



## Grades 9-12

# Life Science Curriculum Framework

### Introduction

Science, Technology & Engineering, and Environmental Literacy & Sustainability (STEELS) Standards guide the study of the natural and human-made world through inquiry, problem-solving, critical thinking, and authentic exploration. This document displays a curriculum framework for **Grades 9-12 Life Science**. It is designed to focus curriculum and teaching, provide guidance for multiple approaches to curriculum development, encourage less reliance on textbooks as curriculum, and avoid activity-oriented teaching without focus/purpose.

### Science Long Term Transfer Goals

In support of the Curriculum Framework, Long Term Transfer Goals (LTTG) provide the overarching practices that ground the foundation for a robust curriculum; thus, all curricula should relate to one or more of the LTTGs detailed below – as they highlight the effective uses of understanding, knowledge, and skill that we seek in the long run; i.e., what we want students to be able to do when they confront new challenges – both in and outside of school.

Students will be able to engage as scientifically literate members of a global society, using their learning to:

1. Approach science as a reliable and tentative way of knowing and explaining the natural world and designed world.
2. Weigh evidence and use scientific approaches to ask questions, investigate, and make informed decisions.
3. Make and use observations to analyze relationships and patterns in order to explain phenomena, develop models, and make predictions.
4. Evaluate systems, in order to connect how form determines function and how any change to one component affects the entire system.
5. Explain how the natural and designed worlds are interrelated and the application of scientific knowledge and technology can have beneficial, detrimental, or unintended consequences.

## Structure and Function

| Key Understanding                                                                                                                | Driving Question                                                                                     | Standard                                                                                                                                                                                                                       | Science and Engineering Practices                                                                                                                                                                                                                                                                                                                                                                                      | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                     | Crosscutting Concepts                                                                                                                                                                                                                                                                | Vocabulary                                                                                        |
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| DNA holds the instructions for the building of every protein in an organism and proteins carry out essential functions for life. | How does information stored in molecules determine what an organism looks like and how it functions? | <b>3.1.9-12.A</b><br><b>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.</b> | <b>Constructing Explanations and Designing Solutions</b><br>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. | Systems of specialized cells within organisms help them perform the essential functions of life.<br><br>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. | <b>Structure and Function</b><br>Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. | DNA<br>gene<br>protein<br>specialized cell                                                        |
| Multicellular organisms can be made of various levels of organization that provide for specific functions.                       | How do the biological systems of an organism work together to sustain life?                          | <b>3.1.9-12.B</b><br><b>Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</b>                                         | <b>Developing and Using Models</b><br>Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.                                                                                                                                                                                                                                                     | 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.                                                                                                                                                     | <b>Systems and System Models</b><br>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.                                          | cell<br>hierarchical organization<br>multicellular<br>organ<br>organ system<br>organism<br>tissue |

| Key Understanding                                              | Driving Question                                                    | Standard                                                                                                                         | Science and Engineering Practices                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                    | Crosscutting Concepts                                                                                 | Vocabulary                                                                 |
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| Organisms utilize feedback mechanisms to maintain homeostasis. | How do organisms maintain a stable internal environment to survive? | <b>3.1.9-12.C</b><br><b>Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</b> | <p><b>Planning and Carrying Out Investigations</b><br/>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.</p> <p><b>Scientific Investigations Use a Variety of Methods</b><br/>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.</p> | <p>Feedback mechanisms maintain a living system’s internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range.</p> <p>Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.</p> | <b>Stability and Change</b><br>Feedback (negative or positive) can stabilize or destabilize a system. | homeostasis<br>negative feedback loop<br>positive feedback loop<br>stimuli |

## Growth and Development of Organisms

| Key Understanding                                                                                                                | Driving Question                                                                                           | Standard                                                                                                                                                          | Science and Engineering Practices                                                                                                                      | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Crosscutting Concepts                                                                                                                                                                                                                       | Vocabulary                 |
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| Multicellular organisms grow through mitosis and use cell differentiation to form specific structures for specialized functions. | What processes allow organisms to grow and develop from a single cell to a complex multicellular organism? | <b>3.1.9-12.D</b><br><b>Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.</b> | <b>Developing and Using Models</b><br>Use a model based on evidence to illustrate the relationships between systems or between components of a system. | 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. | <b>Systems and System Models</b><br>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. | differentiation<br>mitosis |

## Organization for Matter and Energy Flow in Organisms

| Key Understanding                                                                                                                            | Driving Question                                                                      | Standard                                                                                                                                                                                                                                   | Science and Engineering Practices                                                                                                                                                                                                                                                                                                                                                                                      | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                | Crosscutting Concepts                                                                                                                                           | Vocabulary                                                                                                     |
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| Photosynthesis transforms light energy into chemical energy.                                                                                 | How is energy from the sun used by organisms on Earth?                                | <b>3.1.9-12.E</b><br><b>Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.</b>                                                                                                              | <b>Developing and Using Models</b><br>Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.                                                                                                                                                                                                                          | The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.                                                                                                                                                                                                                                                                                               | <b>Energy and Matter</b><br>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. | chemical energy<br>light energy<br>matter<br>photosynthesis<br>transformation                                  |
| Elements from the breakdown of sugars and other substances can combine to form new molecules, which may also combine to form macromolecules. | How are carbon, hydrogen, and oxygen used to make large molecules essential for life? | <b>3.1.9-12.F</b><br><b>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.</b> | <b>Constructing Explanations and Designing Solutions</b><br>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. | The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.<br><br>As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. | <b>Energy and Matter</b><br>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. | amino acid<br>carbon-based molecule<br>hydrocarbon backbone<br>macromolecule<br>molecule<br>monomer<br>polymer |

| Key Understanding                                                                          | Driving Question                      | Standard                                                                                                                                                                                                                                                   | Science and Engineering Practices                                                                                                                      | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Crosscutting Concepts                                                                                                                                                   | Vocabulary                                                                      |
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| Organisms break bonds in food to release energy using the process of cellular respiration. | How do organisms use food for energy? | <b>3.1.9-12.G</b><br><b>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.</b> | <b>Developing and Using Models</b><br>Use a model based on evidence to illustrate the relationships between systems or between components of a system. | As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. | <b>Energy and Matter</b><br>Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. | ATP<br>cellular respiration<br>chemical bond<br>energy transfer<br>net transfer |
| <b>Interdependent Relationships in Ecosystems</b>                                          |                                       |                                                                                                                                                                                                                                                            |                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                         |                                                                                 |
| Key Understanding                                                                          | Driving Question                      | Standard                                                                                                                                                                                                                                                   | Science and Engineering Practices                                                                                                                      | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Crosscutting Concepts                                                                                                                                                   | Vocabulary                                                                      |

| A much smaller amount of energy and matter is transferred along each step in a food web. This leads to fewer organisms from one level to the next level up. | Why are there fewer organisms at the top of the energy pyramid? | <b>3.1.9-12.H</b><br><b>Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.</b> | <b>Using Mathematical and Computational Thinking</b><br>Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. | 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. | <b>Energy and Matter</b><br>Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. | 10% rule<br>biomass<br>conservation of energy<br>conservation of matter<br>food chain<br>food web<br>trophic level |
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| Key Understanding                                                                                                                                           | Driving Question                                                | Standard                                                                                                                                                     | Science and Engineering Practices                                                                                                                                                                                   | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Crosscutting Concepts                                                                                                                                                   | Vocabulary                                                                                                         |

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| Interdependent factors affect the number of organisms that can be sustained in an ecosystem. | Why don't populations show unlimited growth? | <b>3.1.9-12.1</b><br><b>Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.</b> | <b>Using Mathematics and Computational Thinking</b><br>Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. | 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. | <b>Scale Proportion and Quantity</b><br>The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. | carrying capacity<br>climate<br>competition<br>ecosystem<br>interdependent factor |
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## Cycles of Matter and Energy Transfer in Ecosystems

| Key Understanding                                                                    | Driving Question                                                                                     | Standard                                                                                                                                                            | Science and Engineering Practices                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Disciplinary Core Idea                                                                                                 | Crosscutting Concepts                                                                       | Vocabulary           |
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| Cycling of matter and flow of energy can occur in the presence or absence of oxygen. | In the presence and/or absence of oxygen, how does energy flow and matter cycle within an ecosystem? | <b>3.1.9-12.J</b><br><b>Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.</b> | <p><b>Constructing Explanations and Designing Solutions</b><br/>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.</p> <p><b>Scientific Knowledge is Open to Revision in Light of New Evidence</b><br/>Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.</p> | Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. | <b>Energy and Matter</b><br>Energy drives the cycling of matter within and between systems. | aerobic<br>anaerobic |

| Key Understanding                                                                                                                        | Driving Question                                                  | Standard                                                                                                                                                                                                  | Science and Engineering Practices                                                                                                                                                                                                                                                                                                                                                                                                                                      | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Crosscutting Concepts                                                                                                                                                                                                                       | Vocabulary                                                                                                    |
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| Within ecosystems, carbon cycles between organisms and the physical environment as well as between different organisms as they interact. | How can we follow an atom of carbon through the spheres of Earth? | <b>3.1.9-12.K</b><br><b>Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.</b>       | <b>Developing and Using Models</b><br>Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.                                                                                                                                                                                                                                                                                                     | <p>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.</p> <p>The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>Systems and System Models</b><br>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. | atmosphere<br>biosphere<br>carbon cycle<br>cellular respiration<br>geosphere<br>hydrosphere<br>photosynthesis |
| Factors that affect biodiversity and populations can be analyzed and represented graphically and/or mathematically.                      | How can we illustrate the biodiversity of populations using data? | <b>3.1.9-12.L</b><br><b>Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.</b> | <p><b>Using Mathematics and Computational Thinking</b><br/>Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.</p> <p><b>Scientific Knowledge is Open to Revision in Light of New Evidence</b><br/>Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.</p> | <p>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. 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.</p> | <b>Scale Proportion and Quantity</b><br>Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.                                                                     | biodiversity<br>competition<br>population<br>predation<br>species                                             |

| Ecosystem Dynamics, Functioning, and Resilience                                                  |                                                 |                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                              |                                    |
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| Key Understanding                                                                                | Driving Question                                | Standard                                                                                                                                                                                                                                                        | Science and Engineering Practices                                                                                                                                                                                                                                                                                                                                                                                                                               | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Crosscutting Concepts                                                                                                                        | Vocabulary                         |
| As the environment and populations of species change, there are resulting changes in ecosystems. | How do environmental changes impact ecosystems? | <b>3.1.9-12.M</b><br><b>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.</b> | <p><b>Engaging in Argument from Evidence</b><br/>Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.</p> <p><b>Scientific Knowledge is Open to Revision in Light of New Evidence</b><br/>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.</p> | <p>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.</p> <p>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.</p> | <p><b>Stability and Change</b><br/>Much of science deals with constructing explanations of how things change and how they remain stable.</p> | ecosystem<br>ecosystem disturbance |

| Key Understanding                                                    | Driving Question                                                                                     | Standard                                                                                                                                    | Science and Engineering Practices                                                                                                                                                                                                                             | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Crosscutting Concepts                                                                                                                | Vocabulary                                                                                                             |
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| Solutions can be generated to reduce the impact of human activities. | What actions can be taken to support biodiversity and ecosystem resiliency alongside human activity? | <b>3.1.9-12.N Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.</b> | <b>Constructing Explanations and Designing Solutions</b><br>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. | <p>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.</p> <p>Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).</p> <p>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.</p> <p>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.</p> | <b>Stability and Change</b><br>Much of science deals with constructing explanations of how things change and how they remain stable. | climate change<br>extinction<br>habitat destruction<br>invasive species<br>overexploitation<br>pollution<br>speciation |

| Social Interactions and Group Behavior                                                   |                                                                             |                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                 |                                                                                                                                                             |            |
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| Key Understanding                                                                        | Driving Question                                                            | Standard                                                                                                                                      | Science and Engineering Practices                                                                                                                                                                                                                                                                                                                                          | Disciplinary Core Idea                                                                                                          | Crosscutting Concepts                                                                                                                                       | Vocabulary |
| Many species live in groups which can increase the chances of survival and reproduction. | How do organisms interact in groups to benefit individuals and the species? | <b>3.1.9-12.O</b><br><b>Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.</b> | <b>Engaging in Argument from Evidence</b><br>Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.<br><br>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. | Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. | <b>Cause and Effect</b><br>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. |            |
| Inheritance of Traits                                                                    |                                                                             |                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                 |                                                                                                                                                             |            |
| Key Understanding                                                                        | Driving Question                                                            | Standard                                                                                                                                      | Science and Engineering Practices                                                                                                                                                                                                                                                                                                                                          | Disciplinary Core Idea                                                                                                          | Crosscutting Concepts                                                                                                                                       | Vocabulary |

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| Information in DNA inherited from parents is organized and regulated to determine the traits different cells and offspring will express. | What is the relationship between DNA and the characteristics of a cell or an organism and how those characteristics may be passed on to offspring? | <b>3.1.9-12.P</b><br><b>Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.</b> | <b>Asking Questions and Defining Problems</b><br>Ask questions that arise from examining models or a theory to clarify relationships. | 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. Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. | <b>Cause and Effect</b><br>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. | chromosome<br>DNA<br>gene<br>inheritance<br>protein<br>trait |
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## Variation of Traits

| Key Understanding                                                                                                                                             | Driving Question                                                                  | Standard                                                                                                                                                                                                                                                                      | Science and Engineering Practices                                                                                                                                                                                                                                                            | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Crosscutting Concepts                                                                                                                                                                                                                                                                                                                                                                                                                                           | Vocabulary                                           |
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| The variation and distribution of traits observed in both sexually and asexually reproducing organisms is affected by both genetic and environmental factors. | How do genetics and the environment affect genetic variation within a population? | <b>3.1.9-12.Q</b><br><b>Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.</b> | <b>Engaging in Argument from Evidence</b><br>Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.                                                                                                           | In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. | <b>Cause and Effect</b><br>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.                                                                                                                                                                                                                                                                                                     | DNA replication<br>meiosis<br>mutation<br>population |
| Mathematics can help predict and explain the variation and distribution of traits in a population.                                                            | How can math help us predict the probability of traits within a population?       | <b>3.1.9-12.R</b><br><b>Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.</b>                                                                                                                       | <b>Analyzing and Interpreting Data</b><br>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. | 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>Scale Proportion and Quantity</b><br>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).<br><br><b>Science is a Human Endeavor</b><br>Technological advances have influenced the progress of science and science has influenced advances in technology. Science and engineering are influenced by society and society is influenced by science |                                                      |

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Evidence of Common Ancestry and Diversity

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| Key Understanding | Driving Question | Standard | Science and Engineering Practices | Disciplinary Core Idea | Crosscutting Concepts | Vocabulary |
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| Common ancestry and evolutionary descent are supported by multiple and diverse empirical evidence. | How are species evolutionarily related? | <b>3.1.9-12.S</b><br><b>Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.</b> | <p><b>Obtaining, Evaluating, and Communicating Information</b><br/>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).</p> <p><b>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</b><br/>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.</p> | <p>Genetic information, like the fossil record, provides evidence of evolution.</p> <p>DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.</p> | <p><b>Patterns</b><br/>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</p> <p><b>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</b><br/>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.</p> | anatomical structure<br>common ancestor<br>embryological development<br>evolution |
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| Natural Selection                                                                                                               |                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                             |                                         |
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| Key Understanding                                                                                                               | Driving Question                                                             | Standard                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Science and Engineering Practices                                                                                                                                                                                                                                                                                                                                                                                      | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Crosscutting Concepts                                                                                                                                       | Vocabulary                              |
| Different traits can increase or decrease the chances that an individual will survive and/or reproduce to pass on their traits. | How does genetic variation among organisms affect survival and reproduction? | <b>3.1.9-12.T</b><br><b>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.</b> | <b>Constructing Explanations and Designing Solutions</b><br>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. | <p>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.</p> <p>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.</p> | <b>Cause and Effect</b><br>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. | biological fitness<br>natural selection |

| Key Understanding                                                                                                                                             | Driving Question                                                                                          | Standard                                                                                                                                                                                                             | Science and Engineering Practices                                                                                                                                                                                                                                                            | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Crosscutting Concepts                                                                                                                                                         | Vocabulary |
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| Statistics and probability can be used to illustrate that individuals with particular traits may be more likely than others to survive and produce offspring. | How does genetic variation alter the statistical odds of an organism's survival and reproductive success? | <b>3.1.9-12.U</b><br><b>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.</b> | <b>Analyzing and Interpreting Data</b><br>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. | <p>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.</p> <p>The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.</p> <p>Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. Adaptation also means that the distribution of traits in a population can change when conditions change.</p> | <b>Patterns</b><br>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. | adaptation |

| Adaptation        |                  |          |                                   |                        |                       |            |
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| Key Understanding | Driving Question | Standard | Science and Engineering Practices | Disciplinary Core Idea | Crosscutting Concepts | Vocabulary |

| Solutions can be evaluated to reduce the impact of human activities. | What actions can be taken to support biodiversity and ecosystem resiliency overall alongside human activity? | <b>3.1.9-12.V</b><br><b>Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.</b> | <b>Using Mathematics and Computational Thinking</b><br>Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. | 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. 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. 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. 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. | <b>Cause and Effect</b><br>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. | endangered species<br>genetic variation<br>threatened species |
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| Key Understanding                                                    | Driving Question                                                                                             | Standard                                                                                                                                    | Science and Engineering Practices                                                                                                                                     | Disciplinary Core Idea                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Crosscutting Concepts                                                                                                                                       | Vocabulary                                                    |

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| If a heritable trait is helpful, individual organisms with that trait are more likely to survive and/or reproduce which will make the trait more common in the population over generations. | Why does the frequency of heritable traits change over time?    | <b>3.1.9-12.W</b><br><b>Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</b>                                                                                                                                        | <b>Constructing Explanations and Designing Solutions</b><br>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. | 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.                         | <b>Cause and Effect</b><br>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.<br><br><b>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</b><br>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. | abiotic<br>biotic<br>gene frequency                      |
| Changes in the environment may cause changes in populations over time.                                                                                                                      | How do changes in the environment cause changes in populations? | <b>3.1.9-12.X</b><br><b>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.</b> | <b>Engaging in Argument from Evidence</b><br>Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.                                                                                                                                                                                                                                    | 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.<br><br>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. | <b>Cause and Effect</b><br>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.                                                                                                                                                                                                                                                  | climate change<br>deforestation<br>drought<br>extinction |