A Correlation of

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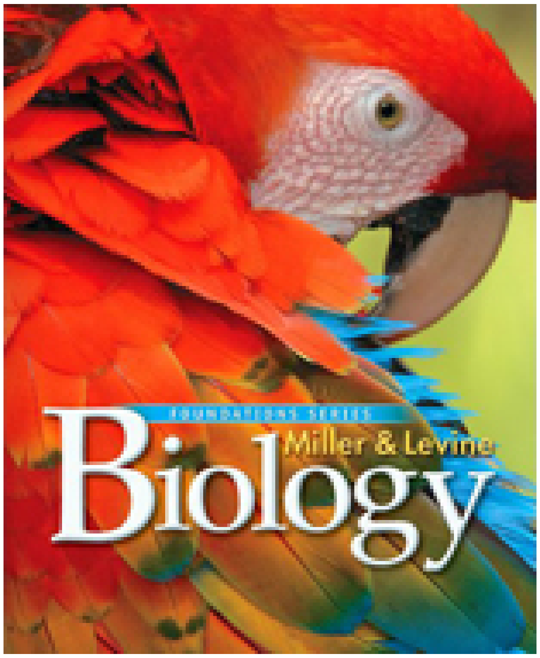

To the

Next Generation Science Standards

Life Science Standards
Earth and Space Science Standards
Engineering Standards
May 2013

Grades 9-12

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Dear Educator,

Pearson is committed to offering its complete support as classrooms transition to the new Next Generation Science Standards.* Ready-to-use solutions for today and a forward-thinking plan for tomorrow connect teacher education and development; curriculum content and instruction; and assessment. We'll be here every step of the way to provide the easiest possible transition to the Next Generation Science Standards with a coherent, phased approach to implementation.

The planning and development of Pearson's ***Miller & Levine Biology*** was informed by the same foundational research as A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Specifically, our development team used Project 2061, the National Science Education Standards (1996) developed by the National Research Council, as well as the Science Anchors Project 2009 developed by the National Science Teachers Association. As a result, students make connections throughout the program to concepts that cross disciplines; practice science and engineering skills; and build on their core science ideas.

Authors Ken Miller and Joe Levine have created a bold, comprehensive on-level program to inspire students with both fundamental and cutting edge biology content. The authors' unique storytelling style, with a greater focus on written and visual analogies, engages students in biology.

Study Workbook A and Laboratory Manual A offer leveled activities for students of varying abilities. Teachers can choose to differentiate activities within a classroom or choose an activity that best fits the whole class profile**.**

Miller & Levine Biology: Foundation Edition, Study Workbook B, and ***Laboratory Manual B*** are the options for below-level students. These items have additional embedded reading support to help students master key biology concepts.

Biology.com, the latest in digital instruction technology, provides a pedagogically relevant interface for your biology classroom.

- Complete Student Foundation Edition online with audio
- Complete Teacher's Foundation Edition
- Untamed Science videos (also on DVD)
- Lesson review presentations
- Editable worksheets
- Test preparation, online assessments, and remediation
- Interactive features and simulations
- Chapter mysteries from the textbook
- Interactive study guides
- Virtual Labs
- STEM activities with worksheets

The following document demonstrates how ***Miller & Levine Biology,*** **Foundation Edition, ©2014,** is compatible with the Next Generation Science Standards for Grades 9-12. Correlation references are to the Student Edition, Teacher Edition, Laboratory Manual B, and Biology.com. (See the correlation for the on-level version of *Miller & Levine Biology* for additional assessment questions and strategies that are compatible with the Next Generation Science Standards.)

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HS-LS1 From Molecules to Organisms: Structures and Processes

HS-LS1 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

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

MILLER & LEVINE BIOLOGY, Foundation Edition: Students are introduced to the structure of DNA in Lesson 12.2 (pp. 292–295) and to DNA replication in Lesson 12.3 (pp. 296–299). Lessons 13.1 and 13.2 (pp. 308–315) provide evidence for how the structure of DNA determines the structure of proteins.

Students **construct an explanation based on evidence** about how the structure of DNA determines the structure of proteins: Students **explain** how the unique structure of DNA makes the functions of DNA possible (Q2, p. 301). Through their responses to a series of questions, students **explain** the central dogma of biology—information is transferred from DNA to RNA to proteins (TE p. 315).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: Students are introduced to levels of organization in Lesson 7.4 (p. 182). Plant structure and function is addressed throughout Chapter 23 (pp. 552–569). Lessons 27.1 (pp. 646–649), 27.2 (pp. 650–652), 27.4 (pp. 656–659), 28.2 (pp. 674–677), 28.3 (pp. 678–683), and 28.4 (pp. 684–687) focus on the interacting systems in animals. The corresponding systems in humans are addressed in Lessons 30.1 (pp. 714–718), 30.3 (pp. 723–728), 30.4 (pp. 729–733), 31.1 (pp. 742–746), 32.1 (pp. 766–769), 33.1 (pp. 786–789), 33.3 (pp. 796–801), 34.1 (pp. 810–812), 34.2 (pp. 813–816), and 35.1 (pp. 838–840).

Representative examples of how students **develop and use a model** to illustrate the organization of systems that provide specific functions: Students **draw** a diagram of a cell membrane and **use it to explain** how the cell regulates what enters or leaves the cell (Q1 and Q2, p. 185). Students **make** a model of a seed plant and **explain** how the model would change if the plant grew in a wet environment (Q1 and Q2, p. 571). Students **evaluate** the usefulness of a swimming pool filter as a model for a nephron (Q1, p. 735).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: The term *homeostasis* is defined in Lesson 1.3 (p. 15). Students learn how cells maintain homeostasis in Lesson 7.4 (pp. 181–183) and the role that stomata play in maintaining homeostasis in plants in Lesson 23.4 (p. 565). The term *feedback inhibition* is defined in Lesson 25.1 (p. 608). Lesson 28.4 (pp. 684–687) explains why all body systems must work together. Mechanisms that control kidney function, gas exchange, and blood glucose levels are discussed in Lesson 30.4 (p. 731), Lesson 33.3 (pp. 799–800), and Lesson 34.2 (p. 814), respectively.

Students **plan and conduct investigations that provide evidence** about homeostasis and feedback mechanisms: Students **develop** a method for maintaining water at a specific temperature for fifteen minutes (Lab Manual B, pp. 377–388). Students **explore** how plant hormones affect leaf loss (Lab Manual B, pp. 151–154).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: The process of cell division is described in Lesson 10.2 (pp. 239–243). The process of cell differentiation is introduced in Lesson 10.4 (pp. 248–251). In Lesson 13.4 (pp. 323–324), students learn that genes control the differentiation of cells in complex organisms.

Students **use a model** to illustrate their understanding of cellular division in complex organisms: Students **draw** a model of the cell cycle for a eukaryotic cell; **label** key events that result in growth and cell division; and **expand** the model to include two additional rounds of cell division (Q1 and Q2, p. 253). Students **compare** the processes cells use to regulate gene expression to a “build to order” manufacturing model (Q4, p. 327).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: The term *photosynthesis* is defined in Lesson 8.1 (p. 194). Lesson 8.2 (pp. 195–197) presents an overview of the process of photosynthesis. Lesson 8.3 (pp. 199–203) provides details about the light-dependent and light-independent sets of reactions.

Representative examples of how students **use a model** to illustrate the conversion of light energy into chemical energy during photosynthesis: Students **use** a visual model to determine what happens to the ATP and NADPH produced during the light-dependent reactions (TE p. 197). Students **draw and label** a model of a chloroplast; **indicate** the key events in the conversion of sunlight to chemical energy; and **expand** the model to show the location of photosystems (Q1 and Q2, p. 205). Students working in small groups **construct** a physical model of photosynthesis that includes both the light-dependent and light-independent reactions (TE p. 204).

HS-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. [Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.] [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.]

MILLER & LEVINE BIOLOGY, Foundation Edition: Carbon compounds are introduced in Lesson 2.3 (pp. 37–41). Students learn about the organelles that build proteins and the organelles that capture and store energy in Lesson 7.2 (pp. 168–169). Lesson 13.2 (pp. 311–315) provides more details about the synthesis of proteins in ribosomes. Lesson 30.2 (pp. 719–722) focuses on the nutrients in food that supply the raw materials that are used to build and repair tissues. In Lesson 30.3 (pp. 723–728), students learn how the digestive system converts food into small molecules that can be used by cells in the body.

HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]

MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 9.1 (pp. 212–215) provides an overview of cellular respiration. Lesson 9.2 (pp. 216–222) provides additional details.
Students **use a model** to illustrate their understanding of cellular respiration: Students **use** paper circles to model the formation of pyruvic acid from glucose (TE p. 217). Students, who are assigned different chemical identities, **arrange** themselves to model what takes place during each stage of cellular respiration (TE p. 222). Groups of students **write** a screenplay that shows how energy is produced in a cell (TE p. 226).

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. ▪ Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-2) **SE:** Q1 and Q2 (p. 185); Q1 and Q2 (p. 571); Q1 (p. 735) ▪ Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-4),(HS-LS1-5),(HS-LS1-7) **SE:** Q1 and Q2 (p. 205); Q1 and Q2 (p. 253); Q4 (p. 327) **TE:** Active Reading (p. 197); Summative Performance Task (p. 204); Hands-On Learning (p. 217); Wrap-Up Activity (p. 222); Summative Performance Task (p. 226)	**LS1.A: Structure and Function** ▪ Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1) **SE/TE:** Cell Specialization (p. 182); Specialized Tissues in Plants (pp. 552–555); Neurons (p. 743); Bones (p. 767); Muscle Tissue (pp. 770–771); Blood (pp. 790–791) ▪ 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-LS1-1) *(Note: This Disciplinary Core Idea is also addressed by HS-LS3-1.)* **SE/TE:** Carbon Compounds (pp. 37–41); The Structure of DNA (pp. 292–285); DNA Replication (pp. 296–299); RNA Synthesis (pp. 309–310); The Genetic Code (pp. 311–312); Translation (pp. 312–315)	**Systems and System Models** ▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS1-2), (HS-LS1-4) **SE:** Build Connections (p. 174); Inquiry into Scientific Thinking (p. 238); Build Connections (p. 244) **LMB:** Making a Model of a Cell (pp. 337–338) **Energy and Matter** ▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5), (HS-LS1-6) **SE:** Light-Dependent Reactions diagram (p. 200); Light-Independent Reactions diagram (p. 202); Q4 (p. 243); Chapter Mystery, Q2 and Q3 (p. 208)

Planning and Carrying Out Investigations
Planning and carrying out in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS1-3)

LMB: Plant Hormones and Leaves (pp. 151–154); Maintaining Temperature (pp. 377–378)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1)

SE: Q2 (p. 301)
TE: Build Connections (p. 315)

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-6)

Connections to Nature of Science
Scientific Investigations Use a Variety of Methods

- Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. (HS-LS1-3)

SE: Lessons 1.1 and 1.2 (pp. 4–12) provide background information in support of this scientific practice.

- 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)

SE/TE: Levels of Organization (p. 182); Structure of Seed Plants (p. 552); Root Structure and Growth (pp. 555–557); Structure and Function of Stems (pp. 560–561); Structure and Function of Leaves (pp. 564–565); Features of Body Plans (pp. 611–612); Organization of the Human Body (pp. 714–716)

- 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)

SE/TE: Homeostasis and Cells (pp. 181–183); Gas Exchange and Homeostasis (p. 565); Maintaining Homeostasis (p. 608); Homeostasis (pp. 684–687); Homeostasis (pp. 717–718); The Kidneys and Homeostasis (pp. 731–732); Integumentary System Functions (p. 775); Breathing and Homeostasis (p. 800); Blood Glucose Regulation (p. 814); Control of the Endocrine System (p. 816)

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)

SE/TE: The Process of Cell Division (pp. 239–243); Cell Differentiation (pp. 248–251); Gametes to Zygotes (p. 277); Genetic Control of Development (pp. 323–324); Fertilization and Early Development (pp. 824–827)

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)

SE/TE: Energy From the Sun (p. 60); Photosynthesis: An Overview (pp. 195–197); The Process of Photosynthesis (pp. 199–203)

TE: Transfer Performance Task (p. 204); Summative Performance Task (p. 226)

- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.(HS-LS1-7)

SE: Comparing Photosynthesis and Respiration (p. 215); Constructed Response, Q1 (p. 228)
TE: Speed Bump (p. 219); Active Reading (p. 222)

Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-LS1-1)

SE: The Human Genome Project (pp. 344–345); Changing DNA (pp. 358–360); Transgenic Organisms (pp. 360–361)

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system. (HS-LS1-3)

SE: Nutrient Transport (pp. 568–569); Inquiry into Scientific Thinking (p. 608); Inquiry into Scientific Thinking (p. 686); Build Connections (p. 844)
LMB: Modeling Breathing (pp. 379–382)
Biology.com: Chapter 28 Data Analysis, Metabolic Activity

	▪ 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) **SE/TE:** Carbon Compounds (pp. 37–41) ▪ 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),(HS-LS1-7) **SE/TE:** Organelles That Build Proteins (pp. 168–169) ▪ As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another and release energy to the surrounding environment and to maintain body temperature. Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. (HS-LS1-7) **SE/TE:** Cellular Respiration: An Overview (pp. 212–215); The Process of Cellular Respiration (pp. 216–222)	

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

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

MILLER & LEVINE BIOLOGY, Foundation Edition: The concept of carrying capacity is introduced in Lesson 5.1 (p. 111). Students learn about factors that affect population growth, such as competition and predation, in Lesson 5.2 (pp. 112–116). Lesson 5.3 (pp. 117–119) provides a historical overview of human population growth and explains how to use age-structure diagrams to analyze population growth.

Students **use mathematics and computational representations** to explain factors that affect carrying capacity: Students **identify** the general trends in a graph of moose and wolf populations and the factors that affect the size of the populations (TE p. 113). Students **explain** how the size of a population can continue to grow as its rate of growth decreases (Q1, p. 121). Students **use** a table of world population milestones to **identify** a trend in population growth (Q16, p. 124).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: Population size is addressed throughout Chapter 5 (pp. 108–119). The concept of biodiversity is addressed in Lesson 6.3 (pp. 138–142).

Students **use mathematics and computational representations** to explain factors that affect biodiversity: Students **use** a graph to **explain** the decline of fish populations in the North Atlantic (p. 146). Students **learn** how to calculate a biodiversity index (Chapter 6 Data Analysis, Analyzing Biodiversity).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: Students are introduced to autotrophs and heterotrophs as they study the relationship between consumers and producers in Lesson 3.2 (pp. 60–61). The interdependence of these categories of organisms is reinforced in Lesson 8.1 (pp. 192–194) and Lesson 9.1 (pp. 212–215). Lesson 21.3 (pp. 509–513) provides a detailed comparison of autotrophic protests and heterotrophic protests.

Students **construct an explanation based on evidence** for how matter and energy are cycled in aerobic and anaerobic conditions: Students **explain** how whales are able to stay underwater for up to 45 minutes (Chapter Mystery, pp. 211 and 230).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: The concept of energy transfer between organisms is introduced in Lesson 3.2 (pp. 60–62). Lesson 3.3 (pp. 63–67) describes food chains and food webs. Students also learn about pyramids of energy and biomass. Cycles of matter are addressed in Lesson 3.4 (pp. 68–73).

Students **use mathematical representations** to support claims for the cycling of energy and matter: Students **calculate** the energy available at each level in a pyramid of energy (Inquiry into Scientific Thinking, p. 66). Students **use** a food web to **calculate** the percentage of energy originally captured by primary producers that is available to specific consumers (Q2, p. 75). Students **use** a graph to **explore** the effect of rainfall on plant tissue productivity (Q16 and Q17, p. 78).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: The cycling of carbon between the biosphere, atmosphere, hydrosphere, and geosphere is addressed in Lesson 3.4 (pp. 70–71). Certain aspects of the cycle are reinforced in Lesson 8.2 (pp. 196–197) and Lesson 9.1 (pp. 213–214).

Students **develop a mode**l to illustrate the role of photosynthesis and cellular respiration in the carbon cycle: Students **design** a museum exhibit about the movement of matter in ecosystems (TE p. 74).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: Students study community interactions in Lesson 4.2 (pp. 85–87). Students study primary and secondary succession in Lesson 4.3 (pp. 88–90). Students learn about different types of population growth in Lesson 5.1 (pp. 108–111) and factors that limit population growth in Lesson 5.2 (pp. 112–115).

Students **evaluate claims, evidence, and reasoning** about what happens to populations in stable and unstable conditions: Students **predict** how changes in an ecosystem will affect the population size of predators and prey (Lab Manual B, pp. 235–236). Students **predict** how the removal of a predator from an ecosystem would affect its prey (Q2, p. 121).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 6.1 (pp. 128–131) provides an overview of the impact of human activities on the environment and of sustainable development. Students learn about ways that humans can use resources wisely in Lesson 6.2 (pp. 132–137). Lesson 6.3 (pp. 138–142) discusses the value of biodiversity, threats to biodiversity, and ways to conserve biodiversity. Lesson 6.4 (pp. 143–149) uses case studies to teach students ways to meet ecological challenges.

Students **design and evaluate solutions** for reducing the impact of humans on the environment and biodiversity: Students **evaluate** ways to reduce dry trash (Inquiry into Scientific Thinking, p. 130). Students **evaluate** reintroduction of species as a way to maintain biodiversity (Lab Manual B, pp. 247–248). Students **determine** ways that their school can conserve water (Q4, p. 151). Groups of students **pick** a specific region that is threatened by human actions; they **create** a Web site that describes the problem and potential solutions (TE p. 100). Students **research** the reduction of mussel populations in tide pools off the Pacific Coast and **propos**e a possible solution (pp. 53a–53b).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: In Lesson 29.1 (p. 696), students learn that many behaviors are essential to survival. Lesson 29.2 (pp. 701–704) expands the concept to include group behaviors such as migration.

Students **evaluate evidence** for the role of group behavior in the ability of individuals and species to survive and reproduce: Students **evaluate** evidence of how wolves behave in a pack (Chapter 29 STEM activity, Yellowstone Wolves).

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Grades 9-12

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

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show how relationships among variables between systems and their components in the natural and designed worlds.

- Develop a model based on evidence to illustrate the relationships between systems or components of a system. (HS-LS2-5)

TE: Summative Performance Task (p. 74)

Using Mathematics and Computational Thinking
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HS-LS2-1)

SE: Q1 (p. 121); Q31 (p. 124)
TE: Active Reading (p. 117)

- Use mathematical representations of phenomena or design solutions to support and revise explanations. (HS-LS2-2)

SE: Case Study #2 (p. 146)
Biology.com: Chapter 6 Data Analysis, Analyzing Biodiversity

- Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4)

SE: Inquiry into Scientific Thinking (p. 66); Q2 (p. 75); Q16 and Q17 (p. 78)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS2-3)

SE: Chapter 9 Mystery (pp. 211 and 230)

- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-LS2-7)

SE: Inquiry into Scientific Thinking (p. 130); Q4 (p. 151); Unit 2 Project (pp. 53a–53b)
TE: Transfer Performance Task (p. 100)

Disciplinary Core Ideas

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)

SE/TE: Competition (pp. 85–86); Exponential Growth (pp. 109–110); Logistic Growth (pp. 110–111); Density-Dependent Limiting Factors (pp. 112–114)

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)

SE/TE: Primary Producers (pp. 60–61); Energy and Life (pp. 192–194); Chemical Energy and Food (p. 212)

- 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)

SE/TE: Food Chains and Food Webs (pp. 63–65); Ecological Pyramids (pp. 66–67); Recycling in the Biosphere (pp. 68–69); Nutrient Cycles (pp. 70–72)

- 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)

SE/TE: The Carbon Cycle (pp. 70–71)

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-8)

TE: Wrap-Up activity (p. 704)
Biology.com: Chapter 29 STEM activity, Yellowstone Wolves

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1)

TE: Active Reading (p. 118)
Biology.com: Chapter 3 Data Analysis, Counting on Nature

- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2)

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS2-5)

SE: The Carbon Cycle diagram (p. 70)
TE: Transfer Performance Task (p. 204)

Energy and Matter

- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (HS-LS2-4)

SE: Photosynthesis equation (p. 61); Consumers visual (p. 62); Pyramid of Energy figure (p. 66)
TE: Lead a Discussion (p. 66)

- Energy drives the cycling of matter within and between systems. (HS-LS2-3)

SE: Build Connections (p. 68)
TE: Build Connections (p. 69)

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6),(HS-LS2-7)

SE: Q2 (p. 101); Q5 (p. 149); Chapter Mystery (p. 154)
TE: Speed Bump (p. 89); Speed Bump (p. 90)
Biology.com: Virtual Lab, Introduction to Ecology

LMB: Saving the Golden Lion Tamarin (pp. 247–248) **Engaging in Argument from Evidence** Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. ▪ Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6) **SE:** Q2 (p. 121) **LMB:** Predator-Prey Dynamics (pp. 235–236) ▪ Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. (HS-LS2-8) **Biology.com:** Chapter 29 STEM activity --- **Connections to Nature of Science** **Scientific Knowledge is Open to Revision in Light of New Evidence** ▪ Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS-LS2-2),(HS-LS2-3) **SE:** Chapter 3 Mystery (pp. 55 and 78); Chapter 4 Mystery (pp. 81 and 104) ▪ Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. (HS-LS2-6),(HS-LS2-8) **SE:** Chapter 5 Mystery (pp. 107 and 124); Chapter 29 Mystery (pp. 695 and 708)	**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) **SE/TE:** Primary and Secondary Succession (pp. 88–89); Climax Communities (pp. 89–90) ▪ 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) **SE/TE:** The Effect of Human Activity (pp. 128–131); Soil Erosion (pp. 132–133); Water Pollution (pp. 134–135); Air Pollution (p. 136); Air Quality and Sustainability (p. 137); Altered Habitats (p. 140) **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) **SE/TE:** Behavioral Cycles (p. 701); Social Behavior (p. 702); Communication (pp. 703–704) **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)* **SE/TE:** The Process of Speciation (pp. 414–416); Speciation and Extinction (pp. 456–457) ▪ 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) (Note: This Disciplinary Core Idea is also addressed by HS-LS4-6.)* **SE/TE:** The Value of Biodiversity (pp. 138–139); Threats to Biodiversity (pp. 140–141); Conserving Biodiversity (pp. 141–142); Ecology in Action (pp. 144–149)	

	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. *(secondary to HS-LS2-5)* **SE/TE:** Energy From the Sun (p. 60); Photosynthesis: An Overview (pp. 195–197); The Process of Photosynthesis (pp. 199–203) **ETS1.B: Developing Possible Solutions** ▪ 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)* **SE/TE:** Case Study #1, Atmospheric Ozone (p. 145); Case Study #2, North Atlantic Fisheries (p. 146); Case Study #3, Climate Change (pp. 147–149); Unit 6 Project, A Living Roof (pp. 477a–477b)	

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

A Correlation of
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to the Next Generation Science Standards, May 2013
Grades 9-12

HS-LS3 Heredity: Inheritance and Variation of Traits

HS-LS3 Heredity: Inheritance and Variation of Traits

Students who demonstrate understanding can:

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

MILLER & LEVINE BIOLOGY, Foundation Edition: In Lesson 7.2 (p. 165), students learn that the nucleus of a cell contains DNA. In Lesson 10.2 (p. 239), students learn about the role of chromosomes in cell division. Lesson 12.1 (pp. 290–291) provides a general description of the role of DNA. Lesson 12.2 (pp. 292–295) describes the structure of DNA. In Lesson 13.2 (pp. 311–312), students learn how the instructions for characteristic traits (the genetic code) are stored in DNA.

Students **ask questions** about the role of DNA and chromosomes in the inheritance of characteristic traits: Students **make** a list of questions about a diagram showing DNA replication (TE p. 296).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: Students are introduced to the process of DNA replication in Lesson 12.3 (pp. 296–299) and mutations in Lesson 13.3 (pp. 316–319). Lesson 17.1 (pp. 406–408) connects genetics to evolutionary theory. Lesson 17.2 (pp. 409-413) focuses on the mechanisms by which genetic variation is introduced into populations. Students revisit the effect of mutations on evolution in Lesson 17.4 (pp. 417–419).

Students **make and defend claims based on evidence** about the causes of inheritable genetic variations: Students **defend** the claim that genetic variation in a population is necessary for natural selection to take place (Q1, p. 422). Students **predict** how specific environmental factors might affect the natural selection of polygenic traits (TE p. 410).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: The term *probability* is defined in Lesson 11.2 (p. 266) in relation to genetic crosses. Exceptions to Mendel's principles are discussed in Lesson 11.3 (pp. 271–273) as is how the environment can affect the expression of genes. Lesson 14.1 (pp. 334-337) focuses on the variation of traits in humans.

Students **apply concepts of statistics and probability** to the variation of traits: Students **use** a Punnett square to **show** the results of a two-factor cross and **explain** why the actual results do not match the expected results (Q1 and Q2, p. 281). Students **use** data to **draw conclusions** about the genotypes involved in a cross (Use Science Graphics, p. 284). Students **use** data to **identify** the genotypes of parakeets (Chapter Mystery, p. 284)

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. ▪ Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1) **TE:** Build Understanding (p. 296)	**LS1.A: Structure and Function** ▪ All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. *(secondary to HS-LS3-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)* **SE/TE:** The Nucleus (p. 165); Passing Traits to Offspring (p. 263); The Role of DNA (pp. 290–291); The Genetic Code (pp. 311–312)	**Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-1),(HS-LS3-2) **SE:** Q2 (p. 283); Q5 (p. 303); Use Science Graphics (p. 304); Inquiry into Scientific Thinking (p. 325) **TE:** Transfer Performance Task (p. 280); Assess and Remediate, Constructing Explanations (p. 286b)

Analyzing and Interpreting Data Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. ▪ Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS3-3) **SE:** Q1 and Q2 (p. 281); Use Science Graphics (p. 284); Chapter Mystery (p. 284) **Engaging in Argument from Evidence** Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. ▪ Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2) **SE:** Constructed Response, Q1 (p. 422) **TE:** Active Reading (p. 410)	**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) **SE/TE:** The Double-Helix Model (pp. 294–295); The Genetic Code (pp. 311–312); The Molecular Basis of Heredity (p. 314); Prokaryotic Gene Regulation (pp. 320–321); Eukaryotic Gene Regulation (pp. 322–323); Genetic Control of Development (pp. 323–324) **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) **SE/TE:** Phases of Meiosis (pp. 276–277); DNA Replication (pp. 296–299); Types of Mutations (pp. 316–318); Effects of Mutations (pp. 318–319); Chromosomal Disorders (p. 341); Sources of Genetic Variation (p. 407) ▪ 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) **SE/TE:** Environmental Influences (p. 324); Genetic Advantages (p. 340)	**Scale, Proportion, and Quantity** ▪ Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-LS3-3) **LMB:** Calculating Haploid and Diploid Numbers (pp. 263–264); Base Percentages (pp. 265–266) --- **Connections to Nature of Science** **Science is a Human Endeavor** ▪ Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-3) **SE:** Representative Examples: The Human Genome Project (pp. 344–345); Q3 (p. 347); Changing DNA (pp. 358–360); Health and Medicine (pp. 363–364) ▪ Science and engineering are influenced by society and society is influenced by science and engineering. (HS-LS3-3) **SE:** Unit 4 Project (pp. 259a–259b); Health and Medicine (pp. 363–364); Ethics and Impacts of Biotechnology (pp. 367–369) **TE:** Building Scientific Literacy, STEM (p. 332a); Transfer Performance Task (p. 346); Active Reading (p. 369)

HS-LS4 Biological Evolution: Unity and Diversity

HS-LS4 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

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

MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 16.1 (pp. 380–383) describes what Darwin observed during the voyage of the *Beagle*. Lesson 16.3 (pp. 388–391) presents Darwin's argument for evolution by natural selection. In Lesson 16.4 (pp. 392–397), students learn about other empirical evidence that supports Darwin's argument. Lesson 17.4 (pp. 417–419) presents the molecular evidence for evolution.

Students **communicate scientific information** about the multiple lines of evidence for biological evolution: Students **explain** how DNA provides evidence of common descent (Q16, p. 402). Students **explain** how fossils support Darwin's theory of evolution (TE p. 395).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: The foundation for understanding the evidence for evolution is laid in Lesson 4.2 (pp. 85–86) where the competitive exclusion principle is discussed; in Lessons 5.1 and 5.2 (pp. 108–115) where population growth and limits to growth are discussed; and in Lesson 13.3 (pp. 316–319) where mutations are discussed. In Lesson 16.3 (pp. 388–391), students are introduced to the concept of natural selection. In Lesson 17.2 (pp. 409–410), students learn about the impact of genetic variation on natural selection. In the Chapter 17 Lab, *Competing for Resources,* students use assorted tools to simulate the competition of birds for seeds.

Students **construct an explanation based on evidence** that evolution results primarily from four factors: Students **use** experimental data to **explain** how genetic variation is important in the survival of a species (Q8, p. 397). Students **identify** heritable variation as a requirement for natural selection (TE p. 390).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: In Lesson 16.3 (pp. 388–391), students learn how advantageous traits affect survival. In Lesson 16.4 (p. 396), students learn how scientists can observe natural selection in a natural environment.

Students **apply concepts of statistics and probability** to the relationship between advantageous traits and population size: Students **identify** a trend in bird survival based on beak size (TE p. 397). Students **use** statistics to **explore** drug resistance as an advantageous trait for bacteria (Inquiry into Scientific Thinking, p. 492). Students **learn** how the presence of mycorrhizae affect the growth and survival of plants (Lab Manual B, pp. 287–288).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 17.1 (pp. 406–408) introduces the concepts of a gene pool and allele frequency. In Lesson 17.2 (pp. 409–413), students learn how natural selection affects allele frequencies. In Lesson 17.3 (pp. 414–416), students learn how different types of isolation can lead to the adaptation of populations.

Students **construct an explanation based on evidence** for how natural selection leads to adaptation of populations: Students **explain** how the evolution of a vascular system affected the ability of plants to survive in various environments (Q2, p. 545). Students **explain** the benefit to vines of thigmotropism (Q10, p. 599).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: In Lesson 17.3 (pp. 414–416), students learn how different types of isolation can lead to the formation of new species. Lesson 19.2 (pp. 456–457) discusses the processes that influence whether species survive or become extinct.

Students **evaluate the evidence for claims** that environmental conditions may result in speciation or extinction: Students **explore** evidence that climate change is causing a genetic decline in alpine chipmunks (pp. 377a–377b). Students **use evidence to suggest** an explanation for the Permian mass extinction (Chapter Mystery, Q2, p. 474).

HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]

MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 6.3 (pp. 138–142) discusses the value of biodiversity, threats to biodiversity, and ways to conserve biodiversity. The Unit 2 Project, Disappearing Mussels! (pp. 53a–53b), asks students to **recommend** ways to prevent the decline of marine populations.

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

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS4-3)

SE: Inquiry into Scientific Thinking (p. 492)

TE: Active Reading (p. 397)

LMB: Mycorrhizae and Tree Height (pp. 287–288)

Using Mathematics and Computational Thinking
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Create or revise a simulation of a phenomenon, designed device, process, or system. (HS-LS4-6)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-2),(HS-LS4-4)

SE: Q8 (p. 397); Q2 (p. 545); Q10 (p. 599)

Disciplinary Core Ideas

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)

SE/TE: Genetics and Molecular Biology (p. 395); Genetics Joins Evolutionary Theory (p. 406); Molecular Evolution (pp. 417–419)

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)

SE/TE: How Natural Selection Works (pp. 409–410)

- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3)

SE/TE: Gene Pools (p. 406); Natural Selection on Single-Gene Traits (p. 409)

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-1),(HS-LS4-3)

SE: Build Connections (p. 389); A Range of Phenotypes graphs (p. 408); Use Science Graphics (p. 424); Q2 (p. 471)

LMB: Molecular Homology in *Hoxc8* (pp. 275–276)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-2),(HS-LS4-4),(HS-LS4-5),(HS-LS4-6)

SE: Build Connections (p. 394); Survival of the Fittest and Beak Size graph (p. 397)

TE: Transfer Performance Task (p. 470)

LMB: Extinctions Through Time (pp. 281–282)

Biology.com: Chapter 16 STEM activity, Bird Beaks; Chapter 19 Data Analysis, Extinctions

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Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-LS4-1),(HS-LS4-4)

SE: An Ancient Changing Earth (pp. 384–385)

TE: Speed Bump (p. 390) **Engaging in Argument from Evidence** Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science. ▪ Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5) **SE:** Unit 5 Project (pp. 377a–377b); Chapter Mystery, Q2 (p. 474) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. ▪ Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-LS4-1) **SE:** Q16 (p. 402) **TE:** Speed Bump (p. 395) --- **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ▪ A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-LS4-1) **SE:** Scientific Theories (p. 11); Testing Natural Selection (p. 396); Evaluating Evolutionary Theory (p. 397)	**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) **SE/TE:** Observations Aboard the *Beagle* (pp. 381–383); Variation and Adaptation (p. 388); Survival of the Fittest (p. 388); Common Descent (p. 391); Sources of Genetic Variation (p. 407) ▪ 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) **SE/TE:** Evolution by Natural Selection (pp. 388–390) ▪ Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3) **SE/TE:** Evolution Versus Genetic Equilibrium (p. 412); Isolating Mechanisms (pp. 414–415) ▪ 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),(HS-LS4-6) **SE/TE:** Genetic Drift (p. 411); Speciation in Darwin's Finches (pp. 415–416) ▪ 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) **SE/TE:** Speciation and Extinction (pp. 456–457)	

	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. (HS-LS4-6) *(Note: This Disciplinary Core Idea is also addressed by HS-LS2-7.)* **SE/TE:** The Value of Biodiversity (pp. 138–139); Threats to Biodiversity (pp. 140–141); Conserving Biodiversity (pp. 141–142); Ecology in Action (pp. 144–149) **ETS1.B: Developing Possible Solutions** ▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-LS4-6) **SE/TE:** Appendix C (pp. A-16 and A-17) ▪ 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)*	

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ESS2 Earth's Systems

HS-ESS2 Earth's Systems

Students who demonstrate understanding can:

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's systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 6.1 (pp. 128–131) discusses the effects of agriculture, development, and industry on Earth's surface. In Lesson 6.2 (pp. 132–137), students learn how poor management of resources can lead to desertification and deforestation. Case Study #3 in Lesson 6.4 (pp. 147–149) addresses the causes and effects of climate change.

Students **analyze geoscience data** about how a change to Earth's surface can cause changes to other Earth systems: Students **use** a map of desertification risk to **categorize** the risk of desertification in their local area (TE p. 133). Students **compare** data on global land-surface air temperature, mean global sea ice, and global sea level (p. 147).

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]

MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 3.4 (pp. 68–70) introduces the different types of processes that are involved in biogeochemical cycles. In Lesson 4.1 (pp. 82–84), students study some factors that affect climate, including solar output. In Lesson 4.4 (pp. 91–95), students learn about additional factors that affect climate, including ocean circulation. In Lesson 6.2 (p. 133), students learn how deforestation can affect local climates. Case Study #3 in Lesson 6.4 (pp. 147–149) provides details about the effects of human activity on climate change. Lesson 19.3 (pp. 462–464) discusses long-term changes in atmospheric composition.

Students **use a model** to describe how variations in energy flow can result in climate change: Students do a hands-on activity to **model** the relationship between latitude and solar energy (TE p. 83).

HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. [Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

MILLER & LEVINE BIOLOGY, Foundation Edition: The cycling of carbon between the biosphere, atmosphere, hydrosphere, and geosphere is addressed in Lesson 3.4 (pp. 70–71). Certain aspects of the cycle are reinforced in Lesson 8.2 (pp. 196–197) and Lesson 9.1 (pp. 213–214).

HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth. [Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of new life forms.] [Assessment Boundary: Assessment does not include a comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems.]

MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 19.1 (pp. 454–455) explains how changes in Earth's physical environment affect life on Earth and how biological forces affect Earth's physical environment. Lesson 22.1 (pp. 529–530) provides the specific example of how the evolution of plants changed the environment in ways that enabled new species to evolve. In Lesson 21.3 (pp. 509–510) and Lesson 21.4 (pp. 517–519), students learn about the key roles photosynthetic protists and fungi play in support of aquatic and terrestrial life forms.

Students **construct an argument based on evidence** about the coevolution of the biosphere and Earth's other systems: Students **explain** how the addition of oxygen to Earth's atmosphere affected the evolution of life (Q15, p. 474).

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

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).
- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-6)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-ESS2-2)

SE: Case Study #3 (p. 147)
TE: Active Reading (p. 133)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
- Construct an oral and written argument or counter-arguments based on data and evidence. (HS-ESS2-7)

SE: Q15 (p. 474)

Connections to Nature of Science
Scientific Knowledge is Based on Empirical Evidence
- Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4)

SE: Inquiry into Scientific Thinking (p. 95)
TE: Science Support (p. 148)
LMB: Comparing Atmospheres (pp. 283–284)

Disciplinary Core Ideas

ESS1.B: Earth and the Solar System
- Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. *(secondary to HS-ESS2-4)*

ESS2.A: Earth Materials and Systems
- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-2)

SE/TE: The Mysteries of Life's Origins (pp. 462–464); Ecological Footprints (pp. 143–144)

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4)

SE/TE: Life on a Changing Planet (pp. 454–455); Case Study #3, Climate Change (pp. 147–149)

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. (HS-ESS2-4)

SE/TE: Weather and Climate (p. 82); Factors That Affect Climate (pp. 82–84)

- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6),(HS-ESS2-7)

SE/TE: Production of Free Oxygen (p. 464)

- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4)

SE/TE: Case Study #3, Climate Change (pp. 147–149)

ESS2.E: Biogeology
- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7)

SE/TE: The Mysteries of Life's Origins (pp. 462–464); Autotrophic Protists (pp. 509–510); The Ecology of Fungi (pp. 517–519)

Crosscutting Concepts

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4)

SE: Inquiry into Scientific Thinking (p. 95)
LMB: Comparing Atmospheres (pp. 283–284)

Energy and Matter
- The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6)

SE: Comparing Photosynthesis and Respiration (p. 215)
TE: Active Reading (p. 222)

Stability and Change
- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-7)

SE: Q7 (p. 455); Q15 (p. 523)
TE: Active Reading (p. 455); Speed Bump (p. 464)

- Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-2)

SE: Case Study #1 (p. 145)
LMB: Vehicle Emission Trends (pp. 245–246)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS2-2)

TE: Building Scientific Literacy, STEM (p. 126a)

HS-ESS3 Earth and Human Activity

HS-ESS3 Earth and Human Activity

Students who demonstrate understanding can:

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 5.2 (p. 114) explains how natural disasters are a limiting factor for population growth. Lesson 6.2 (pp. 133–135) discusses the importance of freshwater for humans. Lesson 24.4 (pp. 593–594) focuses on the effect of agriculture on human civilizations.

Students **construct an explanation** for how natural resources, natural hazards, or climate influence human activity: Students **explore** how the presence or absence of trees affected the inhabitants of Easter Island (pp. 127 and 154).

HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.]

MILLER & LEVINE BIOLOGY, Foundation Edition: Chapter 6 (pp. 128–142) discusses the effect of human activity on the environment.

Students **create a computational simulation** to illustrate the relationship between management of natural resources and biodiversity: Students **use** mathematical and computational tools to **analyze** data about the genetic decline of alpine chipmunks due to climate change caused by human activities (pp. 377a–377b).

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

MILLER & LEVINE BIOLOGY, Foundation Edition: Lessons 6.1, 6.2, and 6.3 (pp. 128–142) focus on the impact of humans on the environment.

Students **evaluate or refine a technological solution** that reduces impacts of human activities on natural systems: Students **evaluate** ways to reduce dry trash (Inquiry into Scientific Thinking, p. 130). Students **design** a green roof system for a building (pp. 477a–477b).

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

MILLER & LEVINE BIOLOGY, Foundation Edition: Case Study #3 in Lesson 6.4 (pp. 147–149) addresses the causes and effects of climate change.

Students **analyze geoscience data** about global climate change: Students **compare** data on air temperature, sea ice, sea level, and greenhouse gas emissions (pp. 147–148).

HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]

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MILLER & LEVINE BIOLOGY, Foundation Edition: Lesson 3.4 (pp. 68–72) describes biogeochemical cycles. Lessons 6.1, 6.2, 6.3, and 6.4 (pp. 128–149) address ways humans modify Earth's systems.
Students **use computational representations** to illustrate relationships among Earth's systems: Students **interpret** data about the effect of rainfall on plant productivity (p. 78). Students **interpret** data on air pollution trends (Q5, p. 137). Students **compare** data on land-surface air temperature, global sea ice, and global sea level (p. 147).

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

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS3-5)

SE: Case Study #3 (pp. 147–149)

Using Mathematics and Computational Thinking
Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-ESS3-3)

SE: Unit 4 Project (pp. 377a–377b)

- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6)

SE: Use Science Graphics (p. 78); Q5 (p. 137); Case Study #3 (p. 147)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.
- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS3-1)

SE: Chapter 6 mystery (pp. 127 and 154)

- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ESS3-4)

SE: Inquiry into Scientific Thinking (p. 130); Unit 6 Project (pp. 477a–477b)

Disciplinary Core Ideas

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. *(secondary to HS-ESS3-6)*

SE/TE: Greenhouse Gases (p. 136); Case Study #3, Climate Change (p. 148)

ESS3.A: Natural Resources
- Resource availability has guided the development of human society. (HS-ESS3-1)

SE/TE: Sustainable Development (pp. 130–131); Soil Resources (pp. 132–133); Freshwater Resources (pp. 133–135); Agriculture (pp. 593–594)

ESS3.B: Natural Hazards
- Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1)

ESS3.C: Human Impacts on Earth Systems
- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3)

SE/TE: Sustainable Development (pp. 130–131); Using Resources Wisely (pp. 132–137); Ecology in Action (pp. 144–149)

- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

SE/TE: Using Resources Wisely (pp. 132–137); Conserving Biodiversity (pp. 141–142); Ecology in Action (pp. 144–149)

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. (HS-ESS3-5)

SE/TE: Case Study #3, Climate Change (pp. 147–149)

- 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)

Crosscutting Concepts

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1)

SE: Inquiry into Scientific Thinking (p. 116)

Systems and System Models
- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS3-6)

TE: Speed Bump (p. 7); Active Reading (p. 135)

Stability and Change
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-3),(HS-ESS3-5)

SE: Case Study #1 (p. 145); Case Study #3 (pp. 147–149)

- Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS3-4)

SE: Chapter 3 Mystery (pp. 55 and 78); Chapter 5 Mystery (pp. 107 and 124)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
- Modern civilization depends on major technological systems. (HS-ESS3-1),(HS-ESS3-3)

SE: The Role of Technology (p. 10)
TE: Activate Prior Knowledge (p. 126)

- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-ESS3-4)

TE: Active Reading (p. 149)

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. (HS-ESS3-3)

SE: Q4 (p. 123)
TE: Building Scientific Literacy, STEM (p. 126a); Wrap-Up Activity (p. 142)

--- **Connections to Nature of Science** **Scientific Investigations Use a Variety of Methods** ▪ Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS-ESS3-5) ▪ New technologies advance scientific knowledge. (HS-ESS3-5) **TE:** Speed Bump (p. 18); Building Scientific Literacy, STEM (p. 126a); Science Support (p. 148) **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based on empirical evidence. (HS-ESS3-5) **SE:** Case Study #3 (pp. 147–149) **TE:** Building Scientific Literacy, Writing (p. 126a) ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-5) **SE:** Case Study #3 (pp. 147–149)	**SE/TE:** Case Study #1, Atmospheric Ozone (p. 145); Case Study #3, Climate Change (pp. 147–149) **ETS1.B: Developing Possible Solutions** ▪ 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 HS-ESS3-4)* **SE/TE:** Appendix C, Technology & Design (pp. A-16 and A-17)	--- **Connections to Nature of Science** **Science is a Human Endeavor** ▪ Science is a result of human endeavors, imagination, and creativity. (HS-ESS3-3) **SE:** Scientific Methodology (pp. 5–7) **TE:** Activate Prior Knowledge (p. 2)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

HS-ETS1 Engineering Design

HS-ETS1 Engineering Design

Students who demonstrate understanding can:

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

MILLER & LEVINE BIOLOGY, Foundation Edition: In Lesson 1.2 (p. 10), students learn that technology, science, and society are closely linked. Lesson 1.2 (p. 12) describes the relationship between science and society. In Lesson 15.4 (pp. 367–369), students explore the ethics and impacts of biotechnology.

Students **specify criteria and constraints for solutions** that account for societal needs and wants: In the Unit 8 Project, Body Mechanics (pp. 711a–711b), students **evaluate** how medical technologies can account for the needs of people living with disabilities or chronic diseases. Students **analyze** how cross-pollination affects the genetics of corn populations (Chapter 17 STEM activity, Pollination or Contamination). Students **analyze** the factors involved with replacing a heart (Chapter 33 STEM activity, The Artificial Heart of the Matter).

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

MILLER & LEVINE BIOLOGY, Foundation Edition: In Appendix C, Technology & Design (pp. A-16 and A-17), students learn the general process for designing a solution to a problem.

Students **design a solution** to a complex real-world problem: In the Unit 6 Project, A Living Roof (pp. 477a–477b), students **design** a green roof. Students **redesign** product packaging to reduce solid waste (Chapter 6 STEM activity, Redesign to Reduce Waste). Students **design** a mosquito net to help combat malaria outbreaks (Chapter 21 STEM activity, Malaria and Fungi). Students **design** technology to help protect workers from blood-borne pathogens (Chapter 35 STEM activity, Reducing the Spread of Blood-borne Pathogens).

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

MILLER & LEVINE BIOLOGY, Foundation Edition: In Appendix C, Technology & Design (pp. A-16 and A-17), students learn to evaluate constraints and make trade-offs.

Students **evaluate a solution** to a complex real-world problem: In the Unit 1 Project, Harnessing the Fear of Water (pp. 1a–1b), students **determine** the criteria for a technological solution to a specific problem. In the Unit 4 Project, Food Fight! (pp. 259a–259b), students **evaluate** the use of GM foods as a way to increase crop yields. In the Unit 8 Project, Body Mechanics (pp. 711a–711b), students **identify** the criteria and constraints for a prosthetic limb.

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

Science and Engineering Practices	Disciplinary Core Ideas	Connections to Engineering, Technology, and Applications of Science
Asking Questions and Defining Problems Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. ▪ Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1) **SE:** Unit 8 Project (pp. 711a–711b) **Biology.com:** Chapter 17 STEM activity; Chapter 33 STEM activity	**ETS1.A: Defining and Delimiting Engineering Problems** ▪ Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1) **SE/TE:** Science and Society (p. 12); Ethics and Impacts of Biotechnology (pp. 367–369) ▪ Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **SE/TE:** Using Resources Wisely (pp. 132–137)	**Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3) **SE:** Building Scientific Literacy, STEM (p. 101) **Biology.com:** Chapter 14 STEM activity, Human Genomes and Medicine; Chapter 15 STEM activity, Recombinant DNA in Genetically Modified Organisms; Chapter 31 STEM activity, Technology and Physical Disabilities

Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. ▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) **SE:** Unit 6 Project (pp. 477a–477b) **Biology.com:** Chapter 6 STEM activity; Chapter 21 STEM activity; Chapter 35 STEM activity ▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3) **SE:** Unit 1 Project (pp. 1a–1b); Unit 4 Project (pp. 259a–259b); Unit 8 Project (pp. 711a–711b)	**ETS1.B: Developing Possible Solutions** ▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) **SE/TE:** Appendix C (pp. A-16 and A-17) **ETS1.C: Optimizing the Design Solution** ▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2) **SE/TE:** Appendix C (pp. A-16 and A-17)	