ARKANSAS
K-12 SCIENCE STANDARDS
EDUCATION FOR A NEW GENERATION

Biology - Integrated

2016

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Notes:

1. Student Performance Expectations (PEs) may be taught in any sequence or grouping within a grade level. Several PEs are described as being "partially addressed in this course" because the same PE is revisited in a subsequent course during which that PE is fully addressed.
2. An asterisk (*) indicates an engineering connection to a practice, core idea, or crosscutting concept.
3. The Clarification Statements are examples and additional guidance for the instructor. AR indicates Arkansas-specific Clarification Statements.
4. The Assessment Boundaries delineate content that may be taught but not assessed in large-scale assessments. AR indicates Arkansas-specific Assessment Boundaries.
5. The section entitled "foundation boxes" is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.
6. The examples given (e.g.,) are suggestions for the instructor.
7. Throughout this document, connections are provided to the nature of science as defined by *A Framework for K-12 Science Education* (NRC 2012).
8. Throughout this document, connections are provided to Engineering, Technology, and Applications of Science as defined by *A Framework for K-12 Science Education* (NRC 2012).
9. Each set of PEs lists connections to other disciplinary core ideas (DCIs) within the Arkansas K-12 Science Standards and to the Arkansas English Language Arts Standards, Arkansas Disciplinary Literacy Standards, and the Arkansas Mathematics Standards.

Arkansas K-12 Science Standards Overview

The Arkansas K-12 Science Standards are based on *A Framework for K-12 Science Education* (NRC 2012) and are meant to reflect a new vision for science education. The following conceptual shifts reflect what is new about these science standards. The Arkansas K-12 Science Standards

- reflect science as it is practiced and experienced in the real world,
- build logically from Kindergarten through Grade 12,
- focus on deeper understanding as well as application of content,
- integrate practices, crosscutting concepts, and core ideas, and
- make explicit connections to literacy and math.

As part of teaching the Arkansas K-12 Science Standards, it will be important to instruct and guide students in adopting appropriate safety precautions for their student-directed science investigations. Reducing risk and preventing accidents in science classrooms begin with planning. The following four steps are recommended in carrying out a hazard and risk assessment for any planned lab investigation:

1) Identify all hazards. Hazards may be physical, chemical, health, or environmental.
2) Evaluate the type of risk associated with each hazard.
3) Write the procedure and all necessary safety precautions in such a way as to eliminate or reduce the risk associated with each hazard.
4) Prepare for any emergency that might arise in spite of all of the required safety precautions.

According to Arkansas Code Annotated § 6-10-113 (2012) for eye protection, every student and teacher in public schools participating in any chemical or combined chemical-physical laboratories involving caustic or explosive chemicals or hot liquids or solids is required to wear industrial-quality eye protective devices (eye goggles) at all times while participating in science investigations.

The Arkansas K-12 Science Standards outline the knowledge and science and engineering practices that all students should learn by the end of high school. The standards are three-dimensional because each student performance expectation engages students at the nexus of the following three dimensions:

- Dimension 1 describes scientific and engineering practices.
- Dimension 2 describes crosscutting concepts, overarching science concepts that apply across science disciplines.
- Dimension 3 describes core ideas in the science disciplines.

Science and Engineering Practices

The eight practices describe what scientists use to investigate and build models and theories of the world around them or that engineers use as they build and design systems. The practices are essential for all students to learn and are as follows:

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

Crosscutting Concepts

The seven crosscutting concepts bridge disciplinary boundaries and unit core ideas throughout the fields of science and engineering. Their purpose is to help students deepen their understanding of the disciplinary core ideas, and develop a coherent, and scientifically based view of the world. The seven crosscutting concepts are as follows:

1. *Patterns*- Observed patterns of forms and events guide organization and classification, and prompt questions about relationships and the factors that influence them.
2. *Cause and effect- Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. *Scale, proportion, and quantity*- In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. *Systems and system models*- Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. *Energy and matter: Flows, cycles, and conservation*- Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. *Structure and function*- The way in which an object or living thing is shaped and its substructure determines many of its properties and functions.
7. *Stability and change*- For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Disciplinary Core Ideas

The disciplinary core ideas describe the content that occurs at each grade or course. The Arkansas K-12 Science Standards focus on a limited number of core ideas in science and engineering both within and across the disciplines and are built on the notion of learning as a developmental progression. The Disciplinary Core Ideas are grouped into the following domains:

- Physical Science (PS)
- Life Science (LS)
- Earth and Space Science (ESS)
- Engineering, Technology and Applications of Science (ETS)

Connections to the Arkansas English Language Arts Standards

Evidence-based reasoning is the foundation of good scientific practice. The Arkansas K-12 Science Standards incorporate reasoning skills used in language arts to help students improve mastery and understanding in all three disciplines. The Arkansas K-8 Science Committee made every effort to align grade-by-grade with the English language arts (ELA) standards so concepts support what students are learning in their entire curriculum. Connections to specific ELA standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons.

The intersections between Arkansas K-12 Science Standards and Arkansas ELA Standards teach students to analyze data, model concepts, and strategically use tools through productive talk and shared activity. Reading in science requires an appreciation of the norms and conventions of the discipline of science, including understanding the nature of evidence used, an attention to precision and detail, and the capacity to make and assess intricate arguments, synthesize complex information, and follow detailed procedures and accounts of events and concepts. These practice-based standards help teachers foster a classroom culture where students think and reason together, connecting around the subject matter and core ideas.

Connections to the Arkansas Disciplinary Literacy Standards

Reading is critical to building knowledge in science. College and career ready reading in science requires an appreciation of the norms and conventions of each discipline, such as the kinds of evidence used in science; an understanding of domain-specific words and phrases; an attention to precise details; and the capacity to evaluate intricate arguments, synthesize complex information, and follow detailed descriptions of events and concepts. When reading scientific and technical texts, students need to be able to gain knowledge from challenging texts that often make extensive use of elaborate diagrams and data to convey information and illustrate concepts. Students must be able to read complex informational texts in science with independence and confidence because the vast majority of reading in college and workforce training programs will be sophisticated nonfiction.

For students, writing is a key means of asserting and defending claims, showing what they know about science, and conveying what they have experienced, imagined, thought, and felt. To be college and career ready writers, students must take task, purpose, and audience into careful consideration, choosing words, information, structures, and formats deliberately. They need to be able to use technology strategically when creating, refining, and collaborating on writing. They have to become adept at gathering information, evaluating sources, and citing material accurately, reporting finds from their research and analysis of sources in a clear and cogent manner. They must have the flexibility, concentration, and fluency to produce high-quality first-draft text under a tight deadline and the capacity to revisit and make improvements to a piece of writing over multiple drafts when circumstances encourage or require it.

Connections to the Arkansas Mathematics Standards

Science is a quantitative discipline, so it is important for educators to ensure that students' science learning coheres well with their understanding of mathematics. To achieve this alignment, the Arkansas K-12 Science Committee made every effort to ensure that the mathematics standards do not outpace or misalign to the grade-by-grade science standards. Connections to specific math standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons.

How to Read
Arkansas K-12 Science

Topic

GRADE TWO

An asterisk indicates an engineering connection to a practice or disciplinary core idea.

Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

2-LS2-1 **Plan and conduct an investigation to determine if plants need sunlight and water to grow.** [Assessment Boundary: Assessment is limited to testing one variab…

2-LS2-2 **Develop a simple model that mimics the function o… …eeds or pollinating plants.** *

2-LS4-1 **Make observations of plants and animals to compa… …fferent habitats.** [Clarification Statement: Emphasis is on the diversity of living things in a variety of habitats.] [Assessment Boundary: Assessment does not include specific animal and plant names in specific habitats.]

Student Performance Expectations (PEs)

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 K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions. ▪ Develop a simple model based on evidence to represent a proposed object or tool. (2-LS2-2) **Planning and Carrying Out Investigations** Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. ▪ Plan and conduct an investi… collaboratively to produce da… as the basis for evidence to a… question. (2-LS2-1) ▪ Make observations (firsthand or from media) to collect data that can be used to make comparisons. (2-LS4-1) --- **Connections to Nature of Science** **Scientific Knowledge is Based on Empirical Evidence** ▪ Scientists look for patterns and order when making observations about the world. (2-LS4-1)	**LS2.A: Interdependent Relationships in Ecosystems** ▪ Plants depend on water and light to grow. (2-LS2-1) ▪ Plants depend on animals for pollination or to move their seeds around. (2-LS2-2) **LS4.D: Biodiversity and Humans** ▪ There are many different kinds of living things in any area, and they exist in different places on land and in water. (2-LS4-1) **ETS1.B: Developing Possible Solutions** ▪ Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (2-LS2-2) ▪	**Cause and Effect** ▪ Events have causes that generate observable patterns. (2-LS2-1) **Structure and Function** ▪ The shape and stability of structures of natural and designed objects are related to their function(s). (2-LS2-2)

Designates which PE uses this practice

Designates which PE incorporates this disciplinary core idea (DCI)

Designates which PE incorporates this crosscutting concept (CC)

Connections to the Nature of Science

DCI codes from *A Framework for K-12 Science Education* in boldface type.

Connections to other DCIs in second grade: N/A

Connections to other DCIs across grade levels: **K.LS1.C** (2-LS2-1); **K-ESS3.A** (2-LS2-1); **K-2.ETS1.A** (2-LS2-2); **3.LS4.C** (2-LS4-1); **3.LS4.D** (2-LS4-1); **5.LS1.C** (2-LS2-1); **5.LS2.A** (2-LS2-2, 2-LS4-1)

Connections to the Arkansas English Language Arts and Mathematics Standards are often found by scrolling to the next page

Biology Course Learning Progression Chart

Topic 1: Cycling of Matter and Energy	Topic 2: Structure and Function	Topic 3: Biodiversity and Population Dynamics	Topic 4: Genetic Variations in Organisms	Topic 5: Evolution by Natural Selection	Topic 6: Life and Earth's Systems	Topic 7: Human Impacts on Earth's Systems
AR BI-LS1-5	BI-LS1-1	BI-LS2-1	BI-LS1-4	BI-LS4-1	BI-ESS2-2	AR BI-ESS3-1
BI-LS1-7	AR BI-LS1-2	BI-LS2-2	BI-LS3-1	BI-LS4-2	BI-ESS2-4	AR BI-ESS3-2
BI-LS2-3	BI-LS1-3	BI-LS2-6	BI-LS3-2	BI-LS4-3	AR BI-ESS2-5	BI-ESS3-3
AR BI-LS 2-4	BI-LS1-6	AR BI-LS2-7	BI-LS3-3	BI-LS4-4	AR BI-ESS3-5	AR BI-ESS3-4
BI-LS2-5		BI-LS2-8		BI-LS4-5	AR BI6-ETS1-2	AR BI-ESS3-6
BI-ESS2-6		AR BI-LS4-6		AR BI-ESS2-7	AR BI6-ETS1-3	AR BI7-ETS1-1
		AR BI3-ETS1-3				AR BI7-ETS1-2
		AR BI3-ETS1-4				AR BI7-ETS1-4

Arkansas Clarification Statement/Assessment Boundary (AR)

Biology - Integrated Course Overview
(Course code 420000)

The Arkansas K-12 Science Standards for biology - integrated is an integrated science course that focuses on conceptual understanding of foundational life and Earth science core ideas, science and engineering practices, and crosscutting concepts, and is an integration of life science, Earth and space science, and engineering design standards. It is recommended that students be enrolled in geometry concurrently with this course. Teachers with biology, life/Earth, and life science licenses are qualified to teach this course. Students will earn 1 unit of Smart Core/biology credit for graduation.

Students in biology - integrated develop understanding of key concepts that help them make sense of the interactions between life science and Earth and space science. The ideas are building upon students' understanding of disciplinary ideas, science and engineering practices, and crosscutting concepts from earlier grades. There are seven topics in biology - integrated: (1) Cycling of Matter and Energy, (2) Structure and Function, (3) Biodiversity and Population Dynamics, (4) Genetic Variations in Organisms, (5) Evolution by Natural Selection, (6) Earth's Changing Climate, and (7) Humans and Natural Systems. The performance expectations (standards) for biology - integrated blend core ideas with scientific and engineering practices and crosscutting concepts to support students in developing usable knowledge that can be applied across the science disciplines. While the performance expectations indicate particular practices to address specific disciplinary core ideas, it is recommended that teachers include a variety of practices and strategies in their instruction.

Connections with other science disciplines help high school students develop these capabilities in various contexts. For example, in the life sciences students are expected to design, evaluate, and refine a solution for reducing human impact on the environment (BI-LS2-7) and to create or revise a simulation to test solutions for mitigating adverse impacts of human activity on biodiversity (BI-LS4-6). In the Earth and space sciences, students apply their engineering capabilities to reduce human impacts on Earth systems, and improve social and environmental cost-benefit ratios (BI-ESS3-2, BI-ESS3-4).

Additionally, it should be noted the biology - integrated standards are not intended to be used as curriculum. Instead, the standards are the minimum that students should know and be able to do. Therefore, teachers should continue to differentiate for the needs of their students by adding depth and additional rigor.

Students in biology - integrated also continue their ability to develop possible solutions for major global problems with engineering design challenges. At the high school level, students are expected to engage with major global issues at the interface of science, technology, society and the environment, and to bring to light the kinds of analytical and strategic thinking that prior training and increased maturity make possible. As in prior levels, these capabilities can be thought of in three stages:

- **Defining the problem** at the high school level requires both qualitative and quantitative analysis. For example, the need to provide food and fresh water for future generations comes into sharp focus when considering the speed at which the world population is growing and conditions in countries that have experienced famine. While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering.
- **Developing possible solutions** for major global problems begins by breaking them down into smaller problems that can be tackled with engineering methods. To evaluate potential solutions, students are expected to not only consider a wide range of criteria but to also recognize that criteria needs to be prioritized. For example, public safety or environmental protection may be more important than cost or even functionality. Decisions on priorities can then guide tradeoff choices.
- **Improving designs** at the high school level may involve sophisticated methods, such as using computer simulations to model proposed solutions. Students are expected to use such methods to take into account a range of criteria and constraints, anticipate possible societal and environmental impacts, and test the validity of their simulations by comparison to the real world.

Biology - Integrated Topics Overview

The performance expectations in **Topic 1: Cycling of Matter and Energy** help students answer the question:

- How do matter and energy move through an ecosystem?

Students construct explanations, develop models, and use mathematical representations to demonstrate how the cycling of carbon-based molecules through photosynthesis and cellular respiration enables the flow of energy among organisms and within ecosystems. Students use quantitative models specifically to illustrate the role of photosynthesis and cellular respiration as two processes by which carbon is cycled among the biosphere, atmosphere, hydrosphere, and geosphere.

The performance expectations in **Topic 2: Structure and Function** help students formulate an answer to the question:

- How do the structures of organisms enable living organisms to function?

Students investigate explanations for the structure and function of cells as the basic units of life, the hierarchical systems of organisms, and the role of specialized cells for maintenance and growth. Students demonstrate understanding of how systems of cells function together to support the life processes by reading critically, using models, and conducting investigations.

The performance expectations in **Topic 3: Biodiversity and Population Dynamics** help students answer the question:

- How do biotic and abiotic factors affect biodiversity?

Students investigate the role of biodiversity in ecosystems and the role of animal behavior on survival of individuals and species. Students analyze how organisms interact with each other and their physical environment, how organisms change the environment, and how these changes affect both organisms and the environment. Students use evidence to explain those interactions and changes. Students explore solutions for major global problems, evaluate possible solutions for reducing the impact of human activities on biodiversity, and use computer simulations to model and test those solutions, considering a wide range of criteria including cost-benefit analysis.

The performance expectations in **Topic 4: Genetic Variations in Organisms** help students in formulating answers to these questions:

- How are the characteristics of one generation related to previous and future generations?
- How does genetic variation contribute to biodiversity?

Students explain the relationship of DNA and chromosomes to cellular division, protein synthesis, and mutations. Students analyze the mechanisms of inheritance and gene expression, as well as environmental and genetic causes of gene mutations. Students formulate questions and construct arguments about ethical issues related to the genetic modification of organisms. Students develop conceptual models for the role of DNA in the unity of life on Earth and use statistical models to explain the importance of variation within population for the survival and evolution of species.

The performance expectations in **Topic 5: Evolution by Natural Selection** help students answer these questions:

- Why do different organisms have many similarities?
- What causes species to change over time?

Students investigate patterns to find relationships between environmental conditions and natural selection, highlighting factors that drive the evolution or extinction of species over time. Students utilize statistics and probability to investigate the distribution of genes and traits in a population over time, demonstrating how natural selection leads to the adaptation of populations. Students analyze scientific evidence, ranging from the fossil record to genetic relationships, to evaluate how multiple lines of evidence support the scientific theories of natural selection and evolution.

The performance expectations in **Topic 6: Life and Earth's Systems** help students answer these questions:

- How does life influence Earth's systems?
- How do Earth's systems influence life?

Students investigate the interrelationships between biotic and abiotic factors that contribute to changes in Earth's dynamic systems. Students examine how Earth's systems may appear stable, change slowly over long periods of time, or change abruptly, with significant consequences for living organisms. Students develop models and analyze data to explain and forecast changes to Earth's various climates. Students examine how climate change can occur when certain parts of Earth's systems are altered and predict how living organisms may affect and be affected. Students study the relationship of blue-green algae and oxygen concentration in the atmosphere; then, investigate how the rate of fresh water intrusion from melting polar ice affects the growth of the blue-green algae. While this topic does not address biological processes specifically, instruction should highlight the connection between climate and living systems.

The performance expectations in **Topic 7: Human Impacts on Earth's Systems** help students formulate answers to these questions:

- How have Earth's systems affected human populations and human activities?
- How do human activities impact Earth's systems?

Students examine the complex interdependence between humans and their environment by simulating specific relationships between natural resources, natural hazards, climate, biodiversity, and the sustainability of human populations. Students analyze geoscience models to highlight the interactions between Earth's various systems, forecast future rates of global or regional climate change, and predict the resulting impacts on the environment. Students utilize science and engineering practices to evaluate and refine solutions that reduce human impacts on natural systems, manage natural resources, protect biodiversity, and maintain healthy ecosystems.

Topic 1: Cycling of Matter and Energy		
Students who demonstrate understanding can: **BI-LS1-5** **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** [AR Clarification Statement: This PE is fully addressed in this course. 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.] **BI-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.] **BI-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.] **BI-LS2-4** **Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.** [AR clarification Statement: This PE is fully addressed in this course. Emphasis is on the transfer of energy and matter between trophic levels and the relative proportion of organisms at each trophic level.] [Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy. **BI-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.] **BI-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.]		
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. ▪ Use a model based on evidence to illustrate the relationships between systems or between components of a system. (BI-LS1-5, B-LS1-7) ▪ Develop a model based on evidence to illustrate the relationships between	**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. (BI-LS1-5) ▪ As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (BI-LS1-7) ▪ As a result of these chemical reactions, energy is transferred from	**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. (BI-LS1-5) ▪ Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (BI-LS1-7, BI-LS2-4)

systems or between components of a system. (BI-ESS2-6, BI-LS2-5) **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. (BI-LS1-6, BI-LS2-3) **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 representations of phenomena or design solutions to support claims. (BI-LS2-4)	one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. (BI-LS1-7) **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** ▪ Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (BI-LS2-3) ▪ Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. (BI-LS2-4) ▪ Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (BI-LS2-5) **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. (BI-LS2-5)	▪ The total amount of energy and matter in closed systems is conserved. (BI-ESS2-6) ▪ Energy drives the cycling of matter within and between systems. (BI-LS2-3) **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. (BI-LS2-5)

	ESS2.D: Weather and Climate ▪ Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (BI-ESS2-6) ▪ Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (BI-ESS2-6)	

Connections to other DCIs in this course: **BI.PS1.A** (BI-ESS2-6)**; BI.PS1.B** (BI-LS1-5,BI-LS1-7, BI-LS2-3, BI-LS2-5, BI-ESS2-6); **BI.PS2.B** (BI-LS1-7); **BI.PS3.B** (BI-LS1-5, BI-LS1-7, BI-LS2-3, BI-LS2-4); **BI.PS3.D** (BI-LS2-3, BI-LS2-4); **BI.LS1.C** (BI-ESS2-6)**; BI.LS2.B** (BI-ESS2-6)**; BI.ESS2.A** (BI-LS2-3); **BI.ESS2.D** (BI-LS2-5); **BI.ESS3.C**(BI-ESS2-6)**; BI.ESS3.D** (BI-ESS2-6)

Connections to DCIs across grade-bands: **7.PS1.A** (BI-ESS2-6); **7.PS1.B** (BI-LS1-5, BI-LS1-7, BI-LS2-3); **6.PS3.D** (BI-LS1-5, BI-LS1-7, BI-LS2-3, BI-LS2-4, BI-LS2-5, BI-ESS2-6); **8.PS4.B** (BI-ESS2-6)**; 7.LS1.C** (BI-LS1-5, BII-LS1-7, B-LS2-3, BI-LS2-5, BI-LS2-4); **7.LS2.B** (BI-LS1-5, BI-LS1-7, BI-LS2-3, BI-LS2-4, BI-LS2-5, BI-ESS2-6); **7.ESS2.A** (BI-LS2-5, BI-ESS2-6)**; 7.ESS2.B** (BI-ESS2-6)**; 7.ESS2.C** (BI-ESS2-6)**; 6.ESS3.C** (BI-ESS2-6)**; 6.ESS3.D** (BI-ESS2-6)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (BI-LS2-3)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (BI-LS2-3)

WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (BI-LS2-3)

Connections to the Arkansas English Language Arts Standards:

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, auditory, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (BI-LS1-5, BI-LS1-7)

Connections to the Arkansas Mathematics Standards:

MP.2 Reason abstractly and quantitatively. (BI-ESS2-6, BI-LS2-4)

MP.4 Model with mathematics. (BI-ESS2-6, BI-LS2-4)

HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (BI-ESS2-6, BI-LS2-4)

HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (BI-ESS2-6, BI-LS2-4)

HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (BI-ESS2-6, BI-LS2-4)

Topic 2: Structure and Function

Students who demonstrate understanding can:

BI-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.]

BI-LS1-2 **Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.** [AR 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. Examinations could include all types of multicellular organisms. Examples of an interacting system could include an artery depending on the proper function of elastic tissue and a smooth muscle regulating and delivering proper amounts of blood within the circulatory system]. [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]

BI-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.]

BI-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.]

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. (BI-LS1-2) **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	**LS1.A: Structure and Function** ▪ Systems of specialized cells within organisms help them perform the essential functions of life. (BI-LS1-1) ▪ 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. (BI-LS1-1, BI-LS3-1) ▪ Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (BI-LS1-2) ▪ Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some	**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. (BI-LS1-2) **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

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. (BI-LS1-3) **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. (BI-LS1-1) ▪ 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. (BI-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. (BI-LS1-3)	range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (BI-LS1-3) **LS1.C: Organization for Matter and Energy Flow in Organisms** ▪ The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (proteins or DNA), used for example to form new cells. (BI-LS1-6) ▪ As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (BI-LS1-6)	function and/or solve a problem. (BI-LS1-1) **Stability and Change** ▪ Feedback (negative or positive) can stabilize or destabilize a system. (BI-LS1-3) **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. (BI-LS1-6)

Connections to other DCIs in this course: **BI.LS3.A** (BI-LS1-1); **BI.PS1.B** (BI-LS1-6)

Connections of DCIs across grade-bands: **6.LS1.A** (BI-LS1-1, BI-LS1-2, BI-LS1-3); **8.LS3.A** (BI-LS1-1); **6.LS3.B** (BI-LS1-1) **7.PS1.A** (BI-LS1-6); **7.PS1.B** (BI-LS1-6,); **6.PS3.D** (BI-LS1-6) **7.LS1.C** (BI-LS1-6)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (BI-LS1-1, BI-LS1-6)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (BI-LS1-1, BI-LS1-6)

WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (BI-LS1-6)

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (BI-LS1-3)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (BI-LS1-1, BI-LS1-6)

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (BI-LS1-3)

Connections to the Arkansas English Language Arts Standards:

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, auditory, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (BI-LS1-2)

Connections to the Arkansas Mathematics Standards: N/A

Topic 3: Biodiversity and Population Dynamics
Students who demonstrate understanding can: **BI-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.] **BI-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.] **BI-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.] **BI-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*** [AR Clarification Statement: This PE is fully addressed in this course. Emphasis is on the impact of human activities on biodiversity such as dissemination of invasive species, habitat degradation, and water quality.] [AR Assessment Boundary: Assessment is to include student choice from multiple scenarios.] **BI-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.] **BI-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*** [AR Clarification Statement: Emphasis is on refining solutions for a proposed problem related to threatened or endangered species, genetic variation of organisms for multiple species, and biodiversity.] **BI3-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**. [AR Clarification Statement: Problems could include effect of logging on animal or human populations, response to invasive species, agricultural practices, creating dams, and maintaining fish populations in public lakes.] **BI3-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.** [AR Clarification Statement: Examples could include simulations of population dynamics, genetic drift, evolution, and migration.]
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

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. (BI-LS2-1)
- Use mathematical representations of phenomena or design solutions to support and revise explanations. (BI-LS2-2)
- Create or revise a simulation of a phenomenon, designed device, process, or system. (BI-LS4-6)
- Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (BI3-ETS1-4)

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, 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. (BI-LS2-7)

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. (BI-LS2-1, BI-LS2-2)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (BI-LS2-2, BI-LS2-6)
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (BI-LS2-7)

LS4.C: Adaptation

- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (BI-LS4-6)

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (BI-LS2-8, BI-LS4-6)

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (BI-LS2-1)
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (BI-LS2-2)

Stability and Change

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

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. (BI3-ETS1-4)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

New technologies can have deep impacts on society and the environment, including

▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (BI3-ETS1-3) **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. (BI-LS2-6) ▪ Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. (BI-LS2-8) --- ***Connections to Nature of Science*** **Scientific Knowledge is Open to Revision in Light of New Evidence** ▪ 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. (BI-LS2-6, BI-LS2-8)	**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. (BI-LS2-8) **LS4.D: Biodiversity and Humans** ▪ Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (BI-LS2-7) ▪ Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (BI-LS4-6, BI-LS2-7) **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. (BI3-ETS1-3, BI-LS2-7, BI-LS4-6) ▪ Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (BI3-ETS1-4, BI-LS4-6)	some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (BI3-ETS1-3)

Connections to other DCIs in this course: **BI.ESS2.D** (BI-LS2-7, BI-LS4-6); **B.ESS3.A** (BI-LS2-2, BI-LS2-7, BI-LS4-6); **BI.ESS3.C** (BI-LS2-2, BI-LS2-7, BI-LS4-6); **BI.ESS3.D** (BI-LS2-2, BI-LS4-6)

Connections of DCIs across grade-bands: **6.LS1.B** (BI-LS2-8); 7**.LS2.A** (BI-LS2-1, BI-LS2-2, BI-LS2-6); **7.LS2.C** (BI-LS2-1, BI-LS2-2, BI-LS2-6, BI-LS2-7, BI-LS4-6); **6.ESS2.E** (BI-LS2-6); **6.ESS3.A** (BI-LS2-1); **6.ESS3.C** (BI-LS2-1, BI-LS2-2, B-LS2-6, BI-LS2-7, BI-LS4-6); **6.ESS3.D** (BI-LS2-7); **6-8.ETS1.A** (BI3-ETS1-3, BI-3-ETS1-4); **6-8.ETS1.B** (BI3-ETS1-3, BI3-ETS1-4); **6-8.ETS1.C** (BI3-ETS1-4)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (BI-LS2-6, BI-LS2-7, BI-LS2-8)

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (BI-LS2-1, BI-LS2-2, BI-LS2-6, BI-LS2-8)

RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (BI-LS2-6, BI-LS2-7, BI-LS2-8, BI3-ETS1-3)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (BI-LS2-6, BI-LS2-7, BI-LS2-8, BI3-ETS1-3)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (BI3-ETS1-3)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (BI-LS2-1, BI-LS2-2)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (BI-LS4-6)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (BI-LS2-7, BI-LS4-6)

Connections to the Arkansas Mathematics Standards:

MP.2	Reason abstractly and quantitatively. (BI-LS2-1, BI-LS2-2, BI-LS2-6, BI-LS2-7, BI3-ETS1-4)
MP.4	Model with mathematics. (BI-LS2-1, BI-LS2-2, BI3-ETS1-4)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (BI-LS2-1, BI-LS2-2, BI-LS2-7)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (BI-LS2-1, BI-LS2-2, BI-LS2-7)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (BI-LS2-1, BI-LS2-2, BI-LS2-7)
HSS.ID.A.1	Represent data with plots on the real number line. (BI-LS2-6)
HSS.IC.A.1	Recognize statistics as a process for making inferences about population parameters based on a random sample from that population. (BI-LS2-6)
HSS.IC.B.6	Read and explain, in context, the validity of data from outside reports by: identifying the variables as quantitative or categorical; describing how the data was collected; indicating any potential biases or flaws; and identifying inferences the author of the report made from sample data. (BI-LS2-6)

Topic 4: Genetic Variations in Organisms

Students who demonstrate understanding can:

BI-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.]

BI-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.]

BI-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.]

BI-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.]

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 worlds.
- Use a model based on evidence to illustrate the relationships between systems or between components of a system. (BI-LS1-4)

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. (BI-LS3-1)

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

Disciplinary Core Ideas

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. (BI-LS1-4)

LS1.A: Structure and Function
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (BI-LS3-1, BI-LS1-1)

LS3.A: Inheritance of Traits
- Each chromosome consists of a single very long DNA molecule,

Crosscutting Concepts

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. (BI-LS1-4)

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (BI-LS3-1, BI-LS3-2)

Scale, Proportion, and Quantity
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (BI-LS3-3)

fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (BI-LS3-3) **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. (BI-LS3-2)	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. (BI-LS3-1) **LS3.B: Variation of Traits** ▪ In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (BI-LS3-2) ▪ Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (BI-LS3-2, BI-LS3-3)	-- ***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. (BI-LS3-3) ▪ Science and engineering are influenced by society and society is influenced by science and engineering. (BI-LS3-3)

Connections to other DCIs in this course: **BI.LS2.A** (BI-LS3-3); **BI.LS4.B** (BI-LS3-3); **BI.LS4.C** (BI-LS3-3)

Connections across grade-bands: **6.LS1.A** (BI-LS1-4); **6.LS1.B** (BI-LS1-4); **7.LS2.A** (BI-LS3-3); **8.LS3.A** (BI-LS1-4, BI-LS3-1, BI-LS3-2); **7.LS3.B** (BI-LS3-1,BI-LS3-2, BI-LS3-3); **BI.LS4.C** (BI-LS3-3)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (BI-LS3-1, BI-LS3-2)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (BI-LS3-1)

WHST.9-12.1 Write arguments focused on *discipline-specific content.* (BI-LS3-2)

Connections to the Arkansas English Language Arts Standards:

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, auditory, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (BI-LS1-4)

Connections to the Arkansas Mathematics Standards:

MP.2 Reason abstractly and quantitatively. (BI-LS3-2, BI-LS3-3)

MP.4 Model with mathematics. (BI-LS1-4)

HSF.IF.C.7 Graph functions expressed symbolically and show key features of the graph, with and without and using technology: given linear and quadratic functions and, when applicable, show intercepts, maxima, and minima; graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions; graph polynomial functions, identifying zeros when suitable factorizations are available, and show end behavior; graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior; graph exponential and logarithmic functions, showing period, midline, and amplitude. (BI-LS1-4)

HSF.BF.A.1 Write a function that describes a relationship between two quantities: from a context, determine an explicit expressions, a recursive process, or steps for calculation; combine standard function types using arithmetic operations (e.g., given that f(x) and g(x) are functions developed from a context, find (f+g)(x), (f – g)(x), (fg)(x), (f/g)(x), and any combination thereof, given g(x)≠0. (BI-LS1-4)

Topic 5: Evolution by Natural Selection
Students who demonstrate understanding can: **BI-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.] **BI-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.] **BI-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.] **BI-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.] **BI-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.] **BI-ESS2-7 Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.** [AR Clarification Statement: This PE is fully addressed in this course. Emphasis in the course is on developing a claim and evaluating and critiquing the evidence for simultaneous co-evolution. Emphasis is on the causes, effects, and feedback loops between the biosphere and Earth's other systems which continuously alters Earth's surface. Examples could include how photosynthetic life altered the atmosphere through the production of oxygen, which increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil which allowed for the evolution of land plants; and how the evolution of corals created reefs which altered patterns of erosion and deposition along coastlines and provided habitats for the evolution of 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.]
The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical	**LS4.A: Evidence of Common Ancestry and Diversity** ▪ Genetic information provides evidence of evolution. DNA sequences vary	**Patterns** ▪ Different patterns may be observed at each of the scales at which

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. (BI-LS4-3)

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. (BI-LS4-2, BI-LS4-4)

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. (BI-LS4-5)
- Construct an oral and written argument or counter-arguments based on data and evidence. (BI-ESS2-7)

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.

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. (BI-LS4-1)

LS4.B: Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (BI-LS4-2, BI-LS4-3)
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (BI-LS4-3)

LS4.C: Adaptation

- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (BI-LS4-2)
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (BI-LS4-3, BI-LS4-4)
- Adaptation also means that the distribution of traits in a population can change when conditions change. (BI-LS4-3)

a system is studied and can provide evidence for causality in explanations of phenomena. (BI-LS4-1, BI-LS4-3)

Cause and Effect

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

Stability and Change

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

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. (BI-LS4-1, BI-LS4-4)

▪ 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). (BI-LS4-1) --- ***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. (BI-LS4-1)	▪ 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. (BI-LS4-5) ▪ Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (BI-LS4-5) **ESS2.D: Weather and Climate** ▪ Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (BI-ESS2-7) **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. (BI-ESS2-7)	

Connections to other DCIs in this course: **BI.LS2.A** (BI-LS4-2, BI-LS4-3, BI-LS4-4, BI-LS4-5, BI-ESS2-7); **BI.LS2.C** (BI-ESS2-7); **BI.LS2.D** (BI-LS4-2, BI-LS4-3, BI-LS4-4, BI-LS4-5); **BI.LS3.A** (BI-LS4-1); **BI.LS3.B** (BI-LS4-1, BI-LS4-2, BI-LS4-3, BI-LS4-5); **BI.LS4.A** (BI-ESS2-7); **BI.LS4.B** (BI-ESS2-7); **BI.LS4.C** (BI-ESS2-7); **BI.LS4.D** (B-ESS2-7); **BI.ESS3.A** (BI-LS4-2, BI-LS4-5)

Connections across grade-bands: **7.LS2.A** (BI-LS4-2, BI-LS4-3, BI-LS4-5, BI-ESS2-7); **7.LS2.C** (BI-LS4-5, BI-ESS2-7);**8.LS3.A** (BI-LS4-1); **6.LS3.B** (BI-LS4-1, BI-LS4-2, BI-LS4-3); **8.LS4.A** (BI-LS4-1, BI-ESS2-7); **8.LS4.B** (BI-LS4-2, BI-LS4-3, BI-LS4-4, BI-ESS2-7); **8.LS4.C** (BI-LS4-2, BI-LS4-3, BI-LS4-4, BI-LS4-5, BI-ESS2-7); **8.ESS1.C** (BI-LS4-1); **7.ESS2.A** (BI-ESS2-7); **6.ESS2.C** (BI-ESS2-7); **6.ESS3.C** (BI-LS4-5, BI-ESS2-7)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (BI-LS4-1, BI-LS4-2, BI-LS4-3, BI-LS4-4)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (BI-LS4-5)

WHST.9-12.1 Write arguments focused on *discipline-specific content.* (BI-ESS2-7)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (BI-LS4-1), BI-LS4-2, BI-LS4-3, BI-LS4-4)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (BI-LS4-1, BI-LS4-2, BI-LS4-3, BI-LS4-4, BI-LS4-5)

Connections to the Arkansas English Language Arts Standards:

SL.11-12.4 Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks. (BI-LS4-1, BI-LS4-2)

Connections to the Arkansas Mathematics Standards:	
MP.2	Reason abstractly and quantitatively. (BI-LS4-1, BI-LS4-2, BI-LS4-3, BI-LS4-4, BI-LS4-5)
MP.4	Model with mathematics. (BI-LS4-2)
HSS.IC.A.1	Recognize statistics as a process for making inferences about population parameters based on a random sample from that population.(BI-LS4-3)

Topic 6: Life and Earth's Systems

Students who demonstrate understanding can:

BI-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. [Clarification Statement: Examples could 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.]

BI-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.]

BI-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. [AR Clarification Statement: This PE is partially addressed in this course. Emphasis is on the properties of water and the water cycle.]

BI-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. [AR Clarification Statement: Examples of evidence (precipitation and temperature) for both data and climate models and the associated impacts (sea level changes, glacial ice volumes, and atmosphere and ocean composition) could be found at National Oceanic and Atmospheric Administration, National Weather Service, and United States Geological Survey.] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

BI6-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. [AR Clarification Statement: Proposed problems could include increases in pollution, greenhouse gases, water runoff and soil erosion, coastal erosion, and loss of wetlands.]

BI6-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. [AR Clarification Statement: Solutions could include those designed by students or identified from scientific studies.]

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

- Use a model to provide mechanistic accounts of phenomena. (BI-ESS2-4)

Planning and Carrying Out Investigations

Planning and carrying out investigations 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. (BI-ESS2-5)

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. (BI-ESS2-2)
- Analyze data using computational models in order to make valid and reliable scientific claims. (BI-ESS3-5)

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.

ESS2.A: Earth Materials and Systems

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (BI-ESS2-2)
- 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. (BI-ESS2-4)

ESS2.C: The Roles of Water in Earth's Surface Processes

- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. BI-ESS2-5)

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. (BI-ESS2-2, BI-ESS2-4)
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (BI-ESS2-4)

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. (BI-ESS3-5)

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. (BI6-ETS1-3)

Structure and Function

- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (BI-ESS2-5)

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system. (BI-ESS2-2)
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (BI-ESS3-5)

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. (BI-ESS2-2, BI6-ETS1-3)

▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (BI6-ETS1-2) ▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (BI6-ETS1-3) **---** ***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. (BI-ESS3-5) ▪ New technologies advance scientific knowledge. (BI-ESS3-5) **Scientific Knowledge is Based on Empirical Evidence** ▪ Science knowledge is based on empirical evidence. (BI-ESS3-5) ▪ Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (BI-ESS2-4, BI-ESS3-5)	**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. (BI6-ETS1-2)	

Connections to other DCIs in this course: **BI.LS1.C** (BI-ESS3-5); **BI.LS2.B** (BI-ESS2-2); **BI.LS2.C** (BI-ESS2-2, BI-ESS2-4); **BI.LS4.D** (BI-ESS2-2); **BI.ESS3.C** (BI-ESS2-2, BI-ESS2-4, BI-ESS2-5); **BI.ESS3.D** (BI-ESS2-2, BI-ESS2-4)

Connections of DCIs across grade-bands: **7.PS1.A** (BI-ESS2-5); **8.PS3.A** (BI-ESS2-4); **8.PS3.B** (BI-ESS2-4, BI-ESS3-5); **6.PS3.D** (BI-ESS2-2, BI-ESS2-4, BI-ESS3-5); **8.PS4.B** (BI-ESS2-2, BI-ESS2-4, BI-ESS2-5); **6.LS1.C** (BI-ESS2-4); **7.LS2.B** (BI-ESS2-2, BI-ESS2-4); **7.LS2.C** (BI-ESS2-2, BI-ESS2-4); **8.LS4.C** (BI-ESS2-2); **7.ESS2.A** (BI-ESS2-2, BI-ESS2-4, BI-ESS2-5, BI-ESS3-5); **7.ESS2.B** (BI-ESS2-2, BI-ESS2-4); **6.ESS2.C** (BI-ESS2-2, BI-ESS2-4, BI-ESS2-5); **6.ESS2.D** (BI-ESS2-2, BI-ESS2-4, BI-ESS2-5, BI-ESS3-5); **7.ESS3.B** (BI-ESS3-5); **6.ESS3.C** (BI-ESS2-2, BI-ESS2-4, BI-ESS3-5); **6.ESS3.D** (BI-ESS2-2, BI-ESS2-4, BI-ESS3-5); **6-8.ETS1.A** (BI6-ETS1-2, BI6-ETS1-3); **6-8.ETS1.B** (BI6-ETS1-2, BI6-ETS1-3); **6-8.ETS1.C** (BI6-ETS1-2)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (BI-ESS2-2, BI-ESS3-5)

RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (BI-ESS2-2, BI-ESS3-5)

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (BI-ESS3-5, BI6-ETS1-3)

RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (BI6-ETS1-3)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (BI6-ETS1-3)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (BI-ESS2-5)

Connections to the Arkansas English Language Arts Standards:

SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, auditory, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (BI-ESS2-4)

Connections to the Arkansas Mathematics Standards:

MP.2	Reason abstractly and quantitatively. (BI-ESS2-2, BI-ESS2-4, BI-ESS3-5. BI6-ETS1-3)
MP.4	Model with mathematics. (BI-ESS2-4, BI6-ETS1-2, BI6-ETS1-3)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (BI-ESS2-2, BI-ESS2-4, BI-ESS3-5)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (BI-ESS2-4, BI-ESS3-5)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (BI-ESS2-2, BI-ESS2-4, BI-ESS2-5, BI-ESS3-5)

Topic 7: Human Impacts on Earth's Systems

Students who demonstrate understanding can:

BI-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. [AR Clarification Statement: This PE is fully addressed in this course. Emphasis is on the way climate change has impacted human populations and how natural resources and natural hazards impact human societies. Examples of climate change results which affect populations or drive mass migrations could include changes to sea level, regional patterns of temperature and precipitation, and types of crops and livestock available. Examples of the dependence of human populations on technology to acquire natural resources and to avoid natural hazards could include damming rivers, natural gas fracking, thunderstorm sirens, and severe weather text alerts.]

BI-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [AR Clarification Statement: This PE is fully addressed in this course. Emphasis is on the designs of possible solutions. Emphasis is on the conservation, recycling, and reuse of resources (minerals and metals), and on minimizing impacts. Examples could include developing best practices for agricultural soil use, mining (coal, tar sands, and oil shales), and pumping (petroleum and natural gas).]

BI-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.]

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

BI-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. [AR Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and biosphere. Examples of far-reaching impacts related to human activity, include how increases in one or more atmospheric gasses (COx, NOx, Sox), and volatile organic compounds), and particulate matter could impact other Earth systems. For example, an increase in carbon dioxide results in an increase in photosynthetic biomass and ocean acidification with resulting impacts on marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]

BI7-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. [AR Clarification Statement: Examples could include recycling, increased atmospheric carbon dioxide, ocean acidification, impacts on marine populations, increased wildfire occurrence, deforestation, and overfishing.]

BI7-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. [AR Clarification Statement: Simulations could include management of natural resources for sustainable yields, agricultural efficiency to feed a growing world population, and urban planning to maximize green space.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking 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. (BI-ESS3-3) ▪ Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (BI-ESS3-6) ▪ Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (BI7-ETS1-4) **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. (BI-ESS3-1) ▪ Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence,	**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. (BI-ESS3-6) **ESS3.A: Natural Resources** ▪ Resource availability has guided the development of human society. (BI-ESS3-1) ▪ All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (BI-ESS3-2) **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. (BI-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. (B-ESS3-3) ▪ Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (BI-ESS3-4) **ESS3.D: Global Climate Change** ▪ Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (BI-ESS3-6)	**Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (BI-ESS3-1) **Systems and System Models** ▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (BI-ESS3-6) ▪ 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. (BI7-ETS1-4) **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. (BI-ESS3-3) ▪ Feedback (negative or positive) can stabilize or destabilize a system. (BI-ESS3-4) ------------------------------------- ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Engineering, Technology, and Science**

prioritized criteria, and tradeoff considerations. (BI-ESS3-4) **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 natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. ▪ Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (BI-ESS3-2) **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. (BI7-ETS1-1)	**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. (BI7-ETS1-1) ▪ 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. (BI7-ETS1-1) **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. (BI-ESS3-2, BI-ESS3-4) ▪ 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. (BI7-ETS1-4)	**on Society and the Natural World** ▪ Modern civilization depends on major technological systems. (BI-ESS3-1, BI-ESS3-3) ▪ Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (BI-ESS3-2, BI-ESS3-4) ▪ New technologies can have deep impacts on society and the environment, including some that were not anticipated. (BI-ESS3-3) ▪ Analysis of costs and benefits is a critical aspect of decisions about technology. (BI-ESS3-2) ▪ 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. (BI7-ETS1-1) ----------------------------------- ***Connections to Nature of Science*** **Science is a Human Endeavor** ▪ Science is a result of human endeavors, imagination, and creativity. (BI-ESS3-3) **Science Addresses Questions About the Natural and Material World**

		▪ Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (BI-ESS3-2) ▪ Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (BI-ESS3-2) ▪ Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (BI-ESS3-2)

Connections to other DCIs in this course: **BI.LS2.A** (BI-ESS3-2, BI-ESS3-3); **BI.LS2.B** (BI-ESS3-2, BI-ESS3-3, BI-ESS3-6); **BI.LS2.C** (BI-ESS3-3, BI-ESS3-4, BI-ESS3-6); **BI.LS4.D** (BI-ESS3-2, BI-ESS3-3, BI-ESS3-4, BI-ESS3-6); **BI.ESS2.A** (BI-ESS3-2, BI-ESS3-3, BI-ESS3-6); **BI.ESS2.E** (BI-ESS3-3)

Connections of DCIs across grade-bands: **7.PS1.B** (BI-ESS3-3); **6.PS3.D** (BI-ESS3-2); **7.LS2.A** (BI-ESS3-1, BI-ESS3-2, BI-ESS3-3); **8.LS2.B** (BI-ESS3-2, BI-ESS3-3); **7.LS2.C** (BI-ESS3-3, BI-ESS3-4, BI-ESS3-6); **8.LS4.C** (BI-ESS3-3); **8.LS4.D** (BI-ESS3-1, BI-ESS3-2, BI-ESS3-3); **7.ESS2.A** (BI-ESS3-1, BI-ESS3-3, BI-ESS3-4, BI-ESS3-6); **6.ESS2.C** (BI-ESS3-6); **7.ESS3.A** (BI-ESS3-1, BI-ESS3-2, BI-ESS3-3); **6.ESS3.B** (BI-ESS3-1, BI-ESS3-4); **6.ESS3.C** (B-ESS3-2 B-ESS3-3, B-ESS3-4, B-ESS3-6); 6**.ESS3.D** (B-ESS3-4, B-ESS3-6) **6-8.ETS1.A** (BI7-ETS1-1, BI7-ETS1-4); **6-8.ETS1.B** (BI7-ETS1-4); **6-8.ETS1.C** (BI7-ETS1-4)

Connections to the Arkansas Disciplinary Literacy Standards:

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (BI-ESS3-1, BI-ESS3-2, BI-ESS3-4)

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (BI7-ETS1-1)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (BI-ESS3-2, BI-ESS3-4, BI7-ETS1-1)

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (BI7-ETS1-1)

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (BI-ESS3-1)

Connections to the Arkansas Mathematics Standards:

MP.2 Reason abstractly and quantitatively. (BI-ESS3-1, BI-ESS3-2, BI-ESS3-3, BI-ESS3-4), BI-ESS3-6, BI7-ETS1-1)

MP.4 Model with mathematics. (BI-ESS3-3, BI-ESS3-6, BI7-ETS1-1)

HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (BI-ESS3-1, BI-ESS3-4, BI-ESS3-6)

HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (BI-ESS3-1, BI-ESS3-4, BI-ESS3-6)
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (BI-ESS3-1, BI-ESS3-4, BI-ESS3-6)

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