C.1: Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes.
Essential knowledge 2.C.2: Organisms respond to changes in their external environments.
Enduring understanding 2.D: Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment.
Essential knowledge 2.D.1: All biological systems from cells and organisms to populations, communities and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy.
Essential knowledge 2.D.2: Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments.

Essential knowledge 2.D.3: Biological systems are affected by disruptions to their dynamic homeostasis.
Essential knowledge 2.D.4: Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.
Enduring understanding 2.E: Many biological processes involved in growth, reproduction and dynamic homeostasis include temporal regulation and coordination.
Essential knowledge 2.E.1: Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.
Essential knowledge 2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms.
Essential knowledge 2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection.

Big Idea 3: Living systems store, retrieve, transmit, and respond to information essential to life processes.

Enduring understanding 3.A: Heritable information provides for continuity of life.
Essential knowledge 3.A.1: DNA, and in some cases RNA, is the primary source of heritable information.
Essential knowledge 3.A.2: In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis or meiosis plus fertilization.
Essential knowledge 3.A.3: The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring.
Essential knowledge 3.A.4: The inheritance pattern of many traits cannot be explained by simple Mendelian genetics.
Enduring understanding 3.B: Expression of genetic information involves cellular and molecular mechanisms.
Essential knowledge 3.B.1: Gene regulation results in differential gene expression, leading to cell specialization.
Essential knowledge 3.B.2: A variety of intercellular and intracellular signal transmissions mediate gene expression.
Enduring understanding 3.C: The processing of genetic information is imperfect and is a source of genetic variation.
Essential knowledge 3.C.1: Changes in genotype can result in changes in phenotype.

Essential knowledge 3.C.2: Biological systems have multiple processes that increase genetic variation.
Essential knowledge 3.C.3: Viral replication results in genetic variation, and viral infection can introduce genetic variation into the hosts.
Enduring understanding 3.D:
Cells communicate by generating, transmitting and receiving chemical signals.
Essential knowledge 3.D.1: Cell communication processes share common features that reflect a shared evolutionary history.
Essential knowledge 3.D.2: Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling.
Essential knowledge 3.D.3: Signal transduction pathways link signal reception with cellular response.
Essential knowledge 3.D.4: Changes in signal transduction pathways can alter cellular response.
Enduring understanding 3.E:
Transmission of information results in changes within and between biological systems.
Essential knowledge 3.E.1: Individuals can act on information and communicate it to others.
Essential knowledge 3.E.2: Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.

Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.

Enduring understanding 4.A:
Interactions within biological systems lead to complex properties.
Essential knowledge 4.A.1: The subcomponents of biological molecules and their sequence determine the properties of that molecule.
Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.
Essential knowledge 4.A.3: Interactions between external stimuli and regulated gene expression result in specialization of cells, tissues and organs.
Essential knowledge 4.A.4: Organisms exhibit complex properties due to interactions between their constituent parts.
Essential knowledge 4.A.5: Communities are composed of populations of organisms that interact in complex ways.
Essential knowledge 4.A.6: Interactions among living systems and with their environment result in the movement

of matter and energy.
Enduring understanding 4.B:
Competition and cooperation are
important aspects of biological
systems.
Essential knowledge 4.B.1: Interactions between molecules affect their structure and function.
Essential knowledge 4.B.2: Cooperative interactions within organisms promote efficiency in the use of energy and matter.
Essential knowledge 4.B.3: Interactions between and within populations influence patterns of species distribution and abundance.
Essential knowledge 4.B.4: Distribution of local and global ecosystems changes over time.
Enduring understanding 4.C: Naturally
occurring diversity among and
between components within biological
systems affects interactions with the
environment.
Essential knowledge 4.C.1: Variation in molecular units provides cells with a wider range of functions.
Essential knowledge 4.C.2: Environmental factors influence the expression of the genotype in an organism.
Essential knowledge 4.C.3: The level of variation in a population affects population dynamics.
Essential knowledge 4.C.4: The diversity of species within an ecosystem may influence the stability of the ecosystem.

OVERVIEW OF THE INVESTIGATIVE LABS

BIG IDEA 1 : EVOLUTION

1: Artificial
Selection
7 weeks, including a
10-day growing period
(See investigation for
lab period breakdown.)
Guided, then
open
Counting, measuring, graphing, statistical analysis
(frequency distribution)

2: Mathematical
Modeling
3 lab periods Guided, then
open
Mendelian genetics equations, Hardy-Weinberg equation,

Excel and spreadsheet operations

3: Comparing DNA
Sequences
3 lab periods Guided, then
open
Statistical analysis, mathematical modeling, and computer
science (bioinformatics)

BIG IDEA 2: CELLULAR PROCESSES: ENERGY AND COMMUNICATION
4: Diffusion and
Osmosis
4–5 lab periods Structured, then
guided
Measuring volumes, calculating surface area-to-volume
ratios, calculating rate, calculating water potential,
graphing
5: Photosynthesis 4 lab periods Structured, then
open
Calculating rate, preparing solutions, preparing serial
dilutions, measuring light intensity, developing and
applying indices to represent the relationship between two
quantitative values, using reciprocals to modify graphical
representations, utilizing medians, graphing
6: Cellular
Respiration
4 lab periods Guided, then
open
Calculating rate, measuring temperature and volume,
graphing
Big IdeA 3: geneTICS And InForMATIon TrAnSFer
7: Cell Division:
Mitosis and
Meiosis
5–6 lab periods Structured, then
guided, then open
Measuring volume, counting, chi-square statistical
analysis, calculating crossover frequency
8: Biotechnology:
Bacterial
Transformation
4–5 lab periods Structured, then
guided
Measuring volume and temperature, calculating
transformation efficiency
9: Biotechnology:
Restriction
Enzyme
Analysis of
DNA
3–4 lab periods Structured, then
guided, then open

Measuring volume and distance, graphing/plotting data using log scale, extrapolating from standard curve

Big IdeA 4: InTerACTIonS

10: Energy Dynamics
4–5 lab periods Structured, then guided, then open
Estimating productivity and efficiency of energy transfer, accounting and budgeting, measuring biomass, calculating unit conversions in simple equations

11: Transpiration 4 lab periods Structured, then guided, then open
Measuring distance, volume, and mass; estimating surface area; calculating surface area; graphing; calculating rate

12: Fruit Fly Behavior
4 lab periods Structured, then open
Preparing solutions, counting, graphing

13: Enzyme Activity
3–4 lab periods Structured, then guided, then open
Measuring volume and mass, measuring color change, graphing, calculating rates of enzymatic reactions

Curriculum Units

Unit 1: Themes in the Study of Life and Biochemistry

Unit 2: Cell Biology

Unit 3: Molecular Genetics and Heredity

Unit 4: Evolutionary Biology

Unit 5: Diversity of Organisms

Unit 6: Ecology

Pacing Guide- Course

Content		Number of Days
Unit 1:	Biological themes, biochemistry of life: water, organic molecules, free energy changes, enzymes, homeostasis	15
Unit 2:	Prokaryotic and eukaryotic cells, membranes, subcelluar organization, cell cycle and its regulation; cellular energetics: respiration and photosynthesis	50
Unit 3:	DNA/RNA structure and function, gene regulation, mutation, viral structure and replication, nucleic acid technology and applications, meiosis, eukaryotic chromosomes, inheritance patterns, protein synthesis	35
Unit 4:	Early evolution of life, evidence for evolution, mechanisms of evolution, Darwin, speciation	15
Unit 5:	Evolutionary patterns, survey of the diversity of life, phylogenetic classification, evolutionary relationships, structure and function of plants and animals/humans	50
Unit 6:	Population dynamics, communities and ecosystems, global issues, ecological interactions, animal behavior, biogeochemical cycles	15

Alignment of AP Biology Enduring Understandings and Essential Knowledge With NGSS Disciplinary Core Ideas

The curriculum guide on the following pages represents an alignment between the NGSS and the AP Biology course. These resources show the conceptual similarities between the two sets of courses. The content in the NGSS was compared to the content in the AP Biology course guides to identify areas of conceptual similarity. The specific language of each AP Essential Knowledge (AP EK) statement was compared to the Disciplinary Core Idea (DCI) elements associated with each Next Generation Science Standards (NGSS) Performance Expectation (PE) to demonstrate similar content or conceptual foundation.

Acknowledgement:
http://www.nextgenscience.org/sites/default/files/NGSS%20Accelerated%20Model%20Course%20Pathways.pdf

Recommended Textbook:

Campbell, Neil and Reece, Jane B. 2008. *AP Edition Biology,* Eighth Edition, San Francisco, CA: Pearson Benjamin Cummings.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.A Change in the genetic makeup of a population over time is evolution.	**1.A.1** Natural selection is a major mechanism of evolution.	**HS.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 fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. **HS.LS3.B: Variation of Traits** 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 occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. **HS.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. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. **HS.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 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. *(continued on next page)*	**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. **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. **HS-LS4-2** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. **HS-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. *(continued on next page)*	The NGSS build a foundation for students to understand the theory of natural selection and how it is a mechanism for evolution. **AP EK 1.A.1** goes beyond the NGSS by including details about how environmental conditions can affect evolutionary rate and direction, the Hardy-Weinberg equilibrium, and the mathematical calculations involved for changes in allele frequency.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	1.A.1 Natural selection is a major mechanism of evolution.	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. 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. 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.	HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations. 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.	

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.A Change in the genetic makeup of a population over time is evolution.	1.A.2 Natural selection acts on phenotypic variations in populations.	**HS.LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Moreover, 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. **HS.LS3.B: Variation of Traits** 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 occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. **HS.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. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. **HS.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 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. 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. *(continued on next page)*	**HS-LS2-7** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* **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. **HS-LS4-2** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. **HS-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. *(continued on next page)*	The NGSS and AP both describe how variations in traits can occur, how environmental factors can act as selective mechanisms, and how the variations can affect the fitness of an organism. **NGSS HS.LS2.C** and **HS.LS4.D** and **AP EK 1.A.2 part d** describe how humans can impact species, but part d focuses specifically on human impact on variation in a species.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	1.A.2 Natural selection acts on phenotypic variations in populations.	Adaptation also means that the distribution of traits in a population can change when conditions change. 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.D: Biodiversity and Humans** 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.	**HS-LS4-4** Construct an explanation based on evidence for how natural selection leads to adaptation of populations. **HS-LS4-6** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*	
1.A Change in the genetic makeup of a population over time is evolution.	**1.A.4** Biological evolution is supported by scientific evidence from many disciplines, including mathematics.	**HS.LS4.A: Evidence of Common Ancestry and Diversity** Genetic information, like the fossil record, 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.ESS1.C: The History of Planet Earth** Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. **HS.ESS2.B: Plate Tectonics and Large-Scale System Interactions** Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. **HS.PS1.C: Nuclear Processes** Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.	**HS-LS4-1** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. **HS-ESS1-5** Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.	The NGSS and AP both describe the scientific evidence that supports biological evolution, including radioactive dating. **AP EK 1.A.4** goes beyond the NGSS by including details on mathematical models and simulations that can support evolution.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.B Organisms are linked by lines of descent from common ancestry.	**1.B.2** Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested.	**HS.LS4.A: Evidence of Common Ancestry and Diversity** Genetic information, like the fossil record, 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** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.	**NGSS HS.LS4.A** sets the foundation for students to learn about phylogenetic trees and cladograms in **AP EK 1.B.2** by describing the evidence for evolution and introducing the graphical representations through the "ongoing branching that produces multiple lines of descent."
1.C Life continues to evolve within a changing environment.	**1.C.1** Speciation and extinction have occurred throughout the Earth's history.	**HS.LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Moreover, 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. **HS.LS4.C: Adaptation** 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. 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. **HS.LS4.D: Biodiversity and Humans** 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.	**HS-LS2-7** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* **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.	Both the NGSS and AP include the concepts of speciation and extinction. **NGSS HS.LS4.C** builds the foundation for **AP EK 1.C.1** which goes beyond the NGSS by including details about the rates of speciation and extinction. **NGSS HS.LS2.C** and **HS.LS4.D** are similar to EK **1.C.1 part b** in its description of how human activity can affect species extinction.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.C Life continues to evolve within a changing environment.	1.C.2 Speciation may occur when two populations become reproductively isolated from each other.	**HS.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 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. 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. 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.	**HS-LS4-4** Construct an explanation based on evidence for how natural selection leads to adaptation of populations. **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.	**NGSS HS.LS4.C** sets the foundation for **AP EK 1.C.2** by describing how changes in the physical environment can lead to the divergence of species. EK 1.C.2 goes beyond the NGSS by including details about the physical separation and pre- and post-zygotic mechanisms that can result in reproductive isolation, and by including details about the rate of speciation.
1.C Life continues to evolve within a changing environment.	1.C.3 Populations of organisms continue to evolve.	**HS.LS4.A: Evidence of Common Ancestry and Diversity** Genetic information, like the fossil record, 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.C: Adaptation** 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. 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.	**HS-LS4-1** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. **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.	Both AP and the NGSS state that there is scientific evidence that supports evolution.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
1.D The origin of living systems is explained by natural processes.	**1.D.2** Scientific evidence from many different disciplines supports models of the origin of life.	**HS.ESS1.C: The History of Planet Earth** Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. **HS.PS1.C: Nuclear Processes** Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.	**HS-ESS1-6** Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.	The NGSS set the foundation for understanding how the rocks on Earth or objects in the solar system can provide information about Earth's early history. **AP EK 1.D.2** goes beyond the NGSS by including details about the origin of life and the molecular and genetic evidence that supports existing models for the origin of life.

Activities for AP Big Idea 1/NGSS: Evolution

Perform :Investigation 2: Mathematical Modeling: Hardy-Weinberg
Investigation 3: Comparing DNA Sequences to Understand Evolutionary Relationships with BLAST
Lab 8: Population Genetics and Evolution

- List the conditions and events leading to the origin of life on earth.
- Complete independent study assignment: research evolutionary patterns.
- Perform Internet searches of all relevant topics.
- Summarize the evidences for evolution.
- Label a diagram of the Stanley Miller apparatus.
- List the cellular structures which evolved as a result of endosymbiosis.
- Describe Darwin's research and his conclusions that led to the theory of natural selection.

- Construct a list of the characteristics of members of the three domains of life.
- Perform an Internet search to examine the diversity of organisms.
- Complete worksheet assignments on plant and animal diversity, classification, phylogeny, and adaptations.
- Analyze and interpret a cladogram.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.A Growth, reproduction and maintenance of the organization of living systems require free energy and matter.	2.A.1 All living systems require constant input of free energy.	**HS.LS1.C: Organization for Matter and Energy Flow in Organisms** As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. **HS.LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** 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.PS1.A: Structure and Properties of Matter** A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. **HS.PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	**HS-LS1-7** Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. **HS-LS2-4** Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. **HS-PS1-4** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. **HS-PS3-4** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	**NGSS HS.PS1.A, HS.PS1.B, HS.PS3.B,** and **HS.PS3.D** set the foundation for **AP EK 2.A.1** by describing the conservation of energy, the role of energy in chemical processes, and energy transfer. **NGSS HS.LS1.C** and **HS.LS2.B** continue to build the foundation for AP EK 2.A.1 by integrating this understanding of energy to energy flow in organisms and ecosystems. EK 2.A.1 goes beyond the NGSS by describing how the input of free energy is required for living systems and the effects changes in free energy can have on organisms, populations, and ecosystems.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.A Growth, reproduction and maintenance of the organization of living systems require free energy and matter.	2.A.2 Organisms capture and store free energy for use in biological processes.	**MS.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.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. The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. **HS.LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. **HS.PS1.A: Structure and Properties of Matter** A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **HS.PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. *(continued on next page)*	**MS-LS1-2** Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. **HS-LS1-5** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. **HS-LS1-6** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. **HS-LS1-7** Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. **HS-LS2-3** Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. **HS-PS1-4** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. *(continued on next page)*	The NGSS and AP both describe the basic role of energy in the processes of photosynthesis and cellular respiration. **AP EK 2.A.2** goes beyond the NGSS by including details about ATP and the flow of energy through the specific steps in the biochemical pathways of photosynthesis and cellular respiration.

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	2.A.2 Organisms capture and store free energy for use in biological processes.	**HS.PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.	**HS-PS3-2** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).	

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.A Growth, reproduction and maintenance of the organization of living systems require free energy and matter.	**2.A.3** Organisms must exchange the matter with the environment to grow, reproduce and maintain organization.	**HS.LS1.C: Organization for Matter and Energy Flow in Organisms** The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. **HS.LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** 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.PS3.D: Energy in Chemical Processes** The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. **HS.ESS2.C: The Roles of Water in Earth's Surface Processes** The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.	**HS-LS1-6** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. **HS-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. **HS-ESS2-5** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	Both AP and the NGSS include details about the flow of carbon through matter and its integration into hydrocarbon backbones that can be used to build other molecules. While **AP EK 2.A.3 part a.2** explicitly addresses the movement and integration of nitrogen and phosphorus into molecules, the NGSS can also cover the same content about nitrogen and phosphorus when students learn about how "carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules" [PE HS-LS1-6]. **NGSS HS.ESS2.C** and **EK 2.A.3 part a.3** both describe the properties of water, but the NGSS does so in the broader context of the Earth's dynamics and AP does so in the context of living systems. **EK 2.A.3 part b** goes beyond the NGSS by including details about the effect of surface area-to-volume ratios on biological systems.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.B Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.	**2.B.1** Cell membranes are selectively permeable due to their structure.	**MS.LS1.A: Structure and Function** Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. **HS.PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.	**MS-LS1-2** Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. **HS-PS1-3** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	**NGSS HS.PS1.A** builds the foundation for understanding the cell membrane's structure and function by including a discussion of polar and non-polar interactions. **NGSS MS.LS1.A** also contributes towards the foundation by introducing the basic function of the cell membrane. **AP EK 2.B.1** goes beyond the NGSS by including details about the structural components of the cell membrane and how they contribute to the membrane's selective permeability.
2.B Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.	**2.B.2** Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.	**MS.LS1.A: Structure and Function** Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. **HS.PS3.B: Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **HS.PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	**MS-LS1-2** Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. **HS-PS3-4** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	The NGSS provide a foundation for **AP EK 2.B.2** by describing the basic function of the cell membrane and the transfer of energy. EK 2.B.2 goes beyond the NGSS by including details about passive and active transport.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.B Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.	**2.B.3** Eukaryotic cells maintain internal membranes that partition the cell into specialized regions.	**MS.LS1.A: Structure and Function** Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.	**MS-LS1-2** Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.	The NGSS provide a foundation for **AP EK 2.B.3** by describing the basic structure and function of cell parts. EK 2.B.3 goes beyond the NGSS by including details on membrane-bound organelles that can create specialized regions.
2.C Organisms use feedback mechanisms to regulate growth and reproduction, and to maintain dynamic homeostasis.	**2.C.1** Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes.	**HS.LS1.A: Structure and Function** 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** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.	The NGSS and AP both discuss negative and positive feedback mechanisms and their role in maintaining living system conditions. **AP EK 2.C.1** goes beyond the NGSS by including details about how alterations to the feedback systems can have deleterious effects.
2.C Organisms use feedback mechanisms to regulate growth and reproduction, and to maintain dynamic homeostasis.	**2.C.2** Organisms respond to changes in their external environments.	**HS.LS1.A: Structure and Function** 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** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.	**AP EK 2.C.2** builds upon **AP EK 2.C.1** and **NGSS HS.LS1.A** by specifying how organisms use behavioral and physiological mechanisms to respond to environmental changes.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.D Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment.	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy.	**HS.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.B: Cycles of Matter and Energy Transfer in Ecosystems** 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.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 fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	**HS-LS2-1** 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-LS2-4** Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. **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.	Both AP and the NGSS describe how the stability of organisms, populations, and ecosystems can be affected by various factors. **AP EK 2.D.1** goes beyond the NGSS by including how cell activities can also be affected.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.D Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment.	2.D.3 Biological systems are affected by disruptions to their dynamic homeostasis.	**HS.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 fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. Moreover, 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. **HS.LS4.C: Adaptation** 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.D: Biodiversity and Humans** 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.	**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. **HS-LS2-7** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. **HS-LS4-6** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*	Both the NGSS and AP include a discussion of the effect of disruptions to biological systems. The NGSS focuses on disruptions to populations and ecosystems, while **AP EK 2.D.3 part a** also includes the effects of disruptions at the molecular and cellular level.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.E Many biological processes involved in growth, reproduction and dynamic homeostasis include temporal regulation and coordination.	**2.E.1** Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.	**HS.LS1.A: Structure and Function** 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. **HS.LS1.B: Growth and Development of Organisms** 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. **HS.LS3.A: Inheritance of Traits** 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.B: Variation of Traits** In sexual reproduction, chromosomes can sometimes swap sections during the process of melosis (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 occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.	**HS-LS1-4** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. **HS-LS3-1** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. **HS-LS3-2** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.	The NGSS build a basic understanding of the structure and function of genes, the variation of traits, gene expression, cellular division, and cellular differentiation. This all contributes towards setting the foundation for **AP EK 2.E.1** which goes beyond the NGSS by including details about the mechanisms that regulate the normal development of organisms.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
2.E Many biological processes involved in growth, reproduction and dynamic homeostasis include temporal regulation and coordination.	**2.E.3** Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection.	**HS.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. **HS.LS4.C: Adaptation** 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. 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.	**HS-LS2-8** Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. **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.	AP and the NGSS both discuss how group behavior can affect the survival of species. **AP EK 2.E.3** goes beyond the NGSS by including details about innate behavior, learned behavior, and communication of and response to information in plants.
3.A Heritable information provides for continuity of life.	**3.A.1** DNA, and in some cases RNA, is the primary source of heritable information.	**HS.LS1.A: Structure and Function** 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. **HS.LS3.A: Inheritance of Traits** 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.B: Variation of Traits** 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 occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.	**HS-LS1-1** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. **HS-LS3-1** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. **HS-LS3-2** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.	The NGSS and AP both describe how genetic information is stored in DNA. **AP EK 3.A.1** goes beyond the NGSS by including details about the structure and function of RNA vs. DNA, the experiments that provide evidence that DNA carries genetic information, the specific steps involved in DNA replication and protein synthesis, the difference in protein synthesis between prokaryotes and eukaryotes, the difference in genetic material between prokaryotes and eukaryotes, and genetic engineering.

Activities for AP Big Idea 2/NGSS: Cellular Processes: Energy and Communication

Perform: Investigation 4: Diffusion and Osmosis
Investigation 5: Photosynthesis
Investigation 6: Cellular Respiration
Investigation 13: Enzyme Activity,

Identify biological molecules based on their molecular structures.
Complete independent assignment on biochemistry.
Design an enzyme experiment, testing variables other than those in AP Biology Inv. #13.

- Perform Internet searches of all relevant content topics, examining animations, diagrams, and performing virtual lab experiences.
- Construct a paper strip protein.

- Conduct a laboratory investigation of cell types using the microscope.
- Identify and label cell organelles on diagrams of plant and animal cells.
- Identify and label cell membrane components on a diagram and explain their functions.
- Investigate cell membrane properties by performing AP Biology Investigation #4—Diffusion and Osmosis.
- Investigate the light stage of photosynthesis by performing AP Biology Inv. #5—Photosynthesis.
- Determine the effect of temperature on respiration by performing Inv.#6—Cellular Respiration.
- Complete independent study assignments on:
  -nerve cells and nerve transmission
  -muscle cells and contraction
  Discuss the role of the plasma membrane as a highly selective barrier in diffusion, osmosis, and active transport

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.A Heritable information provides for continuity of life.	**3.A.2** In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis or meiosis plus fertilization.	**HS.LS1.A: Structure and Function** 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. **MS.LS1.B: Growth and Development of Organisms** Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. **HS.LS1.B: Growth and Development of Organisms** 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. **MS.LS3.A: Inheritance of Traits** Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. **HS.LS3.A: Inheritance of Traits** 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. **MS.LS3.B: Variation of Traits** In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. *(continued on next page)*	**MS-LS3-2** Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. **HS-LS1-4** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. **HS-LS3-1** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. **HS-LS3-2** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.	The NGSS and AP both describe the processes of mitosis and meiosis. **AP EK 3.A.2** goes beyond the NGSS by including details about the steps and regulation of the processes.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	3.A.2 In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis or meiosis plus fertilization.	**HS.LS3.B: Variation of Traits** 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 occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.		

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.A Heritable information provides for continuity of life.	**3.A.3** The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring.	**HS.LS1.A: Structure and Function** 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. **MS.LS1.B: Growth and Development of Organisms** Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. **MS.LS3.A: Inheritance of Traits** Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. **HS.LS3.A: Inheritance of Traits** 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. **MS.LS3.B: Variation of Traits** In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. **HS.LS3.B: Variation of Traits** 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 occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.	**MS-LS3-2** Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. **HS-LS3-1** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. **HS-LS3-2** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.	The NGSS build an understanding of the inheritance of traits and genetic variation. This contributes towards setting the foundation for **AP EK 3.A.3**, which goes beyond the NGSS by including the different patterns of inheritance; rules of probability; human genetic disorders; and ethical, medical, and social issues.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.B Expression of genetic information involves cellular and molecular mechanisms.	**3.B.1** Gene regulation results in differential gene expression, leading to cell specialization.	**HS.LS1.A: Structure and Function** 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. **HS.LS1.B: Growth and Development of Organisms** 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. **HS.LS3.A: Inheritance of Traits** 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-LS1-4** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. **HS-LS3-1** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.	The NGSS introduce the concept of gene regulation. **AP EK 3.B.1** goes beyond the NGSS by describing how genes are regulated in eukaryotes and the specific control mechanisms that are present for gene regulation in bacteria and viruses.
3.B Expression of genetic information involves cellular and molecular mechanisms.	**3.B.2** A variety of intercellular and intracellular signal transmissions mediate gene expression.	**HS.LS1.B: Growth and Development of Organisms** 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.	**HS-LS1-4** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.	**NGSS HS.LS1.B** builds an understanding of cell division and differentiation that sets a foundation for **AP EK 3.B.2.** EK 3.B.2 includes details about intercellular and intracellular signal transmissions that are involved with gene expression.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.C The processing of genetic information is imperfect and a source of genetic variation.	**3.C.1** Changes in genotype can result in changes in phenotype.	**MS.LS3.A: Inheritance of Traits** Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. **MS.LS3.B: Variation of Traits** In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism. **HS.LS3.B: Variation of Traits** 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 occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. **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. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. **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 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.	**MS-LS3-1** Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. **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-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.	Both the NGSS and AP describe how changes in a gene can affect traits, and that the changes in the genes are subject to natural selection. **AP EK 3.C.1** specifically uses the terms genotype and phenotype in this discussion. AP EK 3.C.1 goes beyond the NGSS by including details about how mutations can arise other than during errors in DNA replication, and how errors during mitosis and meiosis can result in changes in chromosome numbers.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.C The processing of genetic information is imperfect and a source of genetic variation.	3.C.2 Biological systems have multiple processes that increase genetic variation.	**HS.LS3.B: Variation of Traits** 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 occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.	**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.	The NGSS and AP both describe how errors during DNA replication and crossing-over during meiosis can contribute towards genetic variation and how the resulting traits are subject to natural selection. **AP EK 3.C.1** goes beyond the NGSS by including details about the processes that increase genetic variation in prokaryotes.
3.D Cells communicate by generating, transmitting and receiving chemical signals.	3.D.2 Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling.	**MS.LS1.D: Information Processing** Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.	**MS-LS1-8** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.	Both the NGSS and AP describe how information is transmitted via nerve cells. **AP EK 3.D.2** differentiates between the different ways that cells can communicate: cell-to-cell contact, short distance signaling, and long distance signaling.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
3.E Transmission of information results in changes within and between biological systems.	3.E.1 Individuals can act on information and communicate it to others.	**HS.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. **HS.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. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. **HS.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 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.	**HS-LS2-8** Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. **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.	Both the NGSS and AP describe how natural selection favors behavior that increases survival. **AP EK 3.E.1** goes beyond the NGSS by include details about how communication between organisms can change behavior and about communication mechanisms. It also separates behavior into learned and innate behavior in **part c.1.**
3.E Transmission of information results in changes within and between biological systems.	3.E.2 Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.	**HS.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. **MS.LS1.D: Information Processing** Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. **HS.PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed.	**MS-LS1-8** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories. **HS-LS1-2** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. **HS-PS3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.	The NGSS set the foundation for **AP EK 3.E.2** by describing how information is processed through nerve cells, how components interact within systems, and how energy can be stored in fields. AP EK 3.E.2 goes beyond the NGSS by including the structure of a neuron, the propagation of impulses, steps involved in transmitting information across synapses, and the different functions of brain regions.

Activities for AP Big Idea 2/NGSS: Cellular Processes: Energy and Communication

Perform: Investigation 4: Diffusion and Osmosis
Investigation 5: Photosynthesis
Investigation 6: Cellular Respiration
Investigation 13: Enzyme Activity,

Identify biological molecules based on their molecular structures.
Complete independent assignment on biochemistry.
Design an enzyme experiment, testing variables other than those in AP Biology Inv. #13.

- Perform Internet searches of all relevant content topics, examining animations, diagrams, and performing virtual lab experiences.
- Construct a paper strip protein.

- Conduct a laboratory investigation of cell types using the microscope.
- Identify and label cell organelles on diagrams of plant and animal cells.
- Identify and label cell membrane components on a diagram and explain their functions.
- Investigate cell membrane properties by performing AP Biology Investigation #4—Diffusion and Osmosis.
- Investigate the light stage of photosynthesis by performing AP Biology Inv. #5—Photosynthesis.
- Determine the effect of temperature on respiration by performing Inv.#6—Cellular Respiration.
- Complete independent study assignments on:
  -nerve cells and nerve transmission
  -muscle cells and contraction
  Discuss the role of the plasma membrane as a highly selective barrier in diffusion, osmosis, and active transport

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.A Interactions within biological systems lead to complex properties.	4.A.1 The subcomponents of biological molecules and their sequence determine the properties of that molecule.	**HS.LS1.A: Structure and Function** 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. **HS.LS1.C: Organization for Matter and Energy Flow in Organisms** The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. **HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**HS-LS1-1** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. **HS-LS1-6** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. **HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.	The NGSS describe how the parts of a molecule determine its properties. **NGSS HS.LS1.C** includes details for the structure of carbohydrates and **NGSS HS.PS2.B** discusses the contribution of attraction and repulsion towards a molecule's properties. **AP EK 4.A.1** goes beyond the NGSS by including details about the structure and properties of nucleic acids (**part a.1**), proteins (**part a.2**) and lipids (**part a.3**). EK 4.A.1 also includes details about how the directionality of components can affect structure and function of the molecule.
4.A Interactions within biological systems lead to complex properties.	4.A.2 The structure and function of subcellular components, and their interactions, provide essential cellular processes.	**MS.LS1.A: Structure and Function** Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. **HS.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.	**MS-LS1-2** Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. **HS-LS1-5** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.	Both the NGSS and AP discuss how subcellular components have specific structures and functions. **NGSS HS.LS.1.A** specifically mentions the cell membrane and **HS.LS1.C** builds a foundation for understanding the structure and function of a chloroplast. **AP EK 4.A.2** includes details about the structure and function of the endoplasmic reticulum, ribosomes, the golgi complex, mitochondria, lysosomes, vacuoles, and chloroplasts.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.A Interactions within biological systems lead to complex properties.	4.A.3 Interactions between external stimuli and regulated gene expression result in specialization of cells, tissues and organs.	**HS.LS1.A: Structure and Function** 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. 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.B: Growth and Development of Organisms** 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. **HS.LS3.A: Inheritance of Traits** 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.B: Variation of Traits** 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-LS1-1** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. **HS-LS1-2** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. **HS-LS1-4** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. **HS-LS3-1** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. **HS-LS3-3** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.	AP and NGSS both describe that genes are regulated, how the environment can affect gene expression, and how differentiation results in specialized tissues and organs. **AP EK 4.A.3** goes beyond the NGSS by including details about the cues for gene regulation, regulation by proteins, and how this regulation leads to differentiation. The NGSS build the foundation for EK 4.A.3 by describing what genes are and how cell division and differentiation contribute towards the growth and development of an organism.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.A Interactions within biological systems lead to complex properties.	4.A.4 Organisms exhibit complex properties due to interactions between their constituent parts.	**HS.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 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	Both the NGSS and AP discuss how the interactions between different systems and between components of a single system contribute towards the functioning of organisms. **AP EK 4.A.4** specifically differentiates between interactions at the organ level and interactions at the system level.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.A Interactions within biological systems lead to complex properties.	4.A.5 Communities are composed of populations of organisms that interact in complex ways.	**MS.LS2.A: Interdependent Relationships in Ecosystems** Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. **HS.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.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 fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. Moreover, 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. **HS.LS4.C: Adaptation** 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.D: Biodiversity and Humans** Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). *(continued on next page)*	**MS-LS2-2** Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. **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. **HS-LS2-7** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. **HS-LS4-6** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* **HS-ESS3-5** Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. *(continued on next page)*	The NGSS build a foundation for **AP 4.A.5** by describing how populations interact, and the use of mathematical models and representations to explain and illustrate both these interactions as well as the factors that affect the interactions. EK 4.A.5 goes beyond the NGSS by including how community structure can be described by species composition and diversity, exponential growth, logistic growth, density-dependent and density-independent factors, and demographics data (for use in human population studies).

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	4.A.5 Communities are composed of populations of organisms that interact in complex ways.	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. **HS.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 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. **HS.ESS3.D: Global Climate Change** Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. 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** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.A Interactions within biological systems lead to complex properties.	4.A.6 Interactions among living systems and with their environment result in the movement of matter and energy.	**HS.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.B: Cycles of Matter and Energy Transfer in Ecosystems** 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.C: Ecosystem Dynamics, Functioning, and Resilience** Moreover, 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. 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. **HS.LS4.D: Biodiversity and Humans** 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. *(continued on next page)*	**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-LS2-4** 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. **HS-LS2-7** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* **HS-LS4-6** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* **HS-ESS3-6** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	The NGSS and AP both describe how interactions in food webs and chains move matter and energy. **NGSS HS.LS2.A** and **HS.LS2.C** build a foundation for **AP EK 4.A.6** by describing the dynamics and relationships in ecosystems. EK 4.A.6 includes details about how changes in ecosystems can affect primary productivity and how competition contributes to logistic model growth and a density-dependent population. **NGSS HS.LS2.C, NGSS HS.LS4.D,** and **EK 4.A.6 part f** describe how human activities impact ecosystems, but EK 4.A.6 part f separates human impact into local, regional, and global scales.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	4.A.6 Interactions among living systems and with their environment result in the movement of matter and energy.	Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). **HS.PS3.D: Energy in Chemical Processes** The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. **HS.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 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. **HS.ESS3.D: Global Climate Change** 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.		

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.B Competition and cooperation are important aspects of biological systems.	4.B.1 Interactions between molecules affect their structure and function.	**HS.PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.	**HS-PS2-6** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.	**NGSS HS.PS2.B** builds a foundation for **AP EK 4.B.1** by describing how attraction and repulsion between charges contributes towards the structure and function of molecules. EK 4.B.1 specifically discusses how the structure of an enzyme determines its function, the binding of molecules to enzymes, and how changes in structure can result changes in function.
4.B Competition and cooperation are important aspects of biological systems.	4.B.2 Cooperative interactions within organisms promote efficiency in the use of energy and matter.	**MS.LS1.A: Structure and Function** Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. **HS.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. 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.	**MS-LS1-2** Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. **HS-LS1-1** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. **HS-LS1-2** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms	**NGSS MS.LS1.A** and **HS.LS1.A** describe the hierarchy of living systems, the components of the different levels, and the interactions within and between each level, leading students to an understanding in **AP EK 4.B.2** of how components at the different levels within an organism have functions involving the use of energy and matter. **EK 4.B.2 part 3** also goes beyond the NGSS by specifically including details about interactions between unicellular organisms.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.B Competition and cooperation are important aspects of biological systems.	4.B.3 Interactions between and within populations influence patterns of species distribution and abundance.	**MS.LS2.A Interdependent Relationships in Ecosystems** Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. **HS.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.C Ecosystem Dynamics, Functioning, and Resilience** Moreover, 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. 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. **HS.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. **HS.LS4.C Adaptation** 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. *(continued on next page)*	**MS-LS2-2** Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. **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. **HS-LS2-7** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* **HS-LS2-8** Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. **HS-LS4-6** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*	Both the NGSS and AP describe how interactions between populations can affect their numbers and how environmental disturbances (human impacts included) can also affect population numbers. **AP EK 4.B.3** goes beyond the NGSS by describing how the properties of a population are different than the properties of the individuals.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	4.B.3 Interactions between and within populations influence patterns of species distribution and abundance.	**HS.LS4.D Biodiversity and Humans** 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.		
4.B Competition and cooperation are important aspects of biological systems.	4.B.4 Distribution of local and global ecosystems changes over time.	**HS.LS2.C Ecosystem Dynamics, Functioning, and Resilience** Moreover, 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. **HS.LS4.C Adaptation** 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.D Biodiversity and Humans** 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. **HS.ESS2.A Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. *(continued on next page)*	**HS-LS2-7** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* **HS-LS4-6** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* **HS-ESS2-2** Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. **HS-ESS3-1** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. **HS-ESS3-6** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	Both AP and the NGSS describe how natural events and human activities impact ecosystems.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
	4.B.4 Distribution of local and global ecosystems changes over time.	**HS.ESS2.D Weather and Climate** The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. 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 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. **HS.ESS3.A Natural Resources** Resource availability has guided the development of human society. **HS.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.D Global Climate Change** 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.		
4.C Naturally occurring diversity among and between components within biological systems affects interactions with the environment.	4.C.1 Variation in molecular unites provides cells with a wider range of functions.	**MS.LS1.B Growth and Development of Organisms** Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. **HS.LS3.A Inheritance of Traits** Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. **HS.LS3.B Variation of Traits** In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.	**MS-LS3-2** Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.	The NGSS build the foundational knowledge needed for **AP EK 4.C.1**, including the transfer of genetic information and the variation of inherited traits. EK 4.C.1 goes beyond the NGSS by describing how variation in molecular classes and gene duplication can result in more functions and phenotypes.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.C Naturally occurring diversity among and between components within biological systems affects interactions with the environment.	4.C.2 Environmental factors influence the expression of the genotype in an organism.	**HS.LS3.B Variation of Traits** 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-LS3-3** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.	Both the NGSS and AP include how environmental factors affect the expression of traits. **AP EK 4.C.2 part b** goes beyond the NGSS by including how "an organism's adaptation to the local environment reflects a flexible response of its genome."
4.C Naturally occurring diversity among and between components within biological systems affects interactions with the environment.	4.C.3 The level of variation in a population affects population dynamics.	**HS.LS3.B Variation of Traits** 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.LS4.C Adaptation** 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. 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.	**HS-LS3-3** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. **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.	The NGSS build a foundation for **AP EK 4.C.3** by describing adaptation and how environmental factors affect gene expression. EK 4.C.3 goes beyond the NGSS by including details about genetic diversity and its contribution toward an organism or population's ability to respond. **EK 4.C.3 part c** also includes the Hardy-Weinberg equation.

AP Enduring Understanding	AP Essential Knowledge Focus	NGSS Disciplinary Core Idea Element(s)	NGSS Performance Expectation(s)	Comments about the Connections
4.C Naturally occurring diversity among and between components within biological systems affects interactions with the environment.	**4.C.4** The diversity of species within an ecosystem may influence the stability of the ecosystem.	**HS.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.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 fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. **HS.LS4.C Adaptation** 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. 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.	**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-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.	The NGSS build a foundation for **AP EK 4.C.4** by describing how disturbances to ecosystems can result in resilience or change. EK 4.C.4 goes beyond the NGSS by including details about how the diversity of the components of an ecosystem contributes towards its resilience. **EK 4.C.4 part b** goes beyond the NGSS by describing keystone species and their contribution towards the diversity of ecosystems.

Activities for AP Big Idea 4/NGSS: Interactions

Perform: Investigation 10: Energy Dynamics
Investigation 11: Transpiration
Investigation 12: Fruit Fly Behavior
Lab 12: Dissolved Oxygen and Aquatic Productivity

- Perform AP Biology Lab #12—Dissolved Oxygen and Aquatic Productivity
- Predict and analyze how a change in an ecosystem from natural causes, climate changes, or human activity can affect both the number of organisms in a population and the biodiversity of species in an ecosystem.
- List the hierarchical groupings within the subject of ecology.
- Draw a food chain, foodweb, and pyramid of energy.
- List and describe the characteristics of the major biomes.

Complete independent study assignment: Ecology

HONORS BIOLOGY CURRICULUM ACTIVITIES - ALIGNED WITH NGSS STANDARDS

Units 1 and 3 Activities – Ecology, Ecosystems, and Biodiversity

Cellular Respiration Activity
Students will model the biochemistry behind cellular respiration by acting out the steps of cellular respiration.
HS-LS1.C: Organization for Matter and Energy Flow in Organisms
Published by NGSS Life Science

Build a Paper Ecosystem
Using biotic and abiotic factors, students will build a food web and energy pyramid using examples of producers, consumers, and decomposers.
HS-LS1.C: Organization for Matter and Energy Flow in Organisms

Photosynthesis Activity
Students learn the chemical formula for photosynthesis by acting out plant's photosynthetic process including photosystem 2, photosystem 1, and the Calvin cycle. Great visual and kinesthetic activity.
HS-LS2.B: Cycles of Matter and Energy Transfer in Organisms

How does Energy Flow Through an Ecosystem?
Virtual lab: Model Ecosystems
http://www.mhhe.com/biosci/genbio/virtual_labs/BL_02/BL_02.html
HS-LS2.B: Cycles of Matter and Energy Transfer in Organisms

These activities help to prepare students to meet **Performance Expectations** (PE)

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

- HS-LS1-5, "Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy."
- HS-LS1-7, "Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy."
- HS-LS2-5. "Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere…"

Activity	Scientific Practices[1]					Crosscutting Concepts[2]		
	Model	Investigation	Data	Explain	Argue	Mechanism	Models	Energy
How do biological organisms use energy? (DCI: LS1.C; PE: HS-LS1-7)				+		+		+
Using Models to Understand Photosynthesis (DCI: LS1.C, LS 2.B; PE: HS-LS1-5, HS-LS1-7, HS-LS2-5)	+			+			+	+
Photosynthesis Investigation (DCI: LS1.C; PE: HS-LS1-5)		+	+	+				+
Where does a plant's mass come from? (DCI: LS1.C; PE: HS-LS1-5)			+		+			+
Plant Growth Puzzle (DCI: LS1.C; PE: HS-LS1-5 and HS-LS1-7)			+	+		+		+

How do muscles get the energy they need for athletic activity? (DCI: LS1.C; PE: HS-LS1-7)				+	+			+
Food, Energy and Body Weight (DCI: LS1.C; PE: HS-LS1-7)				+				+

[1] Model = Developing and Using Models; Investigation = Planning and Carrying out Investigations; Data = Analyzing and Interpreting Data; Explain = Constructing Explanations and Designing Solutions; Argue = Engaging in Argument from Evidence

[2] Mechanism = Cause and effect: Mechanism and explanation; Models = Systems and System Models; Energy = Energy and Matter: Flows, Cycles and Conservation

Learning Activities for Disciplinary Core Idea (DCI) **LS1.C - Organization for Matter and Energy Flow in Organisms**

LS2.B - Photosynthesis and Cellular Respiration – Carbon Cycle

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities help to prepare students to meet **Performance Expectations** (PE)

- HS-LS1-5, "Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy."
- HS-LS1-7, "Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy."
- HS-LS2-5. "Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere..."

[1] Model = Developing and Using Models; Investigation = Planning and Carrying out Investigations; Data = Analyzing and Interpreting Data; Explain = Constructing Explanations and Designing Solutions; Argue = Engaging in Argument from Evidence

[2] Mechanism = Cause and effect: Mechanism and explanation; Models = Systems and System Models; Energy = Energy and Matter: Flows, Cycles and Conservation

Learning Activities for Disciplinary Core Ideas (DCI) **LS2.A – Interdependent Relationships in Ecosystems**

LS2.B – Cycles of Matter and Energy Transfer in Ecosystems

LS2.C – Ecosystem Dynamics, Functioning and Resilience

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities prepare students to meet **Performance Expectations** (PE)

- MS-LS2-3. "Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem."
- HS-LS2-1,"Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems..."
- HS-LS2-2, "Use mathematical representations to support and revise explanations based on evidence about factors affecting... populations in ecosystems..."
- HS-LS2-4. "Use a mathematical representation 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."
- 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."

Activity	Scientific Practices[1]					Crosscutting concepts[2]			
	Model	Math	Data	Explain	Argue	Mechanism	Models	Stability/ Change	Energy/ Matter
Population Growth - Exponential and Logistic Models vs.	+	+	+	+			+	+	

Complex Realities (DCI: LS2.A, LS2.C; PE: HS-LS2-1, HS-LS2-2)									
Food Webs, Energy Flow, Carbon Cycles and Trophic Pyramids (DCI: LS2.B; PE: MS-LS2-3, HS-LS2-4, HS-LS2-5	+	+	+	+					+
Changing Biological Communities - Disturbance and Succession (DCI: LS2.C)	+		+	+	+	+	+	+	

[1] Model = Developing and Using Models; Math = Using Mathematics and Computational Thinking; Data = Analyzing and Interpreting Data; Explain = Constructing Explanations; Argue = Engaging in Argument from Evidence

[2] Mechanism = Cause and effect: Mechanism and explanation; Models = Systems and system models; Stability/Change = Stability and Change; Energy/Matter= Energy and Matter: Flows, Cycles and Conservation

NGS Standard: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity (HS-LS2-7).

Culminating Showcase Lesson: Bye, Bye Birdie

https://www.populationeducation.org/sites/default/files/activity-bye_bye_birdie.pdf

Curriculum CD: Earth Matters,Biodiversity (Earth Matters Unit)

Grade Level: High School

Subjects: biology, environmental science, language arts, civics

Lesson Objectives: In this lesson students will be able to:

- Develop criteria that ecologists, wildlife managers, and public officials might use to make decisions about protecting endangered species.
- Conduct research on an endangered species through the Internet and other sources.
- Present their findings, showing how their species measures up against the chosen decision criteria.

Many human activities have adverse effects on the environment. Human induced climate change, deforestation, land use conversion, and pollution are causing a great loss in species biodiversity across the planet. Scientists estimate that as much as species could go extinct by the year 2020, and some argue humans are the primary driver behind a sixth mass extinction. High species biodiversity provides many valuable ecosystem services that keep our planet in equilibrium. With the rate of wildlife endangerment increasing, difficult decisions are required in order to prioritize efforts to save endangered species. In Bye, Bye Birdie students determine which factors should be considered in species conservation and conduct research on an endangered species to justify it preservation.

Note: This lesson is targeted to meet NGS Standard HS-LS2-7 –however– it is most closely aligned to its supporting Disciplinary Core Idea LS4.D (by grade 12), which examines the ways in which humans adversely impact biodiversity. This activity should be used to supplement a series of lessons aimed at meeting standard HS-LS2-7.

Units 2 and 4 Activities- Cell Specialization, Homeostasis, and DNA/Inheritance

Learning Activities for Disciplinary Core Idea (DCI) **LS1.A - Structure and Function (Part 1)**

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities help to prepare students to meet **Performance Expectations** (PE):

- MS-LS1-2, "Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function."

- MS-LS1-3, "Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells."

Activity[1]	Scientific Practices[2]						Crosscutting Concepts[3]		
	Model	Investigation	Data	Explain	Argue	Info	Mechanism	Models	Structure/Function
Structure and Function of Cells, Organs and Organ Systems (DCI: LS1.A; PE: MS-LS1-2, MS-LS1-3)[4]				+	+	+			+
Diffusion Across a Selectively Permeable Membrane (DCI: LS1.A; PE: MS-LS1-2)	+	+	+	+			+	+	+
Introduction to Osmosis (DCI: LS1.A; PE: MS-LS1-2)		+	+	+			+		+

[1]For each activity, Student Handouts and Teacher Notes with instructional suggestions and background information are available at the link given.

[2]Model = Developing and Using Models; Investigation = Planning and Carrying out Investigations; Data = Analyzing and Interpreting Data; Explain = Constructing

Explanations and Designing Solutions; Argue = Engaging in Argument from Evidence; Info = Obtaining, Evaluating and Communicating Information

[3]Mechanism = Cause and effect; Mechanism and explanation; Models = Systems and system models; Structure/Function = Structure and function

[4]DCI = Disciplinary Core Idea; PE = Performance Expectation. Additional information is provided in the Teacher Notes (see footnote 1) and the Next Generation Science Standards website where you can use the search function to find more specifics.

Learning Activities for Disciplinary Core Ideas (DCI) **LS1.A - Structure and Function (Part 2) and**

LS1.B - Growth and Development of Organisms

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities help to prepare students to meet **Performance Expectations** (PE)

- HS-LS1-1, "Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells."
- HS-LS1-2, "Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms."
- HS-LS1-3. "Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis."
- HS-LS1-4, "Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms."

Activity	Scientific Practices[1]						Crosscutting Concepts[2]		
	Ask	Model	Investigation	Data	Explain	Argue	Models	Structure and function	Stability/ change
Understanding the Functions of Proteins and DNA (DCI: LS1.A, LS3.A; PE: HS-LS1-1, HS-LS3-1)			+		+			+	

Enzymes Help Us Digest Food (DCI: LS1.A; PE: HS-LS1-1, HS-LS1-2)			+	+	+			+	
Structure and Function of Molecules and Cells (DCI: LS1.A; PE: HS-LS1-1)					+	+		+	
DNA (DCI: LS1.A, LS3.A; PE: HS-LS1-1, MS-LS3-1, HS-LS3-1)		+			+			+	
DNA Structure, Function and Replication (DCI: LS1.A, LS3.A; PE: HS-LS1-1, MS-LS3-1, HS-LS3-1)		+			+			+	
From Gene to Protein - Transcription and Translation (DCI: LS1.A,		+					+	+	

LS3.A, LS3.B; PE: HS-LS1-1, HS-LS3-1)									
Mitosis - How Each New Cell Gets a Complete Set of Genes (DCI: LS1.A, LS1.B, LS3.A; PE: MS-LS3-2, HS-LS1-4, HS-LS3-1)		+			+		+	+	
Meiosis and Fertilization - Understanding How Genes Are Inherited (DCI: LS1.A, LS1.B, LS3.A, LS3.B; PE: MS-LS3-2, HS-LS3-1, HS-LS3-2)		+			+		+		
Homeostasis and Negative Feedback - Concepts and Breathing Experiments (DCI: LS1.A; PE: HS-LS1-3)	+		+	+	+				+

[1] Ask = Asking Questions; Model = Developing and Using Models; Investigation = Planning and Carrying out Investigations; Data = Analyzing and Interpreting Data; Explain = Constructing Explanations; Argue = Engaging in Argument from Evidence

[2] Models = Systems and system models; Structure/Function = Structure and function; Stability/Change = Stability and Change

Learning Activities for Disciplinary Core Idea (DCI) **LS3A – Inheritance of Traits**

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities help to prepare students to meet **Performance Expectations** (PE)

- MS-LS3-1, "Develop and use a model to describe why structural changes to genes located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism."
- 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."

Activity	Scientific and Engineering Practices[1]					Crosscutting Concepts[2]		
	Model	Investigation	Data	Explain	Argue	Mechanism	Models	Structure/ Function
Mitosis - How Each New Cell Gets a Complete Set of Genes (DCI: LS1.A, LS1.B, LS3.A; PE: MS-LS3-2, HS-LS1-4, HS-LS3-1)	+			+			+	+
Meiosis and Fertilization - Understanding	+			+			+	

How Genes Are Inherited (DCI: LS1.A, LS1.B, LS3.A, LS3.B; PE: MS-LS3-2, HS-LS3-1, HS-LS3-2)								
Genetics (DCI: LS1.A, LS3.A, LS3.B; PE: HS-LS3-1, HS-LS3-2, HS-LS3-3)	+		+	+	+		+	
Soap Opera Genetics - Genetics to Resolve Family Arguments (DCI: LS1.A, LS3.A, LS3.B; PE: HS-LS3-1, HS-LS3-2, HS-LS3-3)	+			+	+		+	
Understanding the Functions of Proteins and DNA (DCI: LS1.A, LS3.A; PE: HS-LS1-1, HS-LS3-1)		+		+				+
DNA (DCI: LS1.A, LS3.A; PE: HS-LS1-1, MS-LS3-	+			+				+

1, HS-LS3-1)								
DNA Structure, Function and Replication (DCI: LS1.A, LS3.A; PE: HS-LS1-1, MS-LS3-1, HS-LS3-1)	+			+				+
From Gene to Protein - Transcription and Translation (DCI: LS1.A, LS3.A, LS3.B; PE: HS-LS1-1, HS-LS3-1)	+						+	+
Genetic Engineering Challenge - How can scientists develop a type of Rice that could prevent vitamin A deficiency? (DCI: LS1.A, LS3.A; PE: HS-LS3-1)				+*		+		+

*Includes Engineering Practice = Designing solutions

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[2] Mechanism = Cause and Effect: Mechanism and explanation; Models = Systems and System Models; Structure/Function = Structure and Function

Units 5 and 6 Activities: Natural Selection and Evolution

Learning Activities for Disciplinary Core Ideas (DCI) **LS4.A - Evidence of Common Ancestry and Diversity**

LS4.B - Natural Selection and **LS4.C - Adaptation**

(from http://serendip.brynmawr.edu/exchange/bioactivities/NGSS)

These activities prepare students to meet **Performance Expectations** (PE)

- MS-LS4-4, "Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment."
- MS-LS4-6, "Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time."
- HS-LS4-2, "Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment."
- HS-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-LS4-4, "Construct an explanation based on evidence for how natural selection leads to adaptation of populations"
- HS-LS4-5, "Evaluate the evidence supporting claims that changes in environmental conditions may result in increases in the number of individuals of some species..."
- HS-LS4-1, "Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence."

Activity	Scientific Practices[1]					Crosscutting Concepts[2]			
	Model	Math	Data	Explain	Argue	Mechanism	Models	Structure/ Function	Stability/ Change
How could complex eyes	+			+	+			+	+

have evolved? (DCI: LS4.A, LS4.C; PE: HS-LS4-1)									
Evolution by Natural Selection (DCI: LS4.B, LS4.C; PE: MS-LS4-4, MS-LS4-6, HS-LS4-2, HS-LS4-3, HS-LS4-4)	+	+	+	+	+	+	+		+
Natural Selection - Major Concepts and Learning Activities (DCI: LS4.B, LS4.C; PE MS-LS4-4, MS-LS4-6, HS-LS4-2, HS-LS4-3, HS-LS4-4)	+	+	+	+	+	+	+		+ See
Using Molecular and Evolutionary Biology to Understand HIV/AIDS and Treatment (DCI: LS3.A LS4.B; PE: HS-LS4-4)				+		+		+	+
Evolution and Adaptations (DCI: LS4.B, LS4.C; PE: HS-			+	+	+	+			+

LS4-4)									
The Ecology of Lyme Disease (DCI: LS4.C; PE: HS-LS4-5)			+	+	+				+

[1] Model = Developing and Using Models; Math = Using Mathematics and Computational Thinking; Data = Analyzing and Interpreting Data; Explain = Constructing Explanations; Argue = Engaging in Argument from Evidence

[2] Mechanism = Cause and effect: Mechanism and explanation; Models = Systems and system models; Structure/Function = Structure and function Stability/Change = Stability and change

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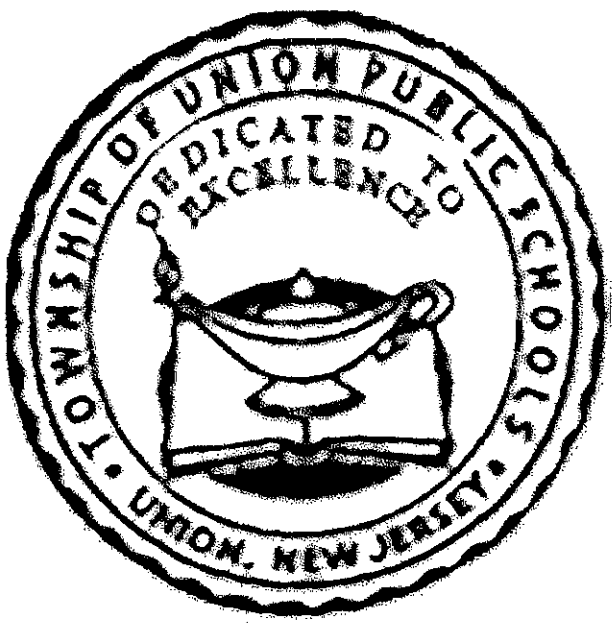

College Preparatory Biology

Curriculum Guide2016

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Biology

References

The following curriculum guide was adapted from the Next Generation Science Standards and the State of New Jersey Department of Education High School Biology Model Curriculum.

"Model Curriculum: HS Biology." *Model Curriculum; HS Biology*. State of New Jersey. 2014. Web. 22 Apr. 2016.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press. Web. 22 Apr. 2016.

Curriculum Unit Overview

Unit 1- Interdependent Relationships in Ecosystems & Population Dynamics

Unit 2- Structure & Function

Unit 3- Matter and Energy in Organisms and Ecosystems

Unit 4- Inheritance and Variation of Traits

Unit 5- Natural Selection and Mechanisms of Evolution

Unit 6- Evidence of Evolution, Relationships and Common Ancestry

Curriculum Pacing Guide – College Preparatory Biology

Unit Name	Estimated Number of Days
Unit 1- Interdependent Relationships in Ecosystems & Population Dynamics	30
Unit 2- Structure & Function	30
Unit 3- Matter and Energy in Organisms and Ecosystems	30
Unit 4- Inheritance and Variation of Traits	45
Unit 5- Natural Selection and Mechanisms of Evolution	20
Unit 6- Evidence of Evolution, Relationships and Common Ancestry	25

Course Proficiencies

For all units, students will understand and follow all laboratory and safety rules, understand scientific explanations, generate scientific evidence through active investigations, reflect on scientific knowledge and participate productively in science.

Unit 1- Interdependent Relationships in Ecosystems & Population Dynamics

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. Additionally, 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. 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.

Unit 2- Structure & Function

Students formulate an answer to the question "*How do the structures of organisms enable life's functions?*" Students 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.

Unit 3- Matter and Energy in Organisms and Ecosystems

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.

Unit 4- Inheritance and Variation of Traits

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.

Unit 5- Natural Selection and Mechanisms of Evolution

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 a organizing concepts for the disciplinary core ideas. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.

Unit 6- Evidence of Evolution, Relationships and Common Ancestry

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.

Unit 1 Summary

Interdependent Relationships in Ecosystems & Population Dynamics

How do organisms interact with the living and nonliving environments to obtain matter and energy?

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.

Student Learning Objectives

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. LS2.A

Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. *[Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.]* (HS-LS2-1)

Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. *[Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]* (HS-LS2-2)

Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. *[Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.]* (HS-LS2-6)

Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. *[Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]* (HS-LS2-7)

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.[Clarification Statement: Emphasis is on: (1)

distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming. (HS-LS2-8)

Unit Sequence

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

Concepts	Formative Assessment
• Ecosystems have carrying capacities, which are limits to the number of organisms and populations they can support. • These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, completion, and disease. • Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (the number of individuals) of species in any given ecosystem. • The significance of carrying capacity in ecosystems is dependent on the scale proportion and quantity at which it occurs. • Quantitative analysis can be used to compare and determine relationships among interdependent factors that affect the carrying capacity of ecosystems at different scales.	*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. • Use quantitative analysis to compare relationships among interdependent factors and represent their effects on the carrying capacity of ecosystems at different scales.

Unit Sequence

Part B: *What limits the number and types of different organisms that live in one place?*

Concepts	Formative Assessment
• 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	*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.

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.	

Unit Sequence

Part C: *How can a one or two inch rise in sea level devastate an ecosystem?*

Concepts	**Formative Assessment**
• Much of science deals with constructing explanations of how things change and how they remain stable. • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. • If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem) as opposed to becoming a very different ecosystem. • Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.	*Students 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. • Construct explanations of how modest biological or physical changes versus extreme changes affect stability and change in ecosystems.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

• Cite specific textual evidence to support analysis of science and technical texts supporting explanations of factors that affect carrying capacity of ecosystems at

different scales, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

- Develop and write explanations of factors that affect carrying capacity of ecosystems at different scales by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
- Cite specific textual evidence to support how factors affect biodiversity and populations in ecosystems of different scale, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write explanatory texts based on scientific procedures/experiments to explain how different factors affect biodiversity and populations in ecosystems at different scales.
- Assess the extent to which the claim 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, is supported by reasoning and evidence.
- Cite specific textual evidence to support claims 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, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address claims 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.
- Evaluate the validity of evidence and reasoning that support claims 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, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Mathematics

- Represent the factors that affect carrying capacity of ecosystems at different scales symbolically and manipulate the representing symbols. Make sense of quantities and relationships between different factors that affect carrying capacity of ecosystems at different scales.
- Use a mathematical model to describe factors that affect carrying capacity of ecosystems at different scales. Identify important quantities in factors that affect carrying capacity of ecosystems at different scales and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand how factors affect the carrying capacity of ecosystems at different scales. Choose and interpret units consistently in formulas to determine carrying capacity. Choose and interpret the scale and origin in graphs and data displays showing factors that affect carrying capacity of ecosystems at different scales.
- Define appropriate quantities for the purpose of descriptive modeling of factors that affect carrying capacity of ecosystems at different scales.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing factors that affect carrying capacity of ecosystems at different scales.
- Represent the factors that affect biodiversity and populations in ecosystems symbolically and manipulate the representing symbols. Make sense of quantities and relationships between different factors and their effects on biodiversity and populations in ecosystems.
- Use a mathematical model to describe the factors that affect biodiversity and populations in ecosystems. Identify important quantities in factors that affect biodiversity and populations in ecosystems and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting

on the results and improving the model if it has not served its purpose.

- Use units as a way to understand factors that affect biodiversity and populations in ecosystems.
- Choose and interpret units consistently in formulas to determine effects on biodiversity and populations in ecosystems. Choose and interpret the scale and the origin in graphs and data displays representing the factors that affect biodiversity and populations in ecosystems.
- Define appropriate quantities for the purpose of descriptive modeling of the factors that affect biodiversity and populations in ecosystems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities of the factors that affect biodiversity and populations in ecosystems.
- Represent claims 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 symbolically and manipulate the representing symbols. Make sense of quantities and relationships between complex interactions in ecosystems and ways in which ecosystems remain stable and ways in which they change.
- Represent data relating to complex interactions in ecosystems and their effects on stability and change in ecosystems with plots on the real number line (graph).
- Understand statistics as a process for making inferences about complex interactions in ecosystems and organism population parameters based on a random sample from that population.
- Evaluate reports of complex interactions and their effects on stability and change in ecosystems based on data showing numbers and types of organisms in stable conditions and in changing conditions.

Suggested Learning Activities

Predator/Prey Relationships: Students will construct and interpret graphs to correlate relationships between population sizes of predator and prey.

Infectious Disease Lab: Students will model spread of disease (density dependent factor) and the exponential growth of bacterial populations.

Human Population Age Structure Study: Students will compare age structure histograms to predict future trends for developing and developed countries.

Live and Let Live Group Project: Students will work in cooperative learning groups to develop a plan to accommodate an increase in human population while having a minimal impact on surrounding ecosystem.

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).

World In Balance Film: Students will view film that reviews age structure trends within various countries.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. *[Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.]* (HS-LS2-1)

Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. *[Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]* (HS-LS2-2)

Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. *[Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.]* (HS-LS2-6)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	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	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.	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

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)	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 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)	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)

Unit 2 Summary

Structure and Function

How do the structures of organisms enable life's functions?

Students formulate an answer to the question *"How do the structures of organisms enable life's functions?"* Students 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.

Student Learning Objectives

Explain the connection between the sequence and the subcomponents of a biomolecule and its properties. *[Clarification Statement: Emphasis is on the general structural properties that define molecules. Examples include r-groups of amino acids, protein shapes, the nucleotide monomers of DNA and RNA, hydrophilic and hydrophobic regions.] [Assessment Boundary: Assessment does not include identification or the molecular sequence and structure of specific molecules]* (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. (LS1.A)

Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. *[Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]* **(HS-LS1-1)**

Construct models that explain the movement of molecules across membranes with membrane structure and function. *[Clarification Statement: Emphasis is on the structure of cell membranes, which results in selective permeability; the movement of molecules across them via osmosis, diffusion and active transport maintains dynamic homeostasis.]* (LS1.A)

Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. *[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]* **(HS-LS1-2)**

Provide examples and explain how organisms use feedback systems to maintain their internal environments. (LS1.A)

Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. *[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]* **(HS-LS1-3)**

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. *[Assessment Boundary:*

Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.] **(HS-LS1-4)**

Unit Sequence

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.

Unit Sequence

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.

Unit Sequence

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.

Unit Sequence

Part D: *Why aren't all elephants the same size?*

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.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Write an explanation that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Draw evidence from informational texts to support how the structure of DNA determines the structure of proteins, which carry out the essential functions of life

through systems of specialized cells.

- Make strategic use of digital media in presentations to enhance understanding of the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- Conduct short as well as more sustained research to determine how feedback mechanisms maintain homeostasis. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- Gather applicable information from multiple reliable sources to support claims that feedback mechanisms maintain homeostasis. Use 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.
- Make strategic use of digital media in presentations to enhance understanding of the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Mathematics

- Use a mathematical model to illustrate the role of cellular division and differentiation in producing and maintaining complex organisms. Identify important quantities in the role of cellular division and differentiation in producing and maintaining complex organisms and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Graph functions expressed symbolically showing the role of cellular division and differentiation in producing and maintaining complex organisms and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
- Write a function that describes a relationship between the role of cellular division and differentiation and the production and maintenance of complex organisms.

Suggested Learning Activities

Model of phospholipid bilayer: Students will recognize structural components of fluid mosaic model.

Osmosis Egg Demonstration: Students will predict cell response to a change in osmotic conditions.

Osmosis in Onion Cell Lab: Students will utilize microscope techniques to observe cell structures that regulate osmotic pressure to maintain homeostasis.

Osmosis & Diffusion Webquest: Students will use internet simulations to study active and passive transport.

Modeling endocytosis and exocytosis: Students will investigate the types of active transport in cells.

Enzyme Liver Lab (Chemical Reactions and Catalysts in Living Organisms): Students will observe the impact of temperature and pH on enzyme activity via. analysis of data.

Amalyse cracker demonstration: Students will use sense of taste in recognizing specificity of digestive enzymes in the body.

Murder Food Lab (macromolecule identification): Students will apply various chemical tests to determine presence or absence of macromolecules of unknown sample.

Methods of Assessment
-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion
Appendix A: NGSS and Foundations for the Unit
Explain the connection between the sequence and the subcomponents of a biomolecule and its properties. *[Clarification Statement: Emphasis is on the general structural properties that define molecules. Examples include r-groups of amino acids, protein shapes, the nucleotide monomers of DNA and RNA, hydrophilic and hydrophobic regions.] [Assessment Boundary: Assessment does not include identification or the molecular sequence and structure of specific molecules]* (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. (LS1.A)
Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. *[Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]* **(HS-LS1-1)**
Construct models that explain the movement of molecules across membranes with membrane structure and function. *[Clarification Statement: Emphasis is on the structure of cell membranes, which results in selective permeability; the movement of molecules across them via osmosis, diffusion and active transport maintains dynamic homeostasis.]* (LS1.A)
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. *[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]* (HS-LS1-2)
Provide examples and explain how organisms use feedback systems to maintain their internal environments. (LS1.A)
Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. *[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]* **(HS-LS1-3)**
Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. *[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]* **(HS-LS1-4)**

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices	Disciplinary Core Ideas	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)

Unit 3 Summary
Matter and Energy in Organisms and Ecosystems

How do matter and energy cycle through ecosystems?

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.

This unit is based on HS-LS1-5, HS-LS2-3, HS-LS2-4, and HS-LS2-5.

Student Learning Objectives

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.]* [Assessment Boundary: Assessment does not include specific biochemical steps.] **(HS-LS1-5)**

Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. *[Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.] [Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]* **(HS-LS2-3)**

Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. *[Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.]* **(HS-LS2-4)**

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. *[Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]* **(HS-LS2-5)**

Unit Sequence

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

Concepts	Formative Assessment
• 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)	*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

provide most of the energy for life processes.	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.

Unit Sequence

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

Concepts	**Formative Assessment**
• Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. • At each link in an ecosystem, matter and energy are conserved. • Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward to produce growth and release energy in cellular respiration at the higher level. • Given this inefficiency, there are generally fewer organisms at higher levels of a food web. • Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. • The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways.	*Students who understand the concepts are able to:* • 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.

Unit Sequence

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,	*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

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.	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.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Develop and write an explanation, based on evidence, for the cycling of matter and flow of energy in aerobic and anaerobic conditions by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples.
- Develop and strengthen an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

Mathematics

- Represent the cycling of matter and flow of energy among organisms in an ecosystem symbolically and manipulate the representing symbols. Make sense of quantities of and relationships between matter and energy as they cycle and flow through an ecosystem.
- Use a mathematical model to describe the cycling of matter and flow of energy among organisms in an ecosystem. Identify important quantities in the cycling of matter and flow of energy among organisms in an ecosystem and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the cycling of matter and flow of energy among organisms in an ecosystem. Choose and interpret units consistently in formulas to determine the cycling of matter and flow of energy among organisms in an ecosystem. Choose and interpret the scale and the origin in graphs and data displays representing the cycling of matter and flow of energy among organisms in an ecosystem.
- Define appropriate quantities to represent matter and energy for the purpose of descriptive modeling of their cycling and flow among organisms in ecosystems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing matter cycles and energy flows among organisms in ecosystems.

Suggested Learning Activities

Experiments in Photosynthesis Film: Students will make predictions on plant response to various conditions pertaining to the reactants and products of photosynthesis.

Photosynthesis Web- Quest: Students will utilize internet resources to observe and make predictions on factors that affect the process of photosynthesis including light intensity, water availability and gas exchange.

Surviving Winter in the Dust Bowl (Food Chains and Trophic Levels): 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.

Exercise & Cellular Respiration Lab: Students will compare rate of aerobic cellular respiration before and after physical activity to confirm the production of CO_2 during aerobic respiration.

Lactic Acid Fermentation in Human Muscle Cells Investigation: Students will investigate the relationship between aerobic respiration, anaerobic respiration and muscle fatigue in living organisms.

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.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.]* [Assessment Boundary: Assessment does not include specific biochemical steps.] **(HS-LS1-5)**

Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. *[Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.] [Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]* **(HS-LS2-3)**

Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. *[Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.]* **(HS-LS2-4)**

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. *[Clarification Statement: Examples of models could include simulations and mathematical models.] [Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.]* **(HS-LS2-5)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	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 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-LS2-3) Using Mathematics and Computational Thinking • Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4) Developing and Using Models • Develop a model based on evidence to illustrate the relationships between systems or components of a system. (HS-LS1-5),(HS-LS2-5)	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) LS2.B: Cycles of Matter and Energy Transfer in Ecosystems • 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	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 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) 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-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)

	geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)	

Unit 4 Summary
Inheritance and Variation of Traits

How are characteristics from one generation related to the previous generation?

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.

Student Learning Objectives

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. *[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]* (HS-LS1-4)

Explain *how* the process of meiosis results in the passage of traits from parent to offspring, and how that results in increased genetic diversity necessary for evolution. *[Clarification Statement: The emphasis is on how meiosis results in genetic diversity, not the rote memorization of the steps of meiosis.]* (LS1.B)

Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. *[Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]* (HS-LS3-1)

Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. (LS3.B)

Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. *[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]* (HS-LS3-2)

Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. *[Clarification Statement: Emphasis on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]* (HS-LS3-3)

Unit Sequence

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

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

Unit Sequence

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	*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.

from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.	

Unit Sequence

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.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, resolving conflicting information when possible.
- Cite specific textual evidence to support analysis of science and technical texts describing the ways that inheritable genetic variation occurs, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write arguments, 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.

Mathematics

- Represent symbolically 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, and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict the ways in which inheritable genetic variation occurs.
- Represent the variation and distribution of expressed traits in a population symbolically and manipulate the representing symbols. Make sense of quantities and

relationships to describe and predict the variation and distribution of expressed traits in a population.

Suggested Learning Resources

Structure and Function: Stem Cell: 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.

Modeling DNA Replication, Transcription and Translation Activities: Model the process of protein synthesis utilizing the genetic codon chart to show how DNA determines the structure of proteins which determine physical characteristics in organisms.

DNA Extraction Lab: Through active investigation of extraction human cheek cells, students will understand the technique and applications of DNA extraction.

Determining Structure of DNA Investigation: Students will analyze given set of data to construct an argument about the molecular structure of DNA. Students will compare synthesized models to determine the validity of their argument.

Karyotype & Pedigree STEM project: Students will explore, explain, elaborate and evaluate karyotypes and pedigrees of human chromosomal disorder case studies.

Probability Lab: Students will be introduced to concepts of probability and inheritance by applying concepts of statistics to bead models.

Investigating Corn Genetics: Students will collect and analyze data of corn kernel population and apply test cross methods in determining genotypes of P generation.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. [*Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.*] **(HS-LS1-4)**

Explain *how* the process of meiosis results in the passage of traits from parent to offspring, and how that results in increased genetic diversity necessary for evolution. [*Clarification Statement: The emphasis is on how meiosis results in genetic diversity, not the rote memorization of the steps of meiosis.]*(LS1.B)

Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*] **(HS-LS3-1)**

Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. (LS3.B)

Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. *[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]*

(HS-LS3-2)

Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. *[Clarification Statement: Emphasis on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]* (HS-LS3-3)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems • Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1) **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-LS1-1) **Engaging in Argument from Evidence** • 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)	**LS1.A: Structure and Function** • 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 HS-LS3-1) **LS3.A: Inheritance of Traits** • 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) **LS3.B: Variation of Traits** • 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	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HSLS3-1; HSLS3-2) **Scale, Proportion, and Quantity** • 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)

	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)	

Unit 5 Summary

Natural Selection and Mechanisms of Evolution

How can there be so many similarities among organisms yet so many different plants, animals, and microorganisms?

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.

This unit is based on Disciplinary Core Idea LS4.C (Adaptation), HS-LS4-4, HS-LS4-3, HS-LS4-5, and HS-LS2-8.

Student Learning Objectives

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

Construct an explanation based on evidence for how natural selection leads to adaptation of populations. *[Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]* **(HS-LS4-4)**

Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. *[Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]* **(HS-LS4-3)**

Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2)

the emergence of new species over time, and (3) the extinction of other species. *[Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]* **(HS-LS4-5)**

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. *[Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]* **(HS-LS2-8)**

Unit Sequence

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

Concepts	Formative Assessment
• 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 natural laws operate today as they did in the past and will continue to do so in the future.	*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.

Unit Sequence

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	*Students who understand the concepts are able to:* • Apply concepts of statistics and probability (including determining function

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.	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.
Unit Sequence	
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.
Unit Sequence	

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. • Empirical evidence is required to differentiate between cause and correlation and to make claims about the role of group behavior in individual and species' chances to survive and reproduce. • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in the revision of an explanation about the role of group behavior on individual and species' chances to survive and reproduce.	*Students who understand the concepts are able to:* • Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. • Distinguish between group and individual behavior. • Identify evidence supporting the outcome of group behavior. • Develop logical and reasonable arguments based on evidence to evaluate the role of group behavior on individual and species' chances to survive and reproduce. • Use empirical evidence to differentiate between cause and correlation and to make claims about the role of group behavior on individual and species' chances to survive and reproduce.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing how natural selection leads to adaptation of populations, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write informative/explanatory texts describing how natural selection leads to adaptation of populations, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Draw evidence from informational texts to support analysis, reflection, and research about how natural selection leads to adaptation of populations.
- Cite specific textual evidence to support analysis of science and technical texts that provide explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write informative/explanatory texts about explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Draw evidence from information texts to support analysis, reflection, and research about organisms with an advantageous heritable trait and their proportional increase as compared to organisms lacking this trait.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text 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, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

- Draw evidence from information texts making 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 to support analysis, reflection, and research.
- Assess the extent to which the reasoning and evidence in a text support the author's claim about the role of group behavior on individual and species' chances to survive and reproduce.
- Cite specific textual evidence to support analysis of science and technical texts about the role of group behavior on individual and species' chances to survive and reproduce.
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address the role of group behavior on individual and species' chances to survive and reproduce.
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text about the role of group behavior on individual and species' chances to survive and reproduce, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Mathematics

- Represent how natural selection leads to adaptation of populations symbolically, and manipulate the representing symbols. 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.
- Represent symbolically the proportional increase in organisms with an advantageous heritable trait as compared with organisms lacking this trait, and manipulate the representing symbols. Make sense of quantities and relationships between the proportional increase in organisms with an advantageous heritable trait as compared with the numbers of organisms lacking this trait.

Suggested Learning Activities

Peppered Moth Evolution: Students explain how variation, selection, and time drive the process of evolution by collecting and analyzing data within peppered moth population. Students will construct graphical representations to visualize trend of change over time within population of moths.

Desert Snakes (Mechanics of Evolution): Students will generate argument using multiple lines of evidence presented via. text, data tables and photos to defend claim about physical similarities between snakes. Students will present and justify their claim to classmates.

Modeling the Process of Natural Selection: Class will act as a varied population of living organisms that over time will change due to external and internal factors.

Genetic Drift Activity: Students will analyze shifts in numerical distribution of traits due to density independent factors.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

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

Construct an explanation based on evidence for how natural selection leads to adaptation of populations. *[Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]* **(HS-LS4-4)**

Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. *[Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]* **(HS-LS4-3)**

Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. *[Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]* **(HS-LS4-5)**

Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. *[Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]* **(HS-LS2-8)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	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. • 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,	**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	**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)

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 or solutions to determine the merits of arguments. (HS-LS4-5)	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 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)	

Unit 6 Summary

Evidence of Evolution, Relationships and Common Ancestry

What evidence shows that different species are related?

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.

Student Learning Objectives

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. (LS4.A)

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. *[Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]* **(HS-LS4-1)**

Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. *[Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]* **(HS-LS4-2)**

Unit Sequence

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.	*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

• Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. • Different patterns in multiple lines of empirical evidence may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of common ancestry and biological evolution.	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.

Unit Sequence

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.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing common ancestry and biological evolution, attending to important

distinctions the author makes and to any gaps or inconsistencies in the account.

- Write informative/explanatory texts describing common ancestry and biological evolution, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Draw evidence from informational texts describing common ancestry and biological evolution to support analysis, reflection, and research.
- Present claims and findings about common ancestry and biological evolution, 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.

Mathematics

- Represent evidence that common ancestry and biological evolution are supported by multiple lines of empirical evidence symbolically, and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict common ancestry and biological evolution.

Suggested Learning Activities

Anatomical Evidence of Evolution Investigation: Students investigate evidence for evolution by analyzing fossil evidence, structural evidence, and genetic evidence in support of common ancestry among living things.

Construction of Cladograms: Students will interpret cladograms and synthesize cladograms to identify shared characteristics and make inferences about the evolutionary history of the group.

Evolutionary Relationships in Mammals: Students will compare amino acid sequences, homologous structures and photographs of various animals to make a claim that incorporates phylogeny between mammal species.

Methods of Assessment

-Do Now, Exit Tickets, Question and Answer techniques, Polling, Debate, Quizzes, Projects, Writing Prompts, Exams, Departmental Cumulative Assessments, Lab performance and analysis, Classwork & Homework reinforcement techniques, Discussion

Appendix A: NGSS and Foundations for the Unit

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. *[Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]* **(HS-LS4-1)**

Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. *[Clarification Statement: Emphasis is on using evidence to*

explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.] **(HS-LS4-2)**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	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 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)	**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)