**HS.Matter and Energy in Organisms and Ecosystems**

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 their photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [Assessment Boundary: Assessment does not include specific biochemical steps.]

**HS-LS1-6.** Construct a model to support the idea that photosynthesis transforms light energy into stored chemical energy in plants and other autotrophs. [Assessment Boundary: Assessment does not include the specific chemical reactions or identification of macromolecules.]

**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.]

**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.]

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

**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.]

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

**Science and Engineering Practices**
- Developing and Using Models
  - Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
  - Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-5),(HS-LS1-7)
  - Develop a model based on evidence to illustrate the relationships between systems or components of a system. (HS-LS2-5)
- Using Mathematics and Computational Thinking
  - Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
  - Use mathematical representations of phenomena or design solutions to support claims. (HS-LS2-4)
- Constructing Explanations and Designing Solutions
  - Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
  - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-6),(HS-LS1-7)

**Disciplinary Core Ideas**

**LS1.C: Organization for Matter and Energy Flow in Organisms**
- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6)
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-6),(HS-LS1-7)
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another and release energy to the surrounding environment and to maintain body temperature. Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. (HS-LS1-7)

**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**
- Photosynthesis and cellular respiration provide most of the energy for life processes. (HS-LS2-3)
- Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. (HS-LS2-4)
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)

**PS3.D: Energy in Chemical Processes**
- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (Secondary to HS-LS2-2)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The section entitled “Disciplinary Core Ideas” is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.*

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## Connections to other DCIs in this grade-band:
- **HS.PS1.B** ([HS-LS1-5], [HS-LS1-6], [HS-LS1-7], [HS-LS2-3], [HS-LS2-5], [HS.PS2.B] ([HS-LS1-7]); **HS.PS3.B** ([HS-LS1-5], [HS-LS1-7], [HS-LS2-3], [HS-LS2-4])
- **HS.PS3.D** ([HS-LS2-3], [HS-LS2-4])
- **HS.ESS2.A** ([HS-LS2-3])
- **HS.ESS2.D** ([HS-LS2-5])

## Articulation across grade-bands:
- **MS.PS1.A** ([HS-LS1-6])
- **MS.PS1.B** ([HS-LS1-5], [HS-LS1-6], [HS-LS1-7], [HS-LS2-3], [HS-LS2-5])
- **MS.PS3.D** ([HS-LS1-5], [HS-LS1-6], [HS-LS1-7], [HS-LS2-3], [HS-LS2-4])
- **MS.LS1.C** ([HS-LS1-5], [HS-LS1-6], [HS-LS1-7], [HS-LS2-3], [HS-LS2-4], [HS-LS2-5])
- **MS.LS2.B** ([HS-LS1-5], [HS-LS1-7], [HS-LS2-3], [HS-LS2-4], [HS-LS2-5])
- **MS.ESS2.A** ([HS-LS2-3])

## Common Core State Standards Connections:
### ELA/Literacy
- **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. ([HS-LS1-6], [HS-LS2-3])
- **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. ([HS-LS1-6], [HS-LS2-3])
- **WHST.9-12.5** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. ([HS-LS1-6], [HS-LS2-3])
- **WHST.9-12.9** Draw evidence from informational texts to support analysis, reflection, and research. ([HS-LS1-6])

### Mathematics
- **MP.2** Reason abstractly and quantitatively. ([HS-LS2-4])
- **MP.4** Model with mathematics. ([HS-LS2-4])
- **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. ([HS-LS2-4])
- **HSN-Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. ([HS-LS2-4])
- **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. ([HS-LS2-4])

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