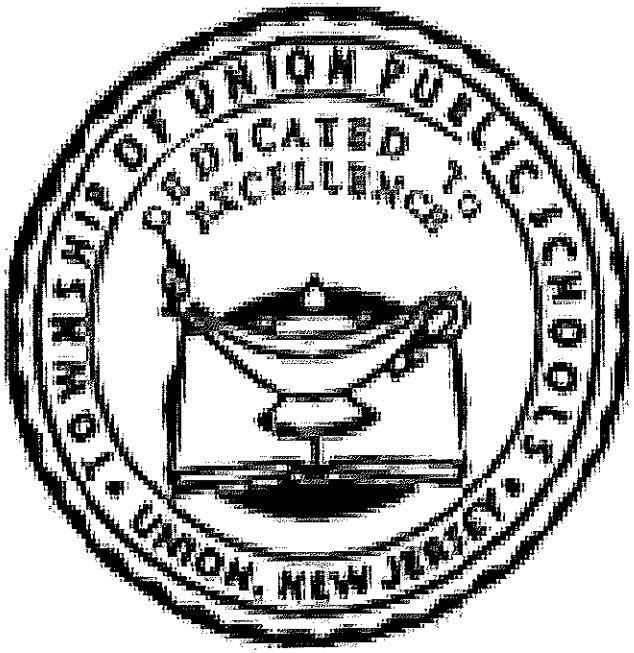
TOWNSHIP OF UNION PUBLIC SCHOOLS



SC310 Advanced Placement Biology

SC310L Advanced Placement Biology Lab

Curriculum Guide June 2016

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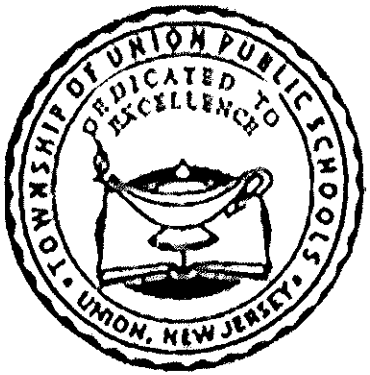

TOWNSHIP OF UNION PUBLIC SCHOOLS

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William Soranno

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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 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-LS1-4** 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 melosis. **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