AP Biology

Unit 1: Chemistry of Life

ESSENTIAL QUESTION	BIG IDEAS
How do the elements make "life"?	• Students will understand the role of energy in the making and breaking of polymers. • Students will understand how living systems transmit information in order to ensure their survival. • Students will understand how the polarity of water affects the function of living systems

GUIDING QUESTIONS

Content:

- 1.1 How do the properties of water that result from its polarity and hydrogen bonding affect its biological function?
- 1.2 What is the composition of macromolecules required by living organisms (carbohydrates, lipids, proteins, & nucleic acids)?
- 1.3-1.4 What are the properties of the monomers and what types of bonds connect the monomers in biological macromolecules?
- 1.5 How does a change in the subunits of a polymer lead to changes in structure or function of the macromolecule?
- 1.6 What are the structural similarities and differences between DNA and RNA.
- 3.1 What are the properties of enzymes?
- 3.2 How do enzymes affect the rate of biological reactions?
- 3.3a How do changes to the structure of an enzyme may affect its function?
- 3.3b How does the cellular environment affect enzyme activity?

Process:

- Using evidence from models of the structure of various organic molecules, how can we explain the formation of amino acids and other large carbon-based molecules from the atoms found in sugars?

Reflective:

- Why is carbon called the building block of life?
- Why must organisms take in matter from their surroundings and rearrange the atoms through chemical reactions?

FOCUS STANDARDS

- **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. [HS-LS1-6]
  - As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. [HS-LS1-6]

AP Biology

Unit 2: Cell Structure and Function

ESSENTIAL QUESTION	BIG IDEAS
How is cell structure related to cell function?	• Students will understand the origin of eukaryotic cells. • Students will understand how the mechanisms for transport across membranes support energy conservation. • Students will understand the advantages and disadvantages of cellular compartmentalization. • Students will understand how living systems are affected by the presence or absence of subcellular components.

GUIDING QUESTIONS

Content:

- 2.1 What is the structure and/or function of subcellular components and organelles?
- 2.2a How do subcellular components and organelles contribute to the function of the cell?
- 2.2b What structural features of a cell allow organisms to capture, store, and use energy?
- 2.3b How are specialized structures and strategies used for the efficient exchange of molecules to the environment?
- 2.4a What are the roles of each of the components of the cell membrane in maintaining the internal environment of the cell?
- 2.4b What is the Fluid Mosaic Model of cell membranes?
- 2.5a How does the structure of biological membranes influence selective permeability?
- 2.5b What is the role of the cell wall in maintaining cell structure and function?
- 2.6a What are the mechanisms that organisms use to maintain solute and water balance?
- 2.6b What are the mechanisms that organisms use to transport large molecules across the plasma membrane?
- 2.7 How does the structure of a molecule affect its ability to pass through the plasma membrane?
- 2.8a How do concentration gradients affect the movement of molecules across membranes?
- 2.8b How do osmoregulatory mechanisms contribute to the health and survival of organisms?
- 2.9 What are the processes that allow ions and other molecules to move across membranes?
- 2.10a What are the membrane-bound structures of the eukaryotic cell?
- 2.10b How do internal membranes and membrane-bound organelles contribute to compartmentalization of eukaryotic cell functions?
- 2.11a What are the similarities and/or differences in compartmentalization between prokaryotic and eukaryotic cells?

- 2.11b What is the relationship between the functions of endosymbiotic organelles and their free-living ancestral counterparts?

Process:

- How can we develop and/or use a model to describe the structure of the cell membrane and explain how the structure regulates movement of molecules across a membrane? [Developing and Using Models]
- 2.3a What is the effect of surface area-to-volume ratios on the exchange of materials between cells or organisms and the environment?

Reflective:

- How do the principles of cell theory contribute to our understanding of the similarity of cell structure and function among living organisms?
- If an organelle or cell does not function properly, how does that impact an organism's ability to maintain homeostasis?

FOCUS STANDARDS

- **LS1.A: Structure and Function**
  - Systems of specialized cells within organisms help them perform the essential functions of life. [HS-LS1-1]
  - Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. [HS-LS1-2]
  - Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. [HS-LS1-3]

AP Biology

Unit 3: Cellular Energetics

ESSENTIAL QUESTION	BIG IDEAS
How do matter and energy move through organisms and ecosystems?	• Students will understand how energy is captured and then used by living systems. • Students will understand how organisms use energy or conserve energy to respond to environmental stimuli.

GUIDING QUESTIONS

Content:

- 3.4 What is the role of energy in living organisms?
- 3.5a What are the photosynthetic processes that allow organisms to capture and store energy?
- 3.5b How do cells capture energy from light and transfer it to biological molecules for storage and use?
- 3.6a What are the processes that allow organisms to use energy stored in biological macromolecules?
- 3.6b How do cells obtain energy from biological macromolecules in order to power cellular functions?
- 3.7 What is the connection between variation in the number and types of molecules within cells and the ability of the organism to survive and/or reproduce in different environments?

Process:

- How can a model be used to illustrate the reactants and products of cellular respiration (include how those products are used by organisms)?
- How can a model be used to illustrate the reactants and products of photosynthesis (include how the products of photosynthesis are used by organisms)?

- How can we design an experiment to test environmental factors that can affect the processes of cellular respiration and/or photosynthesis?
- How can we construct and/or revise an explanation based on evidence for the flow of energy in aerobic and anaerobic conditions?

Reflective:

- How does breathing relate to cellular respiration?
- How does cellular respiration harvest energy from food?
- Why do trees change color in the fall?

FOCUS STANDARDS

- **LS1.C: Organization for Matter and Energy Flow in Organisms**
  - The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. [HS-LS1-5]
  - As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. [HS-LS1-7]
  - 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-LS1-7]
- **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**
  - Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. [HS-LS2-3]
  - Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. [HS-LS2-4].

AP Biology

Unit 4: Cell Communication and Cell Cycle

ESSENTIAL QUESTION	BIG IDEAS
How do organisms grow and develop?	• Students will understand the ways in which cells use energy to communicate with one another. • Students will understand how the cell cycle aids in the conservation of genetic information. • Students will understand why and in what ways cells communicate with one another.

GUIDING QUESTIONS

Content:

- 4.1a How do cells communicate with one another?
- 4.1b How do cells communicate with one another over short and long distances?
- 4.2a What are the components of a signal transduction pathway?
- 4.2b What are the roles of each component of a signal transduction pathway in producing a cellular response?
- 4.3a What is the role of the environment in eliciting a cellular response?
- 4.3b What are the different types of cellular responses elicited by a signal transduction pathway?
- 4.4 How does a change in the structure of any signaling molecule affect the activity of the signaling pathway?
- 4.5a What are positive and/or negative feedback mechanisms?
- 4.5b How does negative feedback help to maintain homeostasis?
- 4.5c How does positive feedback affect homeostasis?
- 4.6a What are events that occur in the cell cycle?
- 4.6b How does mitosis result in the transmission of chromosomes from one generation to the next?
- 4.7a What is the role of checkpoints in regulating the cell cycle?

Process:

- How can a model show that the process of cell reproduction contributes to maintenance, growth, and repair? [Developing and Using Models]
- How can we use cell division mechanisms to construct an explanation as to why mitosis and meiosis are both necessary during

the human life cycle? [Constructing Explanations and Designing Solutions]

- How can evidence of mutations caused by environmental factors be used to make and defend a claim about mutations as a potential source of genetic variation in organisms? [Engaging in Argument from Evidence]
- How can an experiment be used to demonstrate how feedback mechanisms impact a living system? [Planning and Carrying Out Investigations]

Reflective:

- Why do our bodies use cell division for growth, repair, and replacement?
- 4.7b What are the effects of disruptions to the cell cycle on the cell or organism?
- How can exposing your body to certain environmental factors increase the chance for mutations to occur leading to cancer?
- How does cancer affect the human body?

FOCUS STANDARDS

- **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]
- **LS1.A: Structure and Function**
  - Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. [HS-LS1-2]
  - Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. [HS-LS1-3]

AP Biology

Unit 5: Heredity

ESSENTIAL QUESTION	BIG IDEAS
How are traits passed from parents to offspring?	• Students will understand why offspring produced by sexual reproduction are genetically diverse. • Students will understand how a phenotype is affected by various patterns of inheritance.

GUIDING QUESTIONS

Content:

- 5.1a How does meiosis result in the transmission of chromosomes from one generation to the next?
- 5.1b What are the similarities and/or differences between the phases and outcomes of mitosis and meiosis?
- 5.2 How does the process of meiosis generate genetic diversity?
- 5.3a How does the existence of shared, conserved, fundamental processes and features support the concept of common ancestry for all organisms?
- 5.4 What patterns of inheritance deviate from Mendel's model of the inheritance of traits?
- 5.5 How can the same genotype result in multiple phenotypes under different environmental conditions?
- 5.6 How does chromosomal inheritance generate genetic variation in sexual reproduction?

Process:

- 5.3b How do Mendel's laws explain the inheritance of genes and traits?
- How can statistics and probability (chi-square hypothesis testing) be used to explain the variation and distribution of expressed traits in a population?
- How can Punnett squares be used to model genetic crosses involving one trait (i.e. monohybrid cross) and to predict the genotypes and phenotypes of possible offspring given any two parental genotypes?

- How can Punnett squares be used to model genetic crosses involving two traits (i.e. dihybrid cross) and to predict the genotypes and phenotypes of possible offspring given any two parental genotypes?
- How can Punnett squares be used to model genetic crosses involving patterns of inheritance that deviate from Mendel's model of the inheritance of traits (i.e. codominance, incomplete dominance, epistasis, pleiotropy, sex-linkage, linked genes, mitochondrial inheritance, nondisjunction)?
- How can we use a pedigree to track a trait or disorder within a family?

Reflective:

- How have our ideas about inheritance changed over time?
- Why do family members look different from one another?

FOCUS STANDARDS

- **LS3.B: Variation of Traits:**
  - In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2) Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. [HS-LS3-2], [HS-LS3-3]
- **LS3.A: Inheritance of Traits:**
  - Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. [HS-LS3-1]

AP Biology

Unit 6: Gene Expression and Regulation

ESSENTIAL QUESTION	BIG IDEAS
How does information flow through living systems?	• Students will understand the structure of DNA and how it is replicated. • Students will understand the flow of information from DNA to RNA to protein. • Students will understand current techniques that are used to study and manipulate DNA.

GUIDING QUESTIONS

Content:

- 6.1a What cellular structures are involved in passing hereditary information from one generation to the next?
- 6.1b What are the characteristics of DNA that allow it to be used as the hereditary material?
- 6.2 What mechanisms copy genetic information for transmission between generations?
- 6.3 What mechanisms are involved in the flow of genetic information from DNA to RNA to protein?
- 6.4 How is the phenotype of an organism determined by its genotype?
- 6.5a What types of interactions regulate gene expression?
- 6.5b How does the location of regulatory sequences relate to their function?
- 6.6a How does the binding of transcription factors to promoter regions affect gene expression and/or the phenotype of the organism?
- 6.6b How does the regulation of gene expression connect to phenotypic differences in cells and organisms?
- 6.7a What are the various types of mutations?
- 6.7b How do changes in genotype result in changes in phenotype?
- 6.7c How do alterations in DNA sequences contribute to variation that can be subject to natural selection?

Process:

- How can we create a model that simulates DNA replication?
- How can evidence of the structure of DNA and RNA be used to construct an explanation for how the information coded in

DNA determines the structure of proteins and an organism's resulting traits?
- How can evidence of errors during replication be used to make and defend a claim about mutations as a potential source of genetic variation in organisms?
- 6.8 What genetic engineering techniques are used in the analysis or manipulation of DNA?

Reflective:
- How is our ever-increasing knowledge of DNA changing society?
- What are the cause and effect relationships between DNA, the proteins it codes for, and the resulting traits observed in an organism?
- What are the limitations, risks, and potential outcomes involved in genetic medicine and gene therapy?

FOCUS STANDARDS

- **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-LS1-1]
- **LS3.A: Inheritance of Traits:**
  - Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. [HS-LS3-1]

AP Biology

Unit 7: Evolution & Natural Selection

ESSENTIAL QUESTION	BIG IDEAS
How do species evolve over time?	• Students will explore and evaluate the various categories of evidence of evolution. • Students will understand and explain the major mechanisms of evolutionary change that lead to descent with modification. • Students will understand how evolutionary principles are applied to solve real world problems.

GUIDING QUESTIONS

Content:

- 7.1a What are the causes of natural selection?
- 7,1b How does natural selection affect populations?
- 7.2 Why is phenotypic variation important in a population?
- 7.3a How do humans affect diversity within a population?
- 7.3b What is the relationship between changes in the environment and evolutionary changes in the population?
- 7.4a How can random occurrences affect the genetic makeup of a population?
- 7.4b What is the role of random processes in the evolution of specific populations?
- 7.4c How does the genetic makeup of a population change over time?
- 7.6a What are the types of data that provide evidence for evolution?
- 7.6b How do morphological, biochemical, and geological data provide evidence that organisms have changed over time?
- 7.6c What are the fundamental molecular and cellular features shared across all domains of life, which provide evidence of common ancestry?
- 7.7 What is the structural and functional evidence on cellular and molecular levels that provides evidence for the common ancestry of all eukaryotes?
- 7.8 What evidence demonstrates that evolution is an ongoing process in all living organisms?
- 7.9a What are the types of evidence that can be used to infer an evolutionary relationship?
- 7.9b How is a phylogenetic tree and/or cladogram used to infer evolutionary relatedness?
- 7.10a What are the conditions under which new species may arise?
- 7.10b How do different ecological conditions affect the rate of evolution and speciation?
- 7.10c What are the processes and mechanisms that drive speciation?

- 7.11a What factors lead to the extinction of a population?
- 7.11b How is the risk of extinction affected by changes in the environment?
- 7.11c How do speciation and extinction rates explain species diversity in an ecosystem?.
- 7.11d How does extinction make new environments available for adaptive radiation?
- 7.12 How does the genetic diversity of a species or population affect its ability to withstand environmental pressures?
- 7.13 What scientific evidence provides support for models of the origin of life on Earth?

Process:

- How are cladograms used to explain evolutionary relationships between species?
- How does understanding group behavior allow us to evaluate its role in individual and species' chances to survive and reproduce?
- How can we construct an explanation based on evidence for the primary factors that influence the process of evolution?
- 7.5a What are the conditions under which allele and genotype frequencies will change in populations?
- 7.5b What are the impacts on the population if any of the conditions of Hardy-Weinberg are not met?

Reflective:

- How can evolutionary theory be used to solve real world problems that have a biological basis?
- What scientific information can be used to communicate that common ancestry and biological evolution are supported by multiple lines of empirical evidence?

FOCUS STANDARDS

- **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-LS2-8]
- **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-LS4-6]
- **LS4.D: Biodiversity and Humans**
  - Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). [secondary to [HS-LS2-7]
  - Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution,

introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. [secondary to [HS-LS2-7], [HS-LS4-6]

- **LS4.A : Evidence of Common Ancestry and Diversity**
  - Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. [HS-LS4-1]
- **LS4.B: Natural Selection**
  - Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. [HS-LS4-2], [HS-LS4-3]
  - The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. [HS-LS4-3]
- **LS4.C: Adaptation**
  - Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. [HS-LS4-2]
  - Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically , behaviorally , and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. [HS-LS4-3], [HS-LS4-4]
  - Adaptation also means that the distribution of traits in a population can change when conditions change. [HS-LS4-3]
  - 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-LS4-5]
  - 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-LS4-5]

AP Biology

Unit 8: Ecology

ESSENTIAL QUESTION	BIG IDEAS
How do ecological interactions influence the structure of ecosystems?	• Students will explain how interactions among species influence populations, communities, and ecosystems. • Students will describe biodiversity and explain its importance to ecosystems. • Students will evaluate the impacts of human activities on the environment and biodiversity.

GUIDING QUESTIONS

Content:

- 8.1a How are the behavioral and/or physiological responses of an organism related to changes in internal or external environment?
- 8.1b How do behavioral responses of organisms affect their overall fitness and contribute to the success of the population?
- 8.2a What are the strategies organisms use to acquire and use energy?
- 8.2b How do changes in energy availability affect populations and ecosystems?
- 8.2c How do the activities of autotrophs and heterotrophs enable the flow of energy within an ecosystem?
- 8.3 What are the factors that influence growth dynamics of populations?
- 8.4 How is the density of a population affected and determined by resource availability in the environment?
- 8.5a How can the structure of a community be described according to its species composition and diversity?
- 8.5b How do interactions within and among populations influence the structure of a community?
- 8.5c How is community structure related to energy availability in the environment?
- 8.6a What is the relationship between ecosystem diversity and its resilience to changes in the environment?
- 8.6b How does the addition or removal of any component of an ecosystem affect its overall short-term and long-term structure?
- 8.7a How does the environment interact with random or preexisting variations in populations?

- 8.7b How do invasive species affect ecosystem dynamics?
- 8.7c What human activities lead to changes in ecosystem structure and/or dynamics?
- 8.7d How can geological and meteorological activity lead to changes in ecosystem structure and/or dynamics?

Process:

- How can mathematical representations be used to describe the flow of energy and the cycling of matter in an ecosystem?
- How do mathematical and/or computational representations help support explanations of factors that affect the carrying capacity of ecosystems at different scales?
- How can mathematical representations be used to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales?
- What factors can be used to 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?
- What solutions can be designed for reducing the impacts of human activities on the environment and biodiversity and how do we evaluate and refine these solutions?
- How can we help to mitigate adverse impacts of human activities on biodiversity by creating or revising simulations?
- How can we develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere?

Reflective:

- How does the process of natural selection shape community interactions?
- What can be learned from the history of human population growth that might allow us to prepare for the future?
- How can we use conservation methods to help protect and restore ecosystems?
- Why is biodiversity important and how can we use conservation ecology to help sustain biodiversity?
- How are photosynthesis and cellular respiration related to climate change?

FOCUS STANDARDS

- **LS2.A: Interdependent Relationships in Ecosystems**
    - Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. [HS-LS2-1], [HS-LS2-2]

- **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**
  - Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. [HS-LS2-3]
  - Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. [HS-LS2-4].
  - Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. [HS-LS2-5]
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- **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**
  - A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. [HS-LS2-2], [HS-LS2-6]
  - 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-LS2-7]
- **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-LS2-8]
- **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-LS4-6]
- **LS4.D: Biodiversity and Humans**
  - Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). [secondary to HS-LS2-7]
  - Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is

also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. [secondary to HS-LS2-7], [HS-LS4-6]

- **ETS1.B: Developing Possible Solution**s
    - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. [secondary to HS-LS2-7], [secondary to HS-LS4-6]
    - Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. [secondary to HS-LS4-6]