HIGH SCHOOL LIFE SCIENCE: CYCLING OF MATTER

Standards Bundle:

Standards are listed within the bundle. Bundles are created with potential instructional use in mind, based upon the potential for related phenomena that can be used throughout a unit.

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. (SEP:6; DCI: LS2.B; CCC: Energy/Matter) [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 mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. (SEP: 5; DCI: LS2.B; CCC: Energy/Matter) [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 proportional reasoning to describe the cycling of matter and flow of energy.]*

HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts on Earth systems. (SEP: 4; DCI: ESS3.D; CCC: Stability/Change) [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] *[Assessment Boundary: Assessment is limited to one example of climate change and its associated impacts.]*

Content Overview

This section provides a generic overview of the content or disciplinary core ideas as an entry point to the standards.

Students will be able to construct explanations based on scientific evidence on how elements, such as nitrogen, phosphorus, and carbon, as well as compounds, such as water are cycled between living and nonliving components of an organism's environment including within the organism itself.

There are other means of capturing energy in places such as deep in the ocean or at the bottom of a slough where there is no light or oxygen.
Students will use mathematical relationships to account for both matters, as well as energy, flowing into various parts of an organism's environment. This would include how and why the number of available energies contained within organisms decreases as one proceeds up the food chain in a stable environment.

If the amounts of energy and elements/compounds are disrupted, there will be changes that occur in the environment affecting both organism numbers and regional weather patterns (climate change). The exact changes are not 100% predictable. Students need to be able to discuss the prediction of complex environmental issues. From this analysis, students will propose ways to stop and/or reverse adverse changes.

Phenomena

Phenomena can be used at varying levels of instruction. One could be used to anchor an entire unit, while another might be more supplemental for anchoring just a unit. Please remember that phenomena should allow students to engage in the SEP and use the CCC/DCI to understand and explain the phenomenon.

- Annual temperature data in graphical form and predicted temperatures from models.
- Video of deep oceanic life forms.
- A small sample of marsh mud or a Winograd sky column.
- Yeast with sugar in a flask with a balloon attached to the top.
- A chart showing prairie ecosystem organisms with relative numbers.
- The Kaibab deer story or one about the prey numbers before and after the reintroduction of timber wolves.
- Video clips of the amount of snowpack in the Arctic regions from year to year.
- Plants in containers with oxygen and carbon dioxide sensors in light and dark.
- Water with bromothymol blue - having students exhale into the water.
- Elodea in bromothymol blue water in the light and the dark.
- How might it be possible that a carbon atom that was once in a dinosaur be part of you?

Storyline

This section aims to decode not only the DCI connections but also the SEP and CCC in a detailed account of how they possibly fit together in a progression for student learning, including both rationale and context for the bundle.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions ● Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' investigations, models, theories, simulations, and 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. **Using Mathematical and Computational Thinking** ● Use mathematical representations of phenomena or design solutions to support claims. **Analyzing and Interpreting Data** ● Analyze data using computational models in order to make valid and reliable scientific claims.	**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** ● Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. ● 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. **ESS3.D: Global Climate Change** ● Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.	**Energy and Matter** ● Energy drives the cycling of matter within and between systems. ● Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems. **Stability and Change** ● Change and rates of change can be quantified and modeled over very short or very long periods. Some system changes are irreversible.

In this standard bundle, students will use modeling to show how photosynthesis and respiration (both aerobic and anaerobic) provide most of the energy to support the many processes that go on within an organism. Students will support their explanations with empirical evidence to discuss why the amounts of matter and energy transferred to higher levels within a food chain/web are only a fraction of the total available matter and energy due to inefficiencies. These models and explanations can be used to predict changes within a stable complex ecosystem when the numbers of organisms and/or energy is changed, and the matter is diverted to different components of the ecosystem.

Students will construct explanations on how both energy and matter are cycled between organisms and their environment through physical and chemical processes. These explanations need to be based on empirical evidence as well as mathematical models that describe the flow of energy and matter between components within the atmosphere, geosphere, hydrosphere, and biosphere as they combine and recombine in different ways to satisfy the needs of the organisms.

Empirical data and mathematical models are used to predict how climate changes will affect stability and change ecosystems. Students will use these predictions and evidence to design solutions to help mitigate these adverse effects while still discussing the complexity of the systems and the uncertainty that is part of scientific models, methods, and data.

Formative Assessment

Formative assessment is crucial because all learners benefit from timely and focused feedback from others. It promotes self-reflection, self-explanation, and social learning. It can also make learning more relevant. Each of the questions below might be used throughout the formative assessment process. Specific prompts may focus on individual practices, core ideas, or crosscutting concepts, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given bundle, standard, or lesson-level performance expectation.

SEP Constructing Explanations and Designing Solutions

- View plants that have been growing with adequate light versus some without. Write an evidence-based account of what happened to the two plants.
- View plants growing and humans growing. Construct explanations for how they obtain the energy needed to grow.
- Construct Winograd sky columns then make observations over time. Write a causal explanation using the model as evidence for what happens in anaerobic environments to obtain energy and make more complex molecules.
- Present students with a range of evidence on climate change (models, data, video). Ask students to construct causal explanations to include the multiple contributing factors.
- After identifying human contributions to climate change, propose ways to reduce or alleviate these sources with prioritizations and reasoning for each.

SEP Using Mathematics and Computational Thinking/Constructing Explanations and Designing Solutions

- Given relative numbers of organisms for a simple food chain in a prairie, forest, or lake ecosystem, construct a model showing those numbers as widths of stacking columns (pyramid). Calculate the percentage decrease and construct possible explanations as to why stable ecosystems have this pyramid-like shape.

SEP Analyzing and Interpreting Data CCC-Energy and Matter

- Given a picture of a plant and an animal, construct a model of how they are connected by indicating the flow of matter and energy between them as well as their environment.

CCC Stability and change

- Show a time-lapse video of the amount of arctic snow melts over time. Give data to accompany the video. Produce an explanation about the mechanism for the phenomena using the data and evidence.

Performance Outcomes

These are statements of how students use knowledge and are similar to the standards in how they blend DCI, SEP, and CCC, but at a smaller grain size. These are potential outcomes for instruction as it plays out in lessons and activities in the classroom. It is important to also think of these as smaller outcomes that build toward the larger goal of mastering the standards.

- **Design and carry out an investigation** to analyze the *effects* of color and intensity of light on plant growth *patterns*.
- **Ask questions** about the products formed when yeast is grown under anaerobic conditions and/or humans don't breathe in enough oxygen when exercising.
- **Develop a model** for how organisms that photosynthesize also undergo respiration to use the sun's *energy*.
- **Use evidence to explain** how organisms obtain energy from respiration for the processes essential to life at the cellular level.
- Given several types of organisms, **use evidence from several scientific sources to construct explanations** about how they obtain *energy* to carry out the functions necessary for life.
- **Given new data, construct explanations** for how life continues in deep ocean vents where there is *no sunlight or oxygen.*
- **Use mathematical thinking to explain** why, as one proceeds up the food chain, there are fewer *organisms and less available energy.*
- **Obtain and evaluate information** on an unstable ecosystem due to disturbances that *affected one part and subsequently affected other parts*.
- **Construct a model** that illustrates the *flow of carbon* between the atmosphere, geosphere, hydrosphere, and biosphere.
- **Analyze and use the mathematical representation(s)** to account for the *energy not transferred to higher trophic levels* but which is instead used for growth, maintenance, or repair, and/or transferred to the environment, and the inefficiencies in the transfer of matter and energy.
- **Organize data (e.g., with graphs) from global climate models** (e.g., computational simulations) and climate observations over time that relate to the *effect* of climate change on the physical parameters or chemical composition of the atmosphere, geosphere, hydrosphere, or cryosphere.
- **Analyze data to describe** the *pattern* of a selected aspect of present or past climate and the associated physical parameters (e.g., temperature, precipitation, sea level) or chemical composition (e.g., ocean pH) of the atmosphere, geosphere, hydrosphere, or cryosphere.
- **When presented with a graph** of annual average atmospheric temperatures, **analyze the data** to predict the *future effect* of temperatures on several aspects of climate change on the physical parameters (e.g., precipitation, sea level) or chemical composition (e.g., ocean pH) of the atmosphere, geosphere, hydrosphere, or cryosphere.
- **Identify sources of uncertainty in the prediction** of the *effect* in the future of a selected aspect of climate change. In their interpretation of the data, students will **make a statement** regarding how **variation or uncertainty in the data** (e.g., limitations, accuracy, any bias in the data resulting from the choice of sample, scale, instrumentation, etc.) may *affect* the interpretation of the data and identify the **limitations of the models** that provided the simulation data and ranges for their predictions.