NEXT GENERATION SCIENCE STANDARDS
For States, By States

HS-LS1-1

Students who demonstrate understanding can:

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

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices

Constructing Explanations and Designing Solutions

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

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

Disciplinary Core Ideas

LS1.A: Structure and Function

- Systems of specialized cells within organisms help them perform the essential functions of life.
- 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. *(Note: This Disciplinary Core Idea is also addressed by HS-LS3-1.)*

Crosscutting Concepts

Structure and Function

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

Observable features of the student performance by the end of the course:

1	Articulating the explanation of phenomena		
	a	Students construct an explanation that includes the idea that regions of DNA called genes determine the structure of proteins, which carry out the essential functions of life through systems of specialized cells.	
2	Evidence		
	a	Students identify and describe the evidence to construct their explanation, including that:	
		i.	All cells contain DNA;
		ii.	DNA contains regions that are called genes;
		iii.	The sequence of genes contains instructions that code for proteins; and
		iv.	Groups of specialized cells (tissues) use proteins to carry out functions that are essential to the organism.
	b	Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, peer review, students' own investigations).	
3	Reasoning		
	a	Students use reasoning to connect evidence, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to construct the explanation. Students describe the following chain of reasoning in their explanation:	
		i.	Because all cells contain DNA, all cells contain genes that can code for the formation of proteins.

		ii. Body tissues are systems of specialized cells with similar structures and functions, each of whose functions are mainly carried out by the proteins they produce in the explanation.
		iii. Proper function of many proteins is necessary for the proper functioning of the cells.
		iv. Gene sequence affects protein function, which in turn affects the function of body tissues.

HS-LS1-2

Students who demonstrate understanding can:

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.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.A: Structure and Function** • Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.	**Systems and System Models** • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	Students develop a model in which they identify and describe the relevant parts (e.g., organ system, organs, and their component tissues) and processes (e.g., transport of fluids, motion) of body systems in multicellular organisms.	
2	Relationships		
	a	In the model, students describe the relationships between components, including:	
		i.	The functions of at least two major body systems in terms of contributions to overall function of an organism;
		ii.	Ways the functions of two different systems affect one another; and
		iii.	A system's function and how that relates both to the system's parts and to the overall function of the organism.
3	Connections		
	a	Students use the model to illustrate how the interaction between systems provides specific functions in multicellular organisms.	
	b	Students make a distinction between the accuracy of the model and actual body systems and functions it represents.	

HS-LS1-3

Students who demonstrate understanding can:

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.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. - - - - - - - - - - - - - - - - ***Connections to Nature of Science*** **Scientific Investigations Use a Variety of Methods** • Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings.	**LS1.A: Structure and Function** • Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.	**Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system.

Observable features of the student performance by the end of the course:			
1	Identifying the phenomenon under investigation		
	a	Students describe the phenomenon under investigation, which includes the following idea: that feedback mechanisms maintain homeostasis.	
2	Identifying the evidence to answer this question		
	a	Students develop an investigation plan and describe the data that will be collected and the evidence to be derived from the data, including:	
		i.	Changes within a chosen range in the external environment of a living system; and
		ii.	Responses of a living system that would stabilize and maintain the system's internal conditions (homeostasis), even though external conditions change, thus establishing the positive or negative feedback mechanism.
	b	Students describe why the data will provide information relevant to the purpose of the investigation.	
3	Planning for the investigation		
	a	In the investigation plan, students describe:	
		i.	How the change in the external environment is to be measured or identified;
		ii.	How the response of the living system will be measured or identified;

		iii. How the stabilization or destabilization of the system's internal conditions will be measured or determined;
		iv. The experimental procedure, the minimum number of different systems (and the factors that affect them) that would allow generalization of results, the evidence derived from the data, and identification of limitations on the precision of data to include types and amounts; and
		v. Whether the investigation will be conducted individually or collaboratively.
4	Collecting the data	
	a	Students collect and record changes in the external environment and organism responses as a function of time.
5	Refining the design	
	a	Students evaluate their investigation, including:
		i. Assessment of the accuracy and precision of the data, as well as limitations (e.g., cost, risk, time) of the investigation, and make suggestions for refinement; and
		ii. Assessment of the ability of the data to provide the evidence required.
	b	If necessary, students refine the investigation plan to produce more generalizable data.

NEXT GENERATION SCIENCE STANDARDS
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HS-LS1-4

Students who demonstrate understanding can:

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

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices

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

- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.

Crosscutting Concepts

Systems and System Models

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

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	From the given model, students identify and describe the components of the model relevant for illustrating the role of mitosis and differentiation in producing and maintaining complex organisms, including:	
		i.	Genetic material containing two variants of each chromosome pair, one from each parent;
		ii.	Parent and daughter cells (i.e., inputs and outputs of mitosis); and
		iii.	A multi-cellular organism as a collection of differentiated cells.
2	Relationships		
	a	Students identify and describe the relationships between components of the given model, including:	
		i.	Daughter cells receive identical genetic information from a parent cell or a fertilized egg.
		ii.	Mitotic cell division produces two genetically identical daughter cells from one parent cell.
		iii.	Differences between different cell types within a multicellular organism are due to gene expression — not different genetic material within that organism.
3	Connections		
	a	Students use the given model to illustrate that mitotic cell division results in more cells that:	
		i.	Allow growth of the organism;
		ii.	Can then differentiate to create different cell types; and
		iii.	Can replace dead cells to maintain a complex organism.
	b	Students make a distinction between the accuracy of the model and the actual process of cellular division.	

HS-LS1-5

Students who demonstrate understanding can:

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.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.	**Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	From the given model, students identify and describe the components of the model relevant for illustrating that photosynthesis transforms light energy into stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen, including:	
		i.	Energy in the form of light;
		ii.	Breaking of chemical bonds to absorb energy;
		iii.	Formation of chemical bonds to release energy; and
		iv.	Matter in the form of carbon dioxide, water, sugar, and oxygen.
2	Relationships		
	a	Students identify the following relationship between components of the given model: Sugar and oxygen are produced by carbon dioxide and water by the process of photosynthesis.	
3	Connections		
	c	Students use the given model to illustrate:	
		i.	The transfer of matter and flow of energy between the organism and its environment during photosynthesis; and
		ii.	Photosynthesis as resulting in the storage of energy in the difference between the energies of the chemical bonds of the inputs (carbon dioxide and water) and outputs (sugar and oxygen).

HS-LS1-6

Students who demonstrate understanding can:

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.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices

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

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

Disciplinary Core Ideas

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

- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells.
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

Crosscutting Concepts

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Observable features of the student performance by the end of the course:			
1	Articulating the explanation of phenomena		
	a	Students construct an explanation that includes:	
		i.	The relationship between the carbon, hydrogen, and oxygen atoms from sugar molecules formed in or ingested by an organism and those same atoms found in amino acids and other large carbon-based molecules; and
		ii.	That larger carbon-based molecules and amino acids can be a result of chemical reactions between sugar molecules (or their component atoms) and other atoms.
2	Evidence		
	a	Students identify and describe the evidence to construct the explanation, including:	
		i.	All organisms take in matter (allowing growth and maintenance) and rearrange the atoms in chemical reactions.
		ii.	Cellular respiration involves chemical reactions between sugar molecules and other molecules in which energy is released that can be used to drive other chemical reactions.
		iii.	Sugar molecules are composed of carbon, oxygen, and hydrogen atoms.
		iv.	Amino acids and other complex carbon-based molecules are composed largely of carbon, oxygen, and hydrogen atoms.
		v.	Chemical reactions can create products that are more complex than the reactants.
		vi.	Chemical reactions involve changes in the energies of the molecules involved in the reaction.
	b	Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations,	

		students' own investigations).
3	Reasoning	
	a	Students use reasoning to connect the evidence, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to construct the explanation that atoms from sugar molecules may combine with other elements via chemical reactions to form other large carbon-based molecules. Students describe the following chain of reasoning for their explanation:
		i. The atoms in sugar molecules can provide most of the atoms that comprise amino acids and other complex carbon-based molecules.
		ii. The energy released in respiration can be used to drive chemical reactions between sugars and other substances, and the products of those reactions can include amino acids and other complex carbon-based molecules.
		iii. The matter flows in cellular processes are the result of the rearrangement of primarily the atoms in sugar molecules because those are the molecules whose reactions release the energy needed for cell processes.
4	Revising the explanation	
	a	Given new evidence or context, students revise or expand their explanation about the relationships between atoms in sugar molecules and atoms in large carbon-based molecules, and justify their revision.

HS-LS1-7

Students who demonstrate understanding can:

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

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices

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

- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas

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

- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.

Crosscutting Concepts

Energy and Matter

- Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	From a given model, students identify and describe the components of the model relevant for their illustration of cellular respiration, including:	
		i.	Matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO_2);
		ii.	The breaking and formation of chemical bonds; and
		iii.	Energy from the chemical reactions.
2	Relationships		
	a	From the given model, students describe the relationships between components, including:	
		i.	Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration; and
		ii.	The process of cellular respiration releases energy because the energy released when the bonds that are formed in CO_2 and water is greater than the energy required to break the bonds of sugar and oxygen.
3	Connections		
	a	Students use the given model to illustrate that:	
		i.	The chemical reaction of oxygen and food molecules releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are formed, but matter and energy are neither created nor destroyed.
		ii.	Food molecules and oxygen transfer energy to the cell to sustain life's processes, including the maintenance of body temperature despite ongoing energy transfer to the surrounding environment.