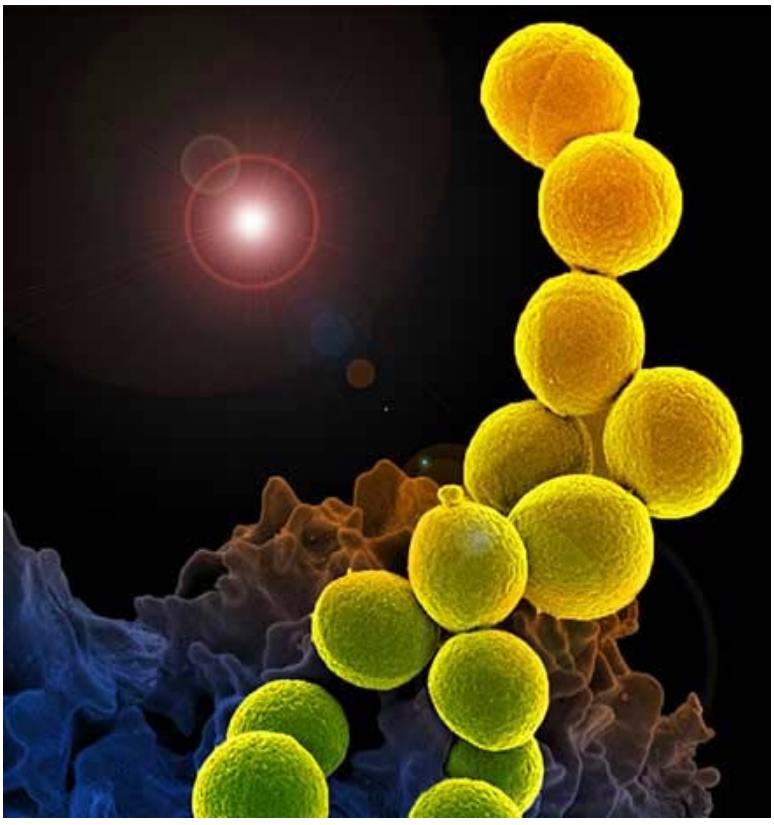
# **Unpacked Life Sciences:** A Compilation of the *Framework for K-12 Science Education*, NGSS Storylines, and the New Jersey Student Learning Standards for Science



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# Contents

## Introduction

Understanding the Performance Expectations (PE) in the *New Jersey Student Learning Standards for Science* (NJSLS) is made easier when one leverages the documents that accompany it. In an effort to support teachers in developing a clear and accurate understanding of the PEs, this document compiles *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), *Example Storylines for the NGSS* by *Disciplinary Core Idea* (NGSS Lead States, 2016), and the *New Jersey Student Learning Standards for Science* (NGSS Lead States, 2013). Each of these documents provide a different perspective and level of detail about the Performance Expectations in the science standards. This compilation was developed at the request of educators who reported that using all of the documents simultaneously is cumbersome and often confusing.

Educators who have piloted the use of the document make the following recommendations.

a) Take the time to read the essential question and narrative for the Disciplinary Core Ideas. This provides a macro-structure for student learning and a description of how its Component Idea fit together.

b) Read the essential question and overview for each Component Idea. This provides a kindergarten through grade 12 structure for student learning and how the Elements fit together. An Element is the grade specific or grade level expectation.

c) Pay attention to the essential questions throughout the document. These questions provide an organizational structure for student learning.

## Credits:

National Research Council. 2012. A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. "Appendix F - Science and Engineering Practices in the NGSS." Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. "Appendix G – Crosscutting Concepts in the NGSS." Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. "Example Storylines for the NGSS by DCI"
doi: http://www.nextgenscience.org/resources/example-storylines-ngss-dci

## LS1: From Molecules to Organisms: Structures and Processes

### Overview of Molecules to Organisms: Structures and Processes from Kindergarten through Grade 12

*How do organisms live, grow, respond to their environment, and reproduce?*

All living organisms are made of cells. Life is the quality that distinguishes living things—composed of living cells—from nonliving objects or those that have died. While a simple definition of life can be difficult to capture, all living things—that is to say all organisms—can be characterized by common aspects of their structure and functioning. Organisms are complex, organized, and built on a hierarchical structure, with each level providing the foundation for the next, from the chemical foundation of elements and atoms, to the cells and systems of individual organisms, to species and populations living and interacting in complex ecosystems. Organisms can be made of a single cell or millions of cells working together and include animals, plants, algae, fungi, bacteria, and all other microorganisms.

Organisms respond to stimuli from their environment and actively maintain their internal environment through homeostasis. They grow and reproduce, transferring their genetic information to their offspring. While individual organisms carry the same genetic information over their lifetime, mutation and the transfer from parent to offspring produce new combinations of genes. Over generations natural selection can lead to changes in a species overall; hence, species evolve over time. To maintain all of these processes and functions, organisms require materials and energy from their environment; nearly all energy that sustains life ultimately comes from the sun.

## LS1.A: Structure and Function

### Overview of Structure and Function from Kindergarten through Grade 12

*How do the structures of organisms enable life's functions?*

A central feature of life is that organisms grow, reproduce, and die. They have characteristic structures (anatomy and morphology), functions (molecular-scale processes to organism-level physiology), and behaviors (neurobiology and, for some animal species, psychology). Organisms and their parts are made of cells, which are the structural units of life and which themselves have molecular substructures that support their functioning.

Organisms range in composition from a single cell (unicellular microorganisms) to multicellular organisms, in which different groups of large numbers of cells work together to form systems of tissues and organs (e.g., circulatory, respiratory, nervous, musculoskeletal), that are specialized for particular functions.

Special structures within cells are also responsible for specific cellular functions. The essential functions of a cell involve chemical reactions between many types of molecules, including water, proteins, carbohydrates, lipids, and nucleic acids. All cells contain genetic information, in the form of DNA. Genes are specific regions within the extremely large DNA molecules that form the chromosomes.

Genes contain the instructions that code for the formation of molecules called proteins, which carry out most of the work of cells to perform the essential functions of life. That is, proteins provide structural components, serve as signaling devices, regulate cell activities, and determine the performance of cells through their enzymatic actions.

**Grade 1:**

*What are some ways plants and animals meet their needs so that they can survive and grow?*

All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow.

*Table 1: Performance Expectation for Grade 1*

| Standard Code | Performance Expectation |
|---|---|
| **1-LS1-1**[1] | **Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.*** *[Clarification Statement: Examples of human problems that can be solved by mimicking plant or animal solutions could include designing clothing or equipment to protect bicyclists by mimicking turtle shells, acorn shells, and animal scales; stabilizing structures by mimicking animal tails and roots on plants; keeping out intruders by mimicking thorns on branches and animal quills; and, detecting intruders by mimicking eyes and ears.]*<br>Click here for the Evidence Statement for 1-LS1-1. |

**Grade 4:**

*How do internal and external structures support the survival, growth, behavior, and reproduction of plants and animals?*

Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (Boundary: Stress at this grade level is on understanding the macroscale systems and their function, not microscopic processes.).

[1] 1-LS1-1 repeats in LS1.D: Information Processing

*Table 2: Performance Expectation for Grade 4*

| Standard Code | Performance Expectation |
|---|---|
| **4-LS1-1** | **Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.** *[Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals, heart, stomach, lung, brain, and skin.]* [Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.*]*<br><br>Click here for the Evidence Statement for 4-LS1-1. |

**Grades 6 through 8:**

*How can one explain the ways cells contribute to the function of living organisms?*

All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). Unicellular organisms (microorganisms), like multicellular organisms, need food, water, a way to dispose of waste, and an environment in which they can live.

Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues or organs that are specialized for particular body functions. (Boundary: At this grade level, only a few major cell structures should be introduced.)

*Table 3: Performance Expectations for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS1-1** | **Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.** *[Clarification Statement: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living things, and understanding that living things may be made of one cell or many and varied cells.]*<br><br>Click here for the Evidence Statement for MS-LS1-1. |
| **MS-LS1-2** | **Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.** *[Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.]* [Assessment Boundary: Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane. Assessment of the function of the other organelles is limited to their |

| Standard Code | Performance Expectation |
|---|---|
| | relationship to the whole cell. Assessment does not include the biochemical function of cells or cell parts.*]*<br><br>Click here for the Evidence Statement for MS-LS1-2. |
| **MS-LS1-3** | **Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.** *[Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [*Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.*]*<br><br>Click here for the Evidence Statement for MS-LS1-3. |

**Grades 9 through 12:**

*How do the structures of organisms enable life's functions?*

Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules, such as water, proteins, carbohydrates, lipids, and nucleic acids. All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.

Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. 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. Outside that range (e.g., at a too high or too low external temperature, with too little food or water available), the organism cannot survive. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

*Table 4: Performance Expectations for Grades 9 through 12*

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

| Standard Code | Performance Expectation |
|---|---|
| | Click here for the Evidence Statement for HS-LS1-1. |
| **HS-LS1-2** | **Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.** *[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.]* [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.*]*<br><br>Click here for the Evidence Statement for HS-LS1-2. |
| **HS-LS1-3** | **Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.** *[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.]* [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.*]*<br><br>Click here for the Evidence Statement for HS-LS1-3. |

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### LS1.B: Growth and Development of Organisms

Overview of Growth and Development of Organisms from Kindergarten through Grade 12

*How do organisms grow and develop?*

The characteristic structures, functions, and behaviors of organisms change in predictable ways as they progress from birth to old age. For example, upon reaching adulthood, organisms can reproduce and transfer their genetic information to their offspring. Animals engage in behaviors that increase their chances for reproduction, and plants may develop specialized structures and/or depend on animal behavior to accomplish reproduction.

Understanding how a single cell can give rise to a complex, multicellular organism builds on the concepts of cell division and gene expression. In multi-cellular organisms, cell division is an essential component of growth, development, and repair. Cell division occurs via a process called mitosis: when a cell divides in two, it passes identical genetic material to two daughter cells. Successive divisions produce many cells. Although the genetic material in each of the cells is identical, small differences in the immediate environments activate or inactivate different genes, which can cause the cells to develop slightly differently. This process of differentiation allows the

body to form specialized cells that perform diverse functions, even though they are all descended from a single cell, the fertilized egg. Cell growth and differentiation are the mechanisms by which a fertilized egg develops into a complex organism. In sexual reproduction, a specialized type of cell division called meiosis occurs and results in the production of sex cells, such as gametes (sperm and eggs) or spores, which contain only one member from each chromosome pair in the parent cell.

**Grade 1:**

*How do the how behaviors of parents and offspring help the offspring survive?*

Plants and animals have predictable characteristics at different stages of development. Plants and animals grow and change. Adult plants and animals can have young. In many kinds of animals, parents and the offspring themselves engage in behaviors that help the offspring to survive.

*Table 5: Performance Expectation for Grade 1*

| Standard Code | Performance Expectation |
|---|---|
| **1-LS1-2** | **Read texts and use media to determine patterns in behavior of parents and offspring that help offspring survive.** *[Examples of patterns of behaviors could include the signals that offspring make (such as crying, cheeping, and other vocalizations) and the responses of the parents (such as feeding, comforting, and protecting the offspring).]*<br>Click here for the 1-LS1-2 Evidence Statements. |

**Grade 3:**

*What are the similarities and differences of organisms' life cycles?*

Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles that include being born (sprouting in plants), growing, developing into adults, reproducing, and eventually dying.

*Table 6: Performance Expectation for Grade 3*

| Standard Code | Performance Expectation |
|---|---|
| **3-LS1-1** | **Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death.** *[Changes organisms go through during their life form a pattern.]* [Assessment of plant life cycles is limited to those of flowering plants. Assessment does not include details of human reproduction.*]*<br>Click here for the Evidence Statement for 3-LS1-1. |

### Grades 6 through 8:

*What influences the growth and development of an organism?*

Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. Animals engage in characteristic behaviors that increase the odds of reproduction. Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (such as attractively colored flowers) for reproduction. Plant growth can continue throughout the plant's life through production of plant matter in photosynthesis. Genetic factors as well as local conditions affect the size of the adult plant. The growth of an animal is controlled by genetic factors, food intake, and interactions with other organisms, and each species has a typical adult size range. (Boundary: Reproduction is not treated in any detail here; for more specifics about grade level, see LS3.A.)

Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited (LS3.A).

In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other (LS3.B).

*Table 7: Performance Expectations for Grades 6through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS1-4** | **Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.** *[Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]*<br><br>Click here for the Evidence Statement for MS-LS1-4. |

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS1-5** | **Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** *[Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [*Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.*]*<br><br>Click here for the Evidence Statement for MS-LS1-5. |

**Grades 9 through 12:**

*How do organisms live and grow?*

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. As successive subdivisions of an embryo's cells occur, programmed genetic instructions and small differences in their immediate environments activate or inactivate different genes, which cause the cells to develop differently—a process called differentiation. 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. In sexual reproduction, a specialized type of cell division called meiosis occurs that results in the production of sex cells, such as gametes in animals (sperm and eggs), which contain only one member from each chromosome pair in the parent cell.

*Table 8: Performance Expectation for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS1-4** | **Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.** *[*Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.*]*<br><br>Click here for HS-LS1-4 Evidence Statements. |

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### LS1.C: Organization for Matter and Energy Flow in Organisms

#### Overview of Organization for Matter and Energy Flow in Organisms Kindergarten through Grade 12

*How do organisms obtain and use the matter and energy they need to live and grow?*

Sustaining life requires substantial energy and matter inputs. The complex structural organization of organisms accommodates the capture, transformation, transport, release, and elimination of the matter and energy needed to sustain them. As matter and energy flow through different organizational levels—cells, tissues, organs, organisms, populations, communities, and ecosystems—of living systems, chemical elements are recombined in different ways to form different products. The result of these chemical reactions is that energy is transferred from one system of interacting molecules to another.

In most cases, the energy needed for life is ultimately derived from the sun through photosynthesis (although in some ecologically important cases, energy is derived from reactions involving inorganic chemicals in the absence of sunlight—e.g., chemosynthesis). Plants, algae (including phytoplankton), and other energy-fixing microorganisms use sunlight, water, and carbon dioxide to facilitate photosynthesis, which stores energy, forms plant matter, releases oxygen, and maintains plants' activities. Plants and algae—being the resource base for animals, the animals that feed on animals, and the decomposers—are energy-fixing organisms that sustain the rest of the food web.

#### Kindergarten:

*Where do animals live and why do they live there?*

All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow.

*Table 9: Performance Expectation for Kindergarten*

| Standard Code | Performance Expectation |
|---|---|
| **K-LS1-1** | **Use observations to describe patterns of what plants and animals (including humans) need to survive.** *[Clarification Statement: Examples of patterns could include that animals need to take in food but plants do not; the different kinds of food needed by different types of animals; the requirement of plants to have light; and, that all living things need water.]*<br>Click here for the Evidence Statement for K-LS1-1. |

#### Grade 5:

*Where does the energy in food come from and what is it used for?*

Animals and plants alike generally need to take in air and water, animals must take in food, and plants need light and minerals; anaerobic life, such as bacteria in the gut, functions without air. *Food provides animals with the materials they need for body repair and growth and is digested*

*to release the energy they need to maintain body warmth and for motion.* Plants acquire their material for growth chiefly from air and water and process matter they have formed to maintain their internal conditions (e.g., at night).

*Table 10: Performance Expectation for Grade 5*

| Standard Code | Performance Expectation |
|---|---|
| **5-LS1-1** | **Support an argument that plants get the materials they need for growth chiefly from air and water.** *[Clarification Statement: Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil.]*<br>Click here for the Evidence Statement for 5-LS1-1. |

**Grades 6 through 8:**

*How can one explain the ways cells contribute to the function of living organisms?*

Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. Animals obtain food from eating plants or eating other animals. Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. In most animals and plants, oxygen reacts with carbon-containing molecules (sugars) to provide energy and produce carbon dioxide; anaerobic bacteria achieve their energy needs in other chemical processes that do not require oxygen.

*Table 11: Performance Expectations for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS1-6** | **Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.** *[Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.]* [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.*]*<br>Click here for the Evidence Statement for MS-LS1-6. |
| **MS-LS1-7** | **Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.** *[Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.]* [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.*]*<br>Click here for the Evidence Statement for MS-LS1-7. |

### Grades 9 through 12:

*How do organisms obtain and use the matter and energy they need to live and grow?*

The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. The sugar molecules thus formed contain carbon, hydrogen, and oxygen; their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. For example, aerobic (in the presence of oxygen) 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. Anaerobic (without oxygen) cellular respiration follows a different and less efficient chemical pathway to provide energy in cells. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy loss to the surrounding environment. Matter and energy are conserved in each change. This is true of all biological systems, from individual cells to ecosystems.

*Table 12: Performance Expectations for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS1-5** | **Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.** *[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.]* [Assessment Boundary: Assessment does not include specific biochemical steps.*]*<br><br>Click here for the Evidence Statement for HS-LS1-5. |
| **HS-LS1-6** | **Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.** *[Clarification Statement: Emphasis is on using evidence from models and simulations to support explanations.]* [Assessment Boundary: Assessment does not include the details of the specific chemical reactions or identification of macromolecules.*]*<br><br>Click here for the Evidence Statement for HS-LS1-6. |
| **HS-LS1-7** | **Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.** *[Clarification Statement: Emphasis is on the conceptual understanding* |

| Standard Code | Performance Expectation |
|---|---|
| | *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.*]*<br><br>Click here for the Evidence Statement for HS-LS1-7. |

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### LS1.D: Information Processing

Overview of Information Processing from Kindergarten through Grade 12

*How do organisms detect, process, and use information about the environment?*

An organism's ability to sense and respond to its environment enhances its chance of surviving and reproducing. Animals have external and internal sensory receptors that detect different kinds of information, and they use internal mechanisms for processing and storing it. Each receptor can respond to different inputs (electromagnetic, mechanical, chemical), some receptors respond by transmitting impulses that travel along nerve cells. In complex organisms, most such inputs travel to the brain, which is divided into several distinct regions and circuits that serve primary roles, in particular functions such as visual perception, auditory perception, interpretation of perceptual information, guidance of motor movement, and decision making. In addition, some of the brain's circuits give rise to emotions and store memories. Brain function also involves multiple interactions between the various regions to form an integrated sense of self and the surrounding world.

**Grade 1:**

*What are some ways plants and animals meet their needs so that they can survive and grow?*

Animals have body parts that capture and convey different kinds of information needed for growth and survival—for example, eyes for light, ears for sounds, and skin for temperature or touch. Animals respond to these inputs with behaviors that help them survive (e.g., find food, run from a predator).

Plants also respond to some external inputs (e.g., turn leaves toward the sun).

*Table 13: Performance Expectation for Grade 1*

| Standard Code | Performance Expectation |
|---|---|
| **1-LS1-1**[2] | **Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.*** *[Clarification Statement: Examples of human problems that can be solved by mimicking plant or animal solutions could include designing clothing or equipment to protect bicyclists by mimicking turtle shells, acorn shells, and animal scales; stabilizing structures by mimicking animal tails and roots on plants; keeping out intruders by mimicking thorns on branches and animal quills; and, detecting intruders by mimicking eyes and ears.]*<br>Click here for the Evidence Statement 1-LS1-1. |

**Grade 4:**

*How do internal and external structures support the survival, growth, behavior, and reproduction of plants and animals?*

Different sense receptors are specialized for particular kinds of information, which may then be processed and integrated by an animal's brain, with some information stored as memories. Animals are able to use their perceptions and memories to guide their actions. Some responses to information are instinctive—that is, animals' brains are organized so that they do not have to think about how to respond to certain stimuli.

*Table 14: Performance Expectation for Grade 4*

| Standard Code | Performance Expectation |
|---|---|
| **4-LS1-2** | **Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.** *[Clarification Statement: Emphasis is on systems of information transfer.]* [Assessment Boundary: Assessment does not include the mechanisms by which the brain stores and recalls information or the mechanisms of how sensory receptors function.*]*<br>Click here for the Evidence Statement for 4-LS1-2. |

**Grades 6 through 8:**

*How do organisms receive and respond to input from their environment?*

Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. Changes in the structure

[2] 1-LS1-1 repeats in LS1.A: Structure and Function

and functioning of many millions of interconnected nerve cells allow combined inputs to be stored as memories for long periods of time.

*Table 15: Performance Expectation for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS1-8** | **Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.** *[*Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.*]*<br><br>Click here for the evidence statement for MS-LS1-8. |

### Grades 9 through 12:

*How do organisms process stimulus?*

In complex animals, the brain is divided into several distinct regions and circuits, each of which primarily serves dedicated functions, such as visual perception, auditory perception, interpretation of perceptual information, guidance of motor movement, and decision making about actions to take in the event of certain inputs. In addition, some circuits give rise to emotions and memories that motivate organisms to seek rewards, avoid punishments, develop fears, or form attachments to members of their own species and, in some cases, to individuals of other species (e.g., mixed herds of mammals, mixed flocks of birds). The integrated functioning of all parts of the brain is important for successful interpretation of inputs and generation of behaviors in response to them.

There are no Performance Expectations for LS1.D in grades 9 through 12.

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## Core Idea LS2: Ecosystems: Interactions, Energy, and Dynamics

Overview of Ecosystems: Interactions, Energy, and Dynamics from Kindergarten through Grade 12

*How and why do organisms interact with their environment and what are the effects of these interactions?*

Ecosystems are complex, interactive systems that include both biological communities (biotic) and physical (abiotic) components of the environment. As with individual organisms, a hierarchal structure exists; groups of the same organisms (species) form populations, different populations interact to form communities, communities live within an ecosystem, and all of the ecosystems on Earth make up the biosphere. Organisms grow, reproduce, and perpetuate their species by obtaining necessary resources through interdependent relationships with other organisms and the physical environment. These same interactions can facilitate or restrain growth and enhance or limit the size of populations, maintaining the balance between available resources and those

who consume them. These interactions can also change both biotic and abiotic characteristics of the environment. Like individual organisms, ecosystems are sustained by the continuous flow of energy, originating primarily from the sun, and the recycling of matter and nutrients within the system. Ecosystems are dynamic, experiencing shifts in population composition and abundance and changes in the physical environment over time, which ultimately affects the stability and resilience of the entire system.

**LS2.A: Interdependent Relationships in Ecosystems**

Overview of Interdependent Relationships in Ecosystems from Kindergarten through Grade 12

*How do organisms interact with the living and nonliving environments to obtain matter and energy?*

Ecosystems are ever changing because of the interdependence of organisms of the same or different species and the nonliving (physical) elements of the environment. Seeking matter and energy resources to sustain life, organisms in an ecosystem interact with one another in complex feeding hierarchies of producers, consumers, and decomposers, which together represent a food web. Interactions between organisms may be predatory, competitive, or mutually beneficial. Ecosystems have carrying capacities that limit the number of organisms (within populations) they can support. Individual survival and population sizes depend on such factors as predation, disease, availability of resources, and parameters of the physical environment. Organisms rely on physical factors, such as light, temperature, water, soil, and space for shelter and reproduction. Earth's varied combinations of these factors provide the physical environments in which its ecosystems (e.g., deserts, grasslands, rain forests, and coral reefs) develop and in which the diverse species of the planet live. Within any one ecosystem, the biotic interactions between organisms (e.g., competition, predation, and various types of facilitation, such as pollination) further influence their growth, survival, and reproduction, both individually and in terms of their populations.

**Grade 2:**

*How many types of living things live in a place?*

Animals depend on their surroundings to get what they need, including food, water, shelter, and a favorable temperature. Animals depend on plants or other animals for food. They use their senses to find food and water, and they use their body parts to gather, catch, eat, and chew the food. Plants depend on air, water, minerals (in the soil), and light to grow. Animals can move around, but plants cannot, and they often depend on animals for pollination or to move their seeds around. Different plants survive better in different settings because they have varied needs for water, minerals, and sunlight

*Table 16: Performance Expectations for Grade 2*

| Standard Code | Performance Expectation |
|---|---|
| **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 variable at a time.*]*<br>Click here for the Evidence Statement for 2-LS2-1. |
| **2-LS2-2** | **Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants.***<br>Click here for the Evidence Statement for 2-LS2-2. |

**Grade 5:**

*How does matter cycle through ecosystems?*

The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Either way, they are "consumers." Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil for plants to use. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.

*Table 17: Performance Expectation for Grade 5*

| Standard Code | Performance Expectation |
|---|---|
| **5-LS2-1** | **Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.** *[Clarification Statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth.] [Assessment Boundary: Assessment does not include molecular explanations.]*<br>Click here for the Evidence Statement for 5-LS2-1. |

**Grades 6 through 8:**

*How does a system of living and non-living things operate to meet the needs of the organisms in an ecosystem?*

Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with

similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

*Table 18: Performance Expectations for grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS2-1** | **Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.** *[Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.]*<br>Click here for the Evidence Statement for MS-LS2-1. |
| **MS-LS2-2** | **Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.** *[Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.]*<br>Click here for the Evidence Statement for MS-LS2-2. |

**Grades 9 through 12:**

*How and why do organisms interact with their environment, and what are the effects of these interactions?*

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 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.

*Table 19: Performance Expectations for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS2-1** | **Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.** *[Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.]* [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.*]*<br><br>Click here for the Evidence Statement for HS-LS2-1. |
| **HS-LS2-2** | **Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.** *[Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.]* [Assessment Boundary: Assessment is limited to provided data.*]*<br><br>Click here for the Evidence Statement for HS-LS2-2. |

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### LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

#### Overview of Cycles of Matter and Energy Transfer in Ecosystems from Kindergarten through Grade 12

*How do matter and energy move through an ecosystem?*

The cycling of matter and the flow of energy within ecosystems occur through interactions among different organisms and between organisms and the physical environment. All living systems need matter and energy. Matter fuels the energy-releasing chemical reactions that provide energy for life functions and provides the material for growth and repair of tissue. Energy from light is needed for plants because the chemical reaction that produces plant matter from air and water requires an energy input to occur. Animals acquire matter from food, that is, from plants or other animals. The chemical elements that make up the molecules of organisms pass through food webs and the environment and are combined and recombined in different ways. At each level in a food web, some matter provides energy for life functions, some is stored in newly made structures, and much is discarded to the surrounding environment. Only a small fraction of the matter consumed at one level is captured by the next level up. As matter cycles and energy flows through living systems and between living systems and the physical environment, matter and energy are conserved in each change.

The carbon cycle provides an example of matter cycling and energy flow in ecosystems. Photosynthesis, digestion of plant matter, respiration, and decomposition are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

**Grade 5:**

*Where does the energy in food come from and what is it used for?*

Organisms obtain the materials they need to grow and survive from the environment. Many of these materials come from organisms and are used again by other organisms.

Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, water, and minerals from the environment and release waste matter (gas, liquid, or solid) back into the environment.

*Table 20: Performance Expectation for Grade 5*

| Standard Code | Performance Expectation |
|---|---|
| **5-LS2-1** | **Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.** *[Clarification Statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth.] [Assessment Boundary: Assessment does not include molecular explanations.]*<br>Click here for the Evidence Statement for 5-LS2-1. |

**Grades 6 through 8:**

*How does a system of living and non-living things operate to meet the needs of the organisms in an ecosystem?*

Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

*Table 21: Performance Expectation for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS2-3** | **Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.** *[Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.]* [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.*]*<br><br>Click here for the Evidence Statement for MS-LS2-3. |

**Grades 9 through 12:**

*How do matter and energy move through an ecosystem?*

Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. 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, and there is a limit to the number of organisms that an ecosystem can sustain.

The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. Competition among species is ultimately competition for the matter and energy needed for life.

Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

*Table 22: Performance Expectations for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS2-3** | **Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.** *[Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.]* [Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.*]*<br><br>Click here for the Evidence Statement for HS-LS2-3. |
| **HS-LS2-4** | **Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.** *[Clarification* |

| Standard Code | Performance Expectation |
|---|---|
| | *Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.] [*Assessment Boundary: Assessment is limited to proportional reasoning to describe the cycling of matter and flow of energy.*]*<br><br>Click here for the Evidence Statement for HS-LS2-4. |
| **HS-LS2-5** | **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** *[Clarification Statement: Examples of models could include simulations and mathematical models.] [*Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.*]*<br><br>Click here for the Evidence Statement for HS-LS2-5. |

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### LS2.C: Ecosystem Dynamics, Functioning and Resilience

#### Overview of Ecosystem Dynamics, Functioning and Resilience from Kindergarten through Grade 12

*What happens to ecosystems when the environment changes?*

Ecosystems are dynamic in nature; their characteristics fluctuate over time, depending on changes in the environment and in the populations of various species. Disruptions in the physical and biological components of an ecosystem—which can lead to shifts in the types and numbers of the ecosystem's organisms, to the maintenance or the extinction of species, to the migration of species into or out of the region, or to the formation of new species (speciation)—occur for a variety of natural reasons. Changes may derive from the fall of canopy trees in a forest, for example, or from cataclysmic events, such as volcanic eruptions. But many changes are induced by human activity, such as resource extraction, adverse land use patterns, pollution, introduction of nonnative species, and global climate change. Extinction of species or evolution of new species may occur in response to significant ecosystem disruptions.

Species in an environment develop behavioral and physiological patterns that facilitate their survival under the prevailing conditions, but these patterns may be maladapted when conditions change or new species are introduced. Ecosystems with a wide variety of species—that is, greater biodiversity—tend to be more resilient to change than those with few species.

**By the end of grade 2:** Being part of a group helps animals obtain food, defend themselves, and cope with changes. Groups may serve different functions and vary dramatically in size. (Note: There is not a Performance Expectations for **LS2.C** at this grade level.)

**By the end of grade 5:** When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. (Note: There is not a Performance Expectations for **LS2.C** at this grade level.)

**Grades 6 through 8:**

*What happens to ecosystems when the environment changes?*

Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations.

Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

*Table 23: Performance Expectations for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS2-4** | **Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.** *[Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]*<br>Click here for the Evidence Statement for MS-LS2-4. |
| **MS-LS2-5** | **Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*** *[Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]*<br>Click here for the Evidence Statement for MS-LS2-5. |

**Grades 9 through 12:**

*What happens to ecosystems when the environment changes?*

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

introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

*Table 24: Performance Expectations for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS2-2** | **Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.** *[Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.]* [Assessment Boundary: Assessment is limited to provided data.*]*<br><br>Click here for the Evidence Statement for HS-LS2-2. |
| **HS-LS2-6** | **Evaluate 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.]*<br><br>Click here for the Evidence Statement for HS-LS2-6. |
| **HS-LS2-7** | **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*** *[Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]*<br><br>Click here for the Evidence Statement for HS-LS2-7. |

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### LS2.D: Social Interactions and Group Behavior

Overview of Social Interactions and Group Behavior for Kindergarten through Grade 12

*How do organisms interact in groups so as to benefit individuals?*

Group behaviors are found in organisms ranging from unicellular slime molds to ants to primates, including humans. Many species, with a strong drive for social affiliation, live in groups formed on the basis of genetic relatedness, physical proximity, or other recognition mechanisms (which may be species specific). Group behavior evolved because group membership can increase the chances of survival for individuals and their relatives. While some groups are stable over long periods of time, others are fluid, with members moving in and out. Groups often dissolve if their size or operation becomes counterproductive, if dominant members lose their place, or if other key members are removed from the group. Group inter-dependence is so strong that animals

that usually live in groups suffer, behaviorally as well as physiologically, when reared in isolation, even if all of their physical needs are met.

**Grade 3:**

*What happens to organisms when their environment changes?*

Being part of a group helps animals obtain food, defend themselves, and cope with changes. Groups may serve different functions and vary dramatically in size.

*Table 25: Performance Expectation in Grade 3*

| Standard Code | Performance Expectation |
|---|---|
| **3-LS2-1** | **Construct an argument that some animals form groups that help members survive.**<br>Click here for the Evidence Statement for 3-LS2-1. |

**Grade 4 and 5:** Groups can be collections of equal individuals, hierarchies with dominant members, small families, groups of single or mixed gender, or groups composed of individuals similar in age. Some groups are stable over long periods of time; others are fluid, with members moving in and out. Some groups assign specialized tasks to each member; in others, all members perform the same or a similar range of functions. (Note: There is not a Performance Expectation for **LS2.D** at this grade level.)

**By the end of Grade 8:** Groups may form because of genetic relatedness, physical proximity, or other recognition mechanisms (which may be species specific). They engage in a variety of signaling behaviors to maintain the group's integrity or to warn of threats. Groups often dissolve if they no longer function to meet individuals' needs, if dominant members lose their place, or if other key members are removed from the group through death, predation, or exclusion by other members. (Note: There is not a Performance Expectation for **LS2.D** at this grade level.)

**Grades 9 through 12:**

*How do organisms interact in groups so as to benefit individuals?*

Animals, including humans, having a strong drive for social affiliation with members of their own species and will suffer, behaviorally as well as physiologically, if reared in isolation, even if all of their physical needs are met. Some forms of affiliation arise from the bonds between offspring and parents. Other groups form among peers. Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.

*Table 26: Performance Expectation for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS2-8** | **Evaluate 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.]*<br>Click here for the Evidence Statement for HS-LS2-8. |

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## LS3: Heredity: Inheritance and Variation of Traits

### Overview of Heredity: Inheritance and Variation of Traits from Kindergarten through Grade 12

*How are characteristics of one generation passed to the next?*

*How can individuals of the same species and even siblings have different characteristics?*

Heredity explains why offspring resemble, but are not identical to, their parents and is a unifying biological principle. Heredity refers to specific mechanisms by which characteristics or traits are passed from one generation to the next via genes. Genes encode the information for making specific proteins, which are responsible for the specific traits of an individual. Each gene can have several variants, called alleles, which code for different variants of the trait in question. Genes reside in a cell's chromosomes, each of which contains many genes. Every cell of any individual organism contains the identical set of chromosomes. When organisms reproduce, genetic information is transferred to their offspring. In species that reproduce sexually, each cell contains two variants of each chromosome, one inherited from each parent. Thus sexual reproduction gives rise to a new combination of chromosome pairs with variations between parent and offspring. Very rarely, mutations also cause variations, which may be harmful, neutral, or occasionally advantageous for an individual. Environmental as well as genetic variation and the relative dominance of each of the genes in a pair play an important role in how traits develop within an individual. Complex relationships between genes and interactions of genes with the environment determine how an organism will develop and function.

### LS3.A: Inheritance of Traits

Overview of Inheritance of Traits from Kindergarten through Grade 12

*How are the characteristics of one generation related to the previous generation?*

In all organisms, the genetic instructions for forming species' characteristics are carried in the chromosomes. Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. DNA molecules contain four different kinds of building blocks, called nucleotides, linked together in a sequential chain. The sequence of nucleotides spells out the information in a gene. Before a cell divides, the DNA sequence of its chromosomes is replicated and each daughter cell receives a copy. DNA controls the expression of proteins by being transcribed into a "messenger" RNA, which is translated in turn by the cellular machinery into a protein. In effect, proteins build an organism's identifiable traits. When organisms reproduce, genetic information is transferred to their offspring, with half coming from each parent in sexual reproduction. Inheritance is the key factor causing the similarity among individuals in a species population.

**Grade 1:**

*How are parents and their children similar and different?*

Organisms have characteristics that can be similar or different. Young animals are very much, but not exactly, like their parents and also resemble other animals of the same kind. Plants also are very much, but not exactly, like their parents and resemble other plants of the same kind.

*Table 27: Performance Expectation for 1st Grade*

| Standard Code | Performance Expectation |
|---|---|
| **1-LS3-1**[3] | **Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.** *[Clarification Statement: Examples of patterns could include features plants or animals share. Examples of observations could include leaves from the same kind of plant are the same shape but can differ in size; and, a particular breed of dog looks like its parents but is not exactly the same.]* [Assessment Boundary: Assessment does not include inheritance or animals that undergo metamorphosis or hybrids.*]*<br><br>Click here for the Evidence Statement for 1-LS3-1. |

[3] 1-LS3-1 repeats in LS3.B: Variation of Traits

### Grade 3:

*How do organisms vary in their traits?*

Many characteristics of organisms are inherited from their parents. Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment.

*Table 28: Performance Expectations for Grade 3*

| Standard Code | Performance Expectation |
|---|---|
| **3-LS3-1**[4] | **Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.** *[Clarification Statement: Patterns are the similarities and differences in traits shared between offspring and their parents, or among siblings. Emphasis is on organisms other than humans.]* [Assessment Boundary: Assessment does not include genetic mechanisms of inheritance and prediction of traits. Assessment is limited to non-human examples.*]*<br><br>Click here for the Evidence Statement for 3-LS3-1. |
| **3-LS3-2**[5] | **Use evidence to support the explanation that traits can be influenced by the environment**. *[Clarification Statement: Examples of the environment affecting a trait could include normally tall plants grown with insufficient water are stunted; and, a pet dog that is given too much food and little exercise may become overweight.]*<br><br>Click here for the Evidence Statement for 3-LS3-2. |

### Grades 6 through 8:

*How do living organisms pass traits from one generation to the next?*

Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of a specific protein, which in turn affects the traits of the individual (e.g., human skin color results from the actions of proteins that control the production of the pigment melanin). Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

Sexual reproduction provides for transmission of genetic information to offspring through egg and sperm cells. These cells, which contain only one chromosome of each parent's chromosome pair, unite to form a new individual (offspring). Thus offspring possess one instance of each parent's chromosome pair (forming a new chromosome pair). Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of

[4] 3-LS3-1 repeats in LS3.B: Variation of Traits
[5] 3-LS3-2 repeats in LS3.B: Variation of Traits

chromosomes (and therefore genes) inherited or (more rarely) from mutations. (Boundary: The stress here is on the impact of gene transmission in reproduction, not the mechanism.)

*Table 29: Performance Expectations for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS3-1**[6] | **Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.** *[Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.]* *[*Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.*]*<br><br>Click here for the Evidence Statement for MS-LS3-1. |
| **MS-LS3-2**[7] | **Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation**. *[Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]*<br><br>Click here for the Evidence Statement for MS-LS3-2. |

**Grades 9 through 12:**

*How are characteristics of one generation passed to the next?*

*How can individuals of the same species and even siblings have different characteristics?*

In all organisms the genetic instructions for forming species' characteristics are carried in the chromosomes. 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.

[6] MS-LS3-1 repeats in LS3.B: Variation of Traits
[7] MS-LS3-2 repeats in LS3.B: Variation of Traits

*Table 30: Performance Expectation for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| HS-LS3-1 | **Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.** *[*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]*<br><br>Click here for the Evidence Statement for HS-LS3-1. |

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### LS3.B: Variation of Traits

Overview of Variation of Traits from Kindergarten through Grade 12

*Why do individuals of the same species vary in how they look, function, and behave?*

Variation among individuals of the same species can be explained by both genetic and environmental factors. Individuals within a species have similar but not identical genes. In sexual reproduction, variations in traits between parent and offspring arise from the particular set of chromosomes (and their respective multiple genes) inherited, with each parent contributing half of each chromosome pair. More rarely, such variations result from mutations, which are changes in the information that genes carry. Although genes control the general traits of any given organism, other parts of the DNA and external environmental factors can modify an individual's specific development, appearance, behavior, and likelihood of producing offspring. The set of variations of genes present, together with the interactions of genes with their environment, determines the distribution of variation of traits in a population.

### Grade 1:

*How are parents and their children similar and different?*

Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways.

*Table 31: Performance Expectation for Grade 1*

| Standard Code | Performance Expectation |
|---|---|
| 1-LS3-1[8] | **Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.** *[Clarification Statement: Examples of patterns could include features plants or animals share. Examples of observations could include leaves from the same kind of plant are the same shape but can differ in size; and, a particular breed of dog looks like its parents* |

[8] 1-LS3-1 repeats in LS3A: Inheritance of Traits

| Standard Code | Performance Expectation |
|---|---|
| | *but is not exactly the same.] [*Assessment Boundary: Assessment does not include inheritance or animals that undergo metamorphosis or hybrids.*]*<br><br>Click here for the Evidence Statement for 1-LS3-1. |

**Grade 3:**

*How do organisms vary in their traits?*

Offspring acquire a mix of traits from their biological parents. Different organisms vary in how they look and function because they have different inherited information. In each kind of organism there is variation in the traits themselves, and different kinds of organisms may have different versions of the trait. The environment also affects the traits that an organism develops—differences in where they grow or in the food they consume may cause organisms that are related to end up looking or behaving differently.

*Table 32: Performance Expectations for Grade 3*

| Standard Code | Performance Expectation |
|---|---|
| **3-LS3-1**[9] | **Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.** *[Clarification Statement: Patterns are the similarities and differences in traits shared between offspring and their parents, or among siblings. Emphasis is on organisms other than humans.] [*Assessment Boundary: Assessment does not include genetic mechanisms of inheritance and prediction of traits. Assessment is limited to non-human examples.*]*<br><br>Click here for the Evidence Statement for 3-LS3-1. |
| **3-LS3-2**[10] | **Use evidence to support the explanation that traits can be influenced by the environment.** *[Clarification Statement: Examples of the environment affecting a trait could include normally tall plants grown with insufficient water are stunted; and, a pet dog that is given too much food and little exercise may become overweight.]*<br><br>Click here for the Evidence Statement for 3-LS3-2. |

[9] 3-LS3-1 repeats in LS3:A: Inheritance of Traits
[10] 3-LS3-2 repeats in LS3:A: Inheritance of Traits

### Grade 6 through 8:

*How do living organisms pass traits from one generation to the next?*

In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.

*Table 33: Performance Expectations for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS3-1**[11] | **Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.** *[Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.]* *[*Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.*]*<br><br>Click here for the Evidence Statement for MS-LS3-1. |
| **MS-LS3-2**[12] | **Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.** *[Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]*<br><br>Click here for the Evidence Statement for MS-LS3-2. |

### Grades 9 through 12:

*Why do individuals of the same species vary in how they look, function, and behave?*

The information passed from parents to offspring is coded in the DNA molecules that form the chromosomes. 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

[11] MS-LS3-1 repeats in LS3:A: Inheritance of Traits
[12] MS-LS3-2 repeats in LS3:A: Inheritance of Traits

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 depend on both genetic and environmental factors.

*Table 34: Performance Expectations for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS3-2** | **Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.** *[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]*<br><br>Click here for the Evidence Statement for HS-LS3-2. |
| **HS-LS3-3** | **Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.** *[Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.]* [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.*]*<br><br>Click here for the Evidence Statement for HS-LS3-3. |

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## LS4: Biological Evolution: Unity and Diversity

### Overview of Biological Evolution: Unity and Diversity from Kindergarten through Grade 12

*How can there be so many similarities among organisms yet so many different kinds of plants, animals, and microorganisms?*

*How does biodiversity affect humans*?

Biological evolution explains both the unity and the diversity of species and provides a unifying principle for the history and diversity of life on Earth. Biological evolution is supported by extensive scientific evidence ranging from the fossil record to genetic relationships among species. Researchers continue to use new and different techniques, including DNA and protein sequence analyses, to test and further their understanding of evolutionary relationships. Evolution, which is continuous and ongoing, occurs when natural selection acts on the genetic variation in a population and changes the distribution of traits in that population gradually over multiple generations. Natural selection can act more rapidly after sudden changes in conditions, which can lead to the extinction of species. Through natural selection, traits that provide an individual with an advantage to best meet environmental challenges and reproduce are the ones most likely to be passed on to the next generation. Over multiple generations, this process can lead to the emergence of new species. Evolution thus explains both the similarities of genetic material across all species and the multitude of species existing in diverse conditions on Earth—its biodiversity—which humans depend on for natural resources and other benefits to sustain themselves.

## LS4.A: Evidence of Common Ancestry and Diversity

### Overview of Evidence of Common Ancestry and Diversity from Kindergarten through Grade 12

*What evidence shows that different species are related?*

Biological evolution, the process by which all living things have evolved over many generations from shared ancestors, explains both the unity and the diversity of species. The unity is illustrated by the similarities found between species; which can be explained by the inheritance of similar characteristics from related ancestors. The diversity of species is also consistent with common ancestry; it is explained by the branching and diversification of lineages as populations adapted, primarily through natural selection, to local circumstances.

Evidence for common ancestry can be found in the fossil record, from comparative anatomy and embryology, from the similarities of cellular processes and structures, and from comparisons of DNA sequences between species. The understanding of evolutionary relationships has recently been greatly accelerated by using new molecular tools to study developmental biology, with researchers dissecting the genetic basis for some of the changes seen in the fossil record, as well as those that can be inferred to link living species (e.g., the armadillo) to their ancestors (e.g., glyptodonts, a kind of extinct gigantic armadillo).

### Grade 3:

*How are plants, animals, and environments of the past similar or different from current plants, animals, and environments?*

Some kinds of plants and animals that once lived on Earth (e.g., dinosaurs) are no longer found anywhere, although others now living (e.g., lizards) resemble them in some ways.

Fossils provide evidence about the types of organisms (both visible and microscopic) that lived long ago and also about the nature of their environments. Fossils can be compared with one another and to living organisms according to their similarities and differences.

*Table 35: Performance Expectation for Grade 3*

| Standard Code | Performance Expectation |
|---|---|
| **3-LS4-1** | **Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.** *[Clarification Statement: Examples of data could include type, size, and distributions of fossil organisms. Examples of fossils and environments could include marine fossils found on dry land, tropical plant fossils found in Arctic areas, and fossils of extinct organisms.]* [Assessment Boundary: Assessment does not include identification of specific fossils or present plants and animals. Assessment is limited to major fossil types and relative ages.*]*<br><br>Click here for the Evidence Statement for 3-LS4-1. |

### Grades 6 through 8:

*How do species change over time?*

Fossils are mineral replacements, preserved remains, or traces of organisms that lived in the past. Thousands of layers of sedimentary rock not only provide evidence of the history of Earth itself but also of changes in organisms whose fossil remains have been found in those layers. The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. Because of the conditions necessary for their preservation, not all types of organisms that existed in the past have left fossils that can be retrieved. Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully formed anatomy.

*Table 36: Performance Expectations for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS4-1** | **Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.** *[Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]*<br><br>Click here for the Evidence Statement for MS-LS4-1. |
| **MS-LS4-2** | **Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.** *[Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]*<br><br>Click here for the Evidence Statement for MS-LS4-2. |
| **MS-LS4-3** | **Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.** *[Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]*<br><br>Click here for the Evidence Statement for MS-LS4-3. |

**Grades 9 through 12:**

*What evidence shows that different species are related?*

Genetic information, like the fossil record, also provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

*Table 37: Performance Expectation for Grades 9 through 12*

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

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### LS4.B: Natural Selection

Overview of Natural Selection from Kindergarten through Grade 12

*How does genetic variation among organisms affect survival and reproduction?*

Genetic variation in a species results in individuals with a range of traits. In any particular environment individuals with particular traits may be more likely than others to survive and produce offspring. This process is called natural selection and may lead to the predominance of certain inherited traits in a population and the suppression of others. Natural selection occurs only if there is variation in the genetic information within a population that is expressed in traits that lead to differences in survival and reproductive ability among individuals under specific environmental conditions. If the trait differences do not affect reproductive success, then natural selection will not favor one trait over others.

**Grades K, 1, and 2:** There are no Performance Expectations for LS4.B in this grade band.

**Grade 3:**

*How are plants, animals, and environments of the past similar or different from current plants, animals, and environments?*

Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing.

*Table 38: Performance Expectation for Grade 3*

| Standard Code | Performance Expectation |
|---|---|
| **3-LS4-2** | **Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.** *[Clarification Statement: Examples of cause and effect relationships could be plants that have larger thorns than other plants may be less likely to be eaten by* |

| Standard Code | Performance Expectation |
|---|---|
| | *predators; and, animals that have better camouflage coloration than other animals may be more likely to survive and therefore more likely to leave offspring.]*<br><br>Click here for the Evidence Statement for 3-LS4-2. |

**Grades 6 through 8:**

*How do organisms change over time in response to changes in the environment?*

Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection. It leads to the predominance of certain traits in a population and the suppression of others. In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.

*Table 39: Performance Expectation for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS4-4** | **Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.** *[Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]*<br><br>Click here for the Evidence Statement for MS-LS4-4. |
| **MS-LS4-5** | **Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms.** *[Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.]*<br><br>Click here for the Evidence Statement for MS-LS4-5. |

### Grades 9 through 12:

*How does genetic variation among organisms affect survival and reproduction?*

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

*Table 40: Performance Expectations for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS4-2** | **Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** *[Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.]* [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.*]*<br><br>Click here for the Evidence Statement for HS-LS4-2. |
| **HS-LS4-3** | **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.** *[Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.]* [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.*]*<br><br>Click here for the Evidence Statement for HS-LS4-3. |

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**LS4.C: Adaptation**

Overview of Adaptation from Kindergarten through Grade 12

*How does the environment influence populations of organisms over multiple generations?*

When an environment changes, there can be subsequent shifts in its supply of resources or in the physical and biological challenges it imposes. Some individuals in a population may have morphological, physiological, or behavioral traits that provide a reproductive advantage in the face of the shifts in the environment. Natural selection provides a mechanism for species to adapt to changes in their environment. The resulting selective pressures influence the survival and reproduction of organisms over many generations and can change the distribution of traits in the population. This process is called adaptation. Adaptation can lead to organisms that are better suited for their environment because individuals with the traits adaptive to the environmental change pass those traits on to their offspring, whereas individuals with traits that are less adaptive produce fewer or no offspring. Over time, adaptation can lead to the formation of new species. In some cases, however, traits that are adaptive to the changed environment do not exist in the population and the species becomes extinct. Adaptive changes due to natural selection, as well as the net result of speciation minus extinction, have strongly contributed to the planet's biodiversity.

Adaption by natural selection is ongoing. For example it is seen in the emergence of antibiotic-resistant bacteria. Organisms like bacteria, in which multiple generations occur over shorter time spans, evolve more rapidly than those for which each generation takes multiple years.

**Grades K, 1, & 2:** There are no Performance Expectations for **LS4.C** in this grade band.

**Grade 3:**

*How are plants, animals, and environments of the past similar or different from current plants, animals, and environments?*

Living things can survive only where their needs are met. If some places are too hot or too cold or have too little water or food, plants and animals may not be able to live there.

Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful. For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.

*Table 41: Performance Expectation for Grade 3*

| Standard Code | Performance Expectation |
|---|---|
| **3-LS4-3** | **Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all**. *[Clarification Statement: Examples of evidence could include needs and characteristics of the organisms and habitats involved. The organisms and their habitat make up a system in which the parts depend on each other.]* |

| Standard Code | Performance Expectation |
|---|---|
| | Click here for the Evidence Statement for 3-LS4-3. |

**Grade 6 through 8:**

*How do organisms change over time in response to changes in the environment?*

Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to become separate species.

*Table 42: Performance Expectation for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS4-6** | **Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.** *[Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.]* *[*Assessment Boundary: Assessment does not include Hardy Weinberg calculations.*]*<br><br>Click here for the Evidence Statement for MS-LS4-6. |

**Grades 9 through 12:**

*How does genetic variation among organisms affect survival and reproduction?*

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

Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as

populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or too drastic, the opportunity for the species' evolution is lost.

*Table 43: Performance Expectations for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS4-2** | **Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** *[Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.]* [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.*]*<br><br>Click here for the Evidence Statement for HS-LS4-2. |
| **HS-LS4-3** | **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.** *[Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.]* [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.*]*<br><br>Click here for the Evidence Statement for HS-LS4-3. |
| **HS-LS4-4** | **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** *[Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]*<br><br>Click here for the Evidence Statement for HS-LS4-4. |

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS4-5** | **Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** *[Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]*<br>Click here for the Evidence Statement for HS-LS4-5. |
| **HS-LS4-6** | **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*** *[Clarification Statement: Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]*<br>Click here for the Evidence Statement for HS-LS4-6. |

**LS4.D: Biodiversity and Humans**

Overview of Biodiversity and Humans from Kindergarten through Grade 12

*What is biodiversity, how do humans affect it, and how does it affect humans?*

Human beings are part of and depend on the natural world. Biodiversity—the multiplicity of genes, species, and ecosystems—provides humans with renewable resources, such as food, medicines, and clean water. Humans also benefit from "ecosystem services," such as climate stabilization, decomposition of wastes, and pollination that are provided by healthy (i.e., diverse and resilient) ecosystems. The resources of biological communities can be used within sustainable limits, but in many cases humans affect these ecosystems in ways—including habitat destruction, pollution of air and water, overexploitation of resources, introduction of invasive species, and climate change—that prevent the sustainable use of resources and lead to ecosystem degradation, species extinction, and the loss of valuable ecosystem services.

**Grade 2:**

*How many types of living things live in a place?*

There are many different kinds of living things in any area, and they exist in different places on land and in water.

*Table 44: Performance Expectation for Grade 2*

| Standard Code | Performance Expectation |
|---|---|
| **2-LS4-1** | **Make observations of plants and animals to compare the diversity of life in different habitats.** *[Clarification Statement: Emphasis is on the diversity of living things in each of a variety of different habitats.]* [Assessment Boundary: Assessment does not include specific animal and plant names in specific habitats.*]*<br>Click here for the Evidence Statement for 2-LS4-1. |

**Grade 3:**

*What happens to organisms when their environment changes?*

Scientists have identified and classified many plants and animals. Populations of organisms live in a variety of habitats, and change in those habitats affects the organisms living there. Humans, like all other organisms, obtain living and nonliving resources from their environments.

*Table 45: Performance Expectations for Grade 3*

| Standard Code | Performance Expectation |
|---|---|
| **3-LS4-4** | **Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.*** *[Clarification Statement: Examples of environmental changes could include changes in land characteristics, water distribution, temperature, food, and other organisms.] [Assessment Boundary: Assessment is limited to a single environmental change. Assessment does not include the greenhouse effect or climate change.]*<br>Click here for the Evidence Statement for 3-LS4-4. |

**Grade 6 through 8:**

*What is biodiversity and how does it affect humans?*

Biodiversity is the wide range of existing life forms that have adapted to the variety of conditions on Earth, from terrestrial to marine ecosystems. Biodiversity includes genetic variation within a species, in addition to species variation in different habitats and ecosystem types (e.g., forests, grasslands, wetlands). Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

*Table 46: Performance Expectation for Grades 6 through 8*

| Standard Code | Performance Expectation |
|---|---|
| **MS-LS2-5** | **Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*** *[Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]* (Note: Secondary to MS-LS2-5.)<br>Click here for the Evidence Statement for MS-LS2-5. |

**Grades 9 through 12:**

*What is biodiversity, how do humans affect it, and how does it affect humans?*

Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Biological extinction, being irreversible, is a critical factor in reducing the planet's natural capital.

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. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things. 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.

*Table 47: Performance Expectation for Grades 9 through 12*

| Standard Code | Performance Expectation |
|---|---|
| **HS-LS4-6** | **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.*** *[Clarification Statement: Emphasis is on testing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]*<br>Click here for the Evidence Statement for HS-LS4-6 |
| **HS-LS2-7** | **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*** *[Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]*<br>Click here for the Evidence Statement for HS-LS2-7. |

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## Appendix A: Vocabulary in the New Jersey Student Learning Standards for Science

Many vocabulary words do not explicitly appear in the standards, because the New Jersey Student Learning Standards for Science (science standards) focus on a deep understanding of the concept behind a vocabulary word. Vocabulary can be introduced and applied, as needed, for instructional purposes.

Mendelian Genetics: The science standards focus on a deep understanding of core ideas and do not include the names of scientists in the performance expectations. The history and work of scientists can and should be incorporated when teaching the concepts their work contributed to. For example, Gregor Mendel and the laws he formed can be included when teaching about heredity. (Grades 6 through 8 and 9 through 12)

Natural Selection: The term "natural selection" is explicitly included in some standards in the middle school and high school grade bands. However, standards in earlier grades also build towards an understanding of natural selection. (Grades 6 through 8 and 9 through 12)