*Unit 3 Matter and Energy Transformations in Ecosystems

Content Area: **Science**
Course(s): **Biology CP, Biology Honors, STEM Biology Honors**
Time Period: **November**
Length: **~12 Blocks**
Status: **Published**

Unit Summary

In this unit of study, students construct explanations for the role of energy in the cycling of matter in organisms and ecosystems. They apply mathematical concepts to develop evidence to support explanations of the interactions of photosynthesis and cellular respiration, and they will develop models to communicate these explanations. Students also understand organisms' interactions with each other and their physical environment and how organisms obtain resources. Students utilize the crosscutting concepts of matter and energy and systems, and system models to make sense of ecosystem dynamics. Students are expected to use students construct explanations for the role of energy in the cycling of matter in organisms and ecosystems. They apply mathematical concepts to develop evidence to support explanations as they demonstrate their understanding of the disciplinary core ideas.

This unit is based on HS-LS1-5, HS-LS2-3, HS-LS2-4, and HS-LS2-5.

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Enduring Understandings

Organisms need a constant supply of matter and energy in order to survive and reproduce.

Matter and energy are neither created nor destroyed in an ecosystem, they are transformed as they flow or cycle through both the biotic and abiotic factors of that ecosystem.

Essential Questions

- Do all organisms in an ecosystem depend on sunlight energy?
- Is oxygen necessary for survival?
- What is the most important abiotic factor in an ecosystem?
- If energy is not created nor destroyed, where does it come from and where does it go?
- How do humans impact the natural cycling of elements such as carbon and nitrogen?

Student Learning Objectives (PE, SEP, DCI, CCC) & Aligned Standards

Performance Expectations

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.]* **(HS-LS1-5)**

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-LS2-3)**

Use mathematical representations 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 proportional reasoning to describe the cycling of matter and flow of energy.]***(HS-LS2-4)**

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.]* **(HS-LS2-5)**

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Science and Engineering Practices

Constructing Explanations and Designing Solutions

- 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-LS2-3)**
- 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)**
- Use a model based on evidence to illustrate the relationships between systems or between components of a system. **(HSLS1-5),(HS-LS1-7)**

Using Mathematics and Computational Thinking

- Use mathematical representations of phenomena or design solutions to support claims. **(HS-LS2-4)**

Developing and Using Models

- Develop a model based on evidence to illustrate the relationships between systems or components of a system. **(HS-LS1-5, HS-LS2-5)**
- Develop a model to descrive unobservable mechanisms. (**HS-LS-1-7)**

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)**
- 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- 7)**
- 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.**(HS-LS1-7)**

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. **(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)**

Crosscutting Concepts

Energy and Matter

- Energy drives the cycling of matter within and between systems. **(HS-LS2-3)**
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. **(HS-LS2-4)**

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. **(HS-LS2-5)**
- 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. **(HS-LS1-5)**
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.**(HS-LS1-7),(HS-LS2-4)**

Scientific Knowledge is Open to Revision in Light of New Evidence

- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. **(HS-LS2-3)**

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)
- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS-LS2-3)

CS.9-12.8.2.12.ETW.3	Identify a complex, global environmental or climate change issue, develop a systemic plan of investigation, and propose an innovative sustainable solution.
CS.9-12.ETW	Effects of Technology on the Natural World
SCI.9-12.4.2	When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
SCI.9-12.4.3	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.
SCI.9-12.5.2	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.
SCI.9-12.5.3	Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
SCI.9-12.5.4	Energy drives the cycling of matter within and between systems.
SCI.9-12.7.3	Feedback (negative or positive) can stabilize or destabilize a system.
SCI.9-12.CCC.2	Cause and effect: Mechanism and explanation.

SCI.9-12.CCC.2.1	students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.
SCI.9-12.CCC.4	Systems and system models.
SCI.9-12.CCC.5	Energy and matter: Flows, cycles, and conservation.
SCI.9-12.CCC.7	Stability and change.
SCI.9-12.SEP.5	Using Mathematics and Computational Thinking
SCI.9-12.SEP.5.b	Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
SCI.9-12.SEP.6	Constructing Explanations and Designing Solutions
SCI.9-12.SEP.6.b	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.
SCI.9-12.SEP.6.e	Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
SCI.9-12.HS-ETS1	Engineering Design
SCI.9-12.HS-LS1-5	Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
SCI.9-12.HS-LS1	From Molecules to Organisms: Structures and Processes
SCI.9-12.HS-LS2	Ecosystems: Interactions, Energy, and Dynamics
SCI.9-12.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.
SCI.9-12.HS-LS2-4	Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
SCI.9-12.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.
SCI.9-12.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.
SCI.9-12.HS-LS1-1.6.1	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.
9-12.HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
	Development and modification of any technological system needs to take into account how the operation of the system will affect natural resources and ecosystems. Impacts of technological systems on the environment need to be monitored and must inform decision-making. Many technologies have been designed to have a positive impact on the environment and to monitor environmental change over time.

Concepts & Formative Assessment

Matter and Energy Transformations in Ecosystems

Part A: Why do astrobiologists look for water on planets and not oxygen when they search for life on other planets?

Concepts

- Energy drives the cycling of matter within and between systems.
- Energy drives the cycling of matter within and between systems in aerobic and anaerobic conditions.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.

Formative Assessment

Students who understand the concepts are able to:

- Construct and revise an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, 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.

- Construct and revise an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, considering that most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.

Part B: Why is there no such thing as a food chain?

Concepts

- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.
- At each link in an ecosystem, matter and energy are conserved.
- 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.

Formative Assessment

Students who understand the concepts are able to:

- Support claims for the cycling of matter and flow of energy among organisms in an ecosystem using conceptual thinking and mathematical representations of phenomena.

- Use a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and to show how matter and energy are conserved as matter cycles and energy flows through ecosystems.
- Use a mathematical model to describe the conservation of atoms and molecules as they move through an ecosystem.
- Use proportional reasoning to describe the cycling of matter and flow of energy through an ecosystem.

Part C: How can the process of photosynthesis and respiration in a cell impact ALL of Earth's systems?

Concepts

- Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
- 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.
- The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.

Formative Assessment

Students who understand the concepts are able to:

- Develop a model, based on evidence, to illustrate the roles of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere, showing the relationships among variables in systems and their components in the natural and designed world.
- Develop a model, based on evidence, to illustrate the roles of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere at different scales.

Resources

MARS Biodome Performance Assessment Resources:

Actively Learn Text selection

Rubric

Open Education Resources

[Leaf Photosynthesis NetLogo Model]: This Java-based NetLogo model allows students to investigate the chemical and energy inputs and outputs of photosynthesis through an interactive simulation.

[Surviving Winter in the Dust Bowl (Food Chains and Trophic Levels)]: This is one of 30 lessons from the NSTA Press book Scientific Argumentation in Biology. The lesson engages students in an argumentation cycle based on an engaging scenario in which their group is a farm family trying to survive a dust bowl winter with limited food and water resources. The family has a bull, a cow, and limited amounts of water and wheat. Students are presented with four options that include various combinations of eating or keeping the animals alive and eating the wheat. Within this scenario, the lesson provides data on nutritional requirements of cows and humans, along with nutritional contents of wheat, milk, and beef. Students then use this data to construct an argument for the best strategy to allow their family to survive. As they construct this argument, students build and apply knowledge of food chains, trophic levels, interdependence among organisms, and energy transfers within ecosystems. This lesson is intended for middle or high school students. Teachers are encouraged to refer to the preface, introduction, student assessment samples, and appendix provided in the full book for important background on the practice of argumentation and resources for classroom implementation.

[Of Microbes and Men]: Students will develop a model to show the relationships among nitrogen and the ecosystem including parts that are not observable but predict observable phenomena. They will then construct an explanation of the affects of the environmental and human factors on this cycle.

Suggested Assessments

MARS Biodome Performance Assessment: (LS2-5, LS2-1, LS2-4, ETS1-2, Comp Sci. Standard 8.2.12.ETW.3)

Students conceptually devise a plan to colonize MARS that takes into consideration the conservation of matter in ecosystem. This builds and understanding of the complex cycles that are at play on our planet which includes our climate. Climate change extensions should be made to have students focus on what needs must be considered to ensure that there is not a change in climate or excess CO2 inside their dome, making a more direct comparison to Earth's climate.

- Develop a model that shows how light energy is converted to chemical energy in photosynthesis (can be a diagram, physical model, etc..)
- Develop a model that compares matter cycling and energy flow in anaerobic vs. aerobic conditions
- Construct an explanation using evidence for the cycling of matter and model how photosynthesis & respiration play a role in that cycling (could just be a detailed diagram of the carbon or nitrogen cycle with explanations of how carbon or nitrogen is transformed by each process)
- Energy transfer lab using butterfly larvae (mathematical representations of energy transfer via biomass measurements

- Vocabulary Assessment and Application of Vocabulary

Connecting with English Language Arts Literacy and Mathematics

Connections to English Language Arts/Literacy-

- Cite specific textual evidence to support an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Develop and write an explanation, based on evidence, for the cycling of matter and flow of energy in aerobic and anaerobic conditions by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples.
- Develop and strengthen an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

Connections to Mathematics-

- Represent the cycling of matter and flow of energy among organisms in an ecosystem symbolically and manipulate the representing symbols. Make sense of quantities of and relationships between matter and energy as they cycle and flow through an ecosystem.
- Use a mathematical model to describe the cycling of matter and flow of energy among organisms in an ecosystem. Identify important quantities in the cycling of matter and flow of energy among organisms in an ecosystem and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Connections to Ela/Literacy and Mathematics Continued:

- Use units as a way to understand the cycling of matter and flow of energy among organisms in an ecosystem. Choose and interpret units consistently in formulas to determine the cycling of matter and flow of energy among organisms in an ecosystem. Choose and interpret the scale and the origin in graphs and data displays representing the cycling of matter and flow of energy among organisms in an ecosystem.
- Define appropriate quantities to represent matter and energy for the purpose of descriptive modeling of their cycling and flow among organisms in ecosystems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing matter cycles and energy flows among organismsin ecosystems.

Modifications

Teacher Note: Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.

- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.

Research on Student Learning

Most high school students seem to know that some kind of cyclical process takes place in ecosystems. Some students see only chains of events and pay little attention to the matter involved in processes such as plant growth or animals eating plants. They think the processes involve creating and destroying matter rather than transforming it from one substance to another. Other students recognize one form of recycling through soil minerals but fail to incorporate water, oxygen, and carbon dioxide into matter cycles. Even after specially designed instruction, students cling to their misinterpretations. Instruction that traces matter through the ecosystem as a basic pattern of thinking may help correct these difficulties (NSDL, 2015).

References

Adapted from the New Jesery NGSS Science Model Curriclum

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Connections to NJSLS

English Language Arts

- 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. **RST.11-12.1** (HS-LS2-3)
- Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. **SL.11-12.5** (HS-LS1-5)
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **RST.11-12.7**(HS-ETS1-3)

- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **RST.11-12.8** (HS-ETS1-3)
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. **RST.11-12.9** (HS-ETS1-3).

Mathematics

- Reason abstractly and quantitatively. **MP.2** (HS-LS2-4)
- Model with mathematics. **MP.4** (HS-LS2-4)
- 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. **HSN-Q.A.1** (HS-LS2-4)
- Define appropriate quantities for the purpose of descriptive modeling. **HSN-Q.A.2** (HS-LS2-4)

- HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HSLS2-4)