

Unit SYNOPSIS**Storyline Narrative:**

To initiate the unit students will watch a brief time-lapse video of a forest fire that occurs in a lush environment. For this particular segment the video will abruptly end with devastation to much of the vegetation. Teacher will challenge students to predict what will happen now that all visible signs of life have been removed from the ecosystem. Starting with the undisturbed ecosystem, students will be prompted to design an initial model, consisting of a series of 4-5 panels, to illustrate their prediction of what will happen to the forest once the fire has cleared.

During the first learning sequence, students will develop an understanding of the importance of carbon in life. Carbon, being able to form four bonds, is able to bond in a variety of ways that make it a versatile element necessary for the regrowth after a forest fire. Students will relate the structure and function of macromolecules to their molecular formulas and describe how molecules are joined and/or broken apart. Essential vocabulary, such as monomer, polymer, dehydration synthesis and hydrolysis will be introduced. The latter terminology will be essential for when students construct carbon cycle models.

To understand the release of energy during cellular respiration, students will create a model showing how glucose and oxygen are rearranged into carbon dioxide and water thereby providing the energy for life. To generate interest students will develop a prediction of what gas(es) germinating seeds produce. Using a carbon dioxide sensor, students will observe that germinating seeds produce carbon dioxide in a closed chamber. They will then explore why germinating seeds produce carbon dioxide and develop an understanding that seeds respire because they need energy for initial growth. To help better understand respiration, students will explore the release of energy from burning food molecules and relate that release of energy to the release of energy during cellular respiration. Students will demonstrate understanding that energy is conserved during energy transfers and that the energy not used for biological work is released as metabolic heat. Students will identify patterns in a molecule of glucose, which will allow them to explain how glucose and oxygen are rearranged into carbon dioxide and water. Additionally, students will revise their initial model to show how seeds will be the source of new growth in the forest.

Initiating the next learning sequence, students are presented a piece of firewood and a video clip and challenged to explain where the mass of a tree comes from. Discussion leads students to propose variables that may affect the mass of a plant and cause plants to grow. The variables essential to photosynthesis and why plants will increase in mass are investigated through a plant growth investigation. The transformation of solar energy and the importance of carbon in the process of photosynthesis will be investigated. Students will readdress the idea of where the mass of a plant comes from. Students will create a model that illustrates their understanding of the inputs, outputs and overall chemical equation of photosynthesis. They will end the sequence by defending or refuting a prompt that they consume processed sunshine.

Students will determine where carbon is found in an ecosystem. Students have thus far gained knowledge into both the process of cellular respiration and photosynthesis. How the processes marry together, however, has not yet been explored. Students will now determine specifically how carbon is moved through an ecosystem. 'The Carbon Cycle Adventures' (purchased through Flinn Scientific) provides students the chance to explore how carbon moves. Students will create a model that shows the movement of carbon between the lithosphere, hydrosphere, biosphere, and atmosphere and identify the processes that move the carbon. They will use their model to predict changes in the carbon cycle when there is a disturbance in the cycle (like the forest fire). Students will then follow the movement of carbon, in the form of biomass, through the trophic levels of an ecosystem and hypothesize why matter and energy is "lost" moving up through the trophic levels.

In the final learning sequence, teacher shows [forest fire video](#) again. Students revisit their initial model showing their understanding of how a forest regrows. Incorporating knowledge gained from the unit, students revise and elaborate on their model.

Suggested time frame:

825 minutes = 13.75 hours

Anchoring Phenomenon/Design Problem:

Forest fire regrowth. Use the [cropped video](#) to introduce phenomenon. [Video link](#) for the entire video is included, but should only be shown during the final learning sequence. Stop the video at 30 seconds showing only the fire. Questions: What happens after the fire; will life come back; **how** does life come back?

NGSS Performance Expectation(s): (Hyperlinks will bring reader to NGSS Evidence Statements)

- [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.]*
- [HS-LS1-6](#). Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other element 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.]*
- [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-PS1-7](#). * Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. *[Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]*
- [HS-LS2-4](#). 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-LS2-5](#). 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.]*

*PE not completely assessable in this Unit

Three Dimensions that form the Foundation for these NGSS Performance Expectations:**Science & 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-LS1-6

Developing and Using Models.

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

Using Mathematics and Computational Thinking

- Use mathematical representations of phenomena to support claims. HS-PS1-7

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. 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
- 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 a result of these chemical reactions, energy is transferred from one system of interacting molecules to another.

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. HS-LS1-6, 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
- The total amount of energy and matter in closed systems is conserved. HS-PS1-7

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and

• Use mathematical representations of phenomena or design solutions to support claims. HS-LS2-4	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 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 LS2.B: Cycles of Matter and Energy Transfer in Ecosystems • 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 PS1.B: Chemical Reactions • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.HS- PS1-7 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. <i>(secondary)</i> HS-LS2-5	interactions—including energy, matter, and information flows—within and between systems at different scales. HS-LS2-5
---	--	--

Possible 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)
- WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-6)
- 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)
- WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-6)
- SL.11-12.5 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. (HS-LS1-5)(HS-LS1-7)

Mathematics -

- MP.2 Reason abstractly and quantitatively. (HS-PS1-7)(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-PS1-7)(HS-LS2-4)
- HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-7)(HS-LS2-4)
- HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-7)(HS-LS2-4)

Prior Student Knowledge:

- [MS.PS1.A](#) Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms ([HS-LS1-6,HS-PS1-7,*](#))
- [MS.PS1.B](#) Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy. ([HS-LS1-5,HS-LS1-6,HS-LS1-7,HS-PS1-7,*](#))
- [MS.PS3.D](#) The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.
Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. ([HS-LS1-5, HS-LS1-6, HS-LS1-7,HS-LS2-4,HS-LS2-5](#))
- [MS.LS1.C](#) 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.
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. ([HS-LS1-5, HS-LS1-6, HS-LS1-7, HS-LS2-4, HS-LS2-5, HS-PS1-7,*](#))
- [MS.LS2.B](#) Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. 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. ([HS-LS1-5,HS-LS1-7,HS-LS2-4,HS-LS2-5,HS-PS1-7,*](#))
- [MS.ESS2.A](#) All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. ([HS-LS2-5,HS-PS1-7,*](#))

Possible Misconceptions:

- Water is food for plants.
- Water is food for animals.
- Plants use oxygen during photosynthesis.
- Carbon dioxide is absorbed through the roots of plants.
- Food is a source of energy but not a source of building materials.

- Carbon dioxide is food for plants.
- Substances in soil are food for plant.
- Plants have multiple food sources, not just the sugars that they make from water and carbon dioxide.
- Plants cannot store molecules from food in their body structure.

PROGRESSION OF LEARNING

Learning Sequence 1: Student Engagement with the Anchoring Phenomenon

- Driving Question: What will happen to a forest community after a fire?
- [Learning Sequence 1](#)
- Relationship to Anchoring Phenomena/Design Problem: This is the introduction to the anchoring phenomenon.
 - To initiate the unit, students will watch a brief time-lapse video of a [forest fire](#) that begins with a lush environment. For this particular segment the video will abruptly end with devastation of much of the vegetation. Teacher will direct students to hypothesize what will happen now that all visible life has been removed from the ecosystem. Starting with the undisturbed ecosystem, students will be prompted to design an original model consisting of a series of 4-5 panels that illustrates their prediction of what will happen to the forest once the fire has cleared.
- Student Expected Outcomes:
 - Students will create an initial model illustrating their understanding of changes in a ecosystem after a forest fire.

Learning Sequence 2

- Driving Question: Why is life carbon based?
- [Learning Sequence 2](#)
- Relationship to Anchoring Phenomena/Design Problem:
 - Students will develop an understanding of the importance of carbon in life. Carbon, being able to form four bonds, is able to bond in a variety of ways that make it a versatile element necessary for regrowth after a forest fire. Students will relate the structure and function of macromolecules to their molecular formulas and describe how molecules are joined and/or broken apart. Students will model how molecules in food are synthesized and broken down for use in biosynthesis. Essential vocabulary, such as monomer, polymer, dehydration synthesis and hydrolysis will be introduced. The terminology will be essential for when students complete phenomenon models.
 - Explains the chemicals necessary for life. Students will understand the structure and function of the chemicals necessary for life and relate the chemicals to their role in the regrowth of the forest after the fire.
- Student Expected Outcomes:
 - Students will identify and describe the components of a model that demonstrate that organic compounds are made of carbon and that matter is conserved in reactions.
 - Students will identify patterns in constructing an explanation of how carbon can combine with other elements in a variety of ways to form organic compounds.
 - Students will develop and revise a model that shows how carbon containing molecules are used as matter that flows through a system.
 - Students will construct an explanation of how carbon compounds can form large molecules for growth and maintenance within living systems.

Learning Sequence 3

- Essential Question: How is chemical energy released for use in living systems?
- [Learning Sequence 3](#)
- Relationship to Anchoring Phenomena/Design Problem:
 - Explains how chemical rearrangements of glucose by living things provides the energy necessary for growth and maintenance of life. As a result of these chemical reactions, energy and matter flows in, out, and within a system and organisms use energy in different forms.
- Student Expected Outcomes:
 - Students will construct and revise an explanation that chemical elements are recombined in different ways to form different products and that energy is transferred from one system of interacting molecules to another.
 - Students will use a model to show that energy can be stored and released in chemical reactions and energy cannot be created or destroyed.

Learning Sequence 4

- Essential Question: How do plants convert light energy to food?
- [Learning Sequence 4](#)
- Relationship to Anchoring Phenomena/Design Problem:
 - Explains how plants obtain the energy necessary for regrowth of the forest, by converting solar energy into chemical energy.
- Student Expected Outcomes:
 - Students will identify relationships between components of a model showing how plants need sunlight, CO₂ and H₂O to make sugar and O₂ demonstrating changes of energy and matter in a system.
 - Students will use evidence to develop a model and illustrate the concept of photosynthesizing organisms convert light energy to chemical energy simulating system interactions (energy, matter, and information flows within and between systems at different scales)

Learning Sequence 5

- Essential Question: How does carbon move through organisms and ecosystems?
- [Learning Sequence 5](#)
- Relationship to Anchoring Phenomena/Design Problem:
 - Understanding of the carbon cycle will allow students to fully describe the movement of carbon necessary for the forest regrowth.
- Student Expected Outcomes:
 - Students will use evidence from a model that identifies how carbon is cycled in a system.
 - Students will construct an explanation of how matter changes as it moves through living and nonliving systems.
 - Students will use mathematical representations to demonstrate that energy cannot be created or destroyed as it moves between objects fields or systems.
 - Students will construct a model(s) to showcase how energy and matter are transferred up the food chain
 - Students will use manipulatives to showcase that, in chemical reactions, atoms are never created nor destroyed, which in turn allows them to be transferred within the food chain

Learning Sequence 6

- Driving Question: How does a forest regrow after a forest fire?
- [Learning Sequence 6](#)
- Relationship to Anchoring Phenomena/Design Problem:
 - Students complete final models of forest regrowth, incorporating all of the learning from this Unit.
- Student Expected Outcomes:
 - Students will identify and describe the components of a model that demonstrate that organic compounds are made of carbon and that matter is conserved in reactions.
 - Students will develop and revise a model that shows how carbon containing molecules are used as matter that flows through a system.
 - Students will use a model to show that energy can be stored and released in chemical reactions and energy cannot be created or destroyed .
 - Students will identify relationships between components of a model showing how plants need sunlight, CO₂ and H₂O to make sugar and O₂ demonstrating changes of energy and matter in a system.
 - Students will use evidence to develop a model and illustrate the concept of photosynthesizing organisms convert light energy to chemical energy simulating system interactions (energy, matter and information flows within and between systems at different scales)
 - Students will use evidence from a model that identifies how carbon is cycled in a system.

Special thanks to all of the individuals that contributed to this unit:

- Unit developed by: Matthew Loiseau, Melissa Moore, Dave DeStefano, Jenna Nalband, Nancy Siedlecki, Beth Marchinkoski
- Edited by Anne Puzzo

Materials Required for this Unit

List Number required for a class of 24 students

Quantity	Description	Potential Supplier (item #)	Estimated Price
	Sequence 1		

1	newsprint 24x36 500 sheets	WB Mason PAC3414	34.95
24	assorted markers	WB MasonCYO587708	5.09 ea
1	video equipment, forest fire		
	Learning Sequence 2		
12	Molecules of Life kit	Lab Aids #505	\$133.35
1 Pad	Poster paper (above)		
24	assorted markers (above)		
	optional lab supplies		
500 mL	benedict solution	Flinn	\$5.20
500 mL	Biuret solution	Flinn	\$7.20
500mL	Lugol's Iodine	Flinn	\$12.50
500g	dextrose	Flinn	\$9.60
36	test tubes	Flinn	\$30.60
6	beakers 400 mL	Flinn	\$38.40
36	plastic pipettes	Flinn	\$3.40
6	hot plate	Flinn	\$1260
12	test tube holder	Flinn	\$39.00
	assorted consumables(apple juice, baby foods, starch, cheeseburger, peanut butter,vegetable oil, etc)		
	Learning Sequence 3		
100	Austrian or Alaskan Peas	Flinn FB0579	3.35
1	Carbon dioxide detector (and interface)	Vernier CO2-BTA	259
1	labquest 2 interface	Vernier LABQ2	329
12	ringstands (12.75)	Flinn AP8354	153
12	test tube clamps (9.55)	Flinn AP4550	114.60
12	thermometer clamps(19.15)	Flinn AP1039	229.8
12	test tubes (18x150mm) .85	Flinn GP6025	10.20
12	digital thermometer(33.75)	Flinn AP8716	405
12	butane lighter (6/9.64)	Amazon	19.28
6	electronic balances (.01g) (349)	Carolina 702010	2094
1 bag/100	large cork or other support (wrap in foil)	Carolina 712193	55.85
1 bag	pin, paperclip or copper wire	Flinn AB1084	13.65
1 box	weigh paper 4x4(14.50)	Flinn AP1122	14.50
	assorted food samples: Cheetos, mini marshmallow, coconut flakes		12.00
12	graduated cylinder 25 mL(7.70)	Flinn AP2295	92.40
	Learning sequence 4		
600	Radish seeds (1lb)	Carolina 159003	18.95
1 ball	cotton string or yarn	Carolina 111115	6.95
1	brown paper towels case /6	webstaurant 5001RT800N	17.49
1	sharpie box/12	wb mason SAN30001	11.98

12	small aluminum trays~7x10 cm 1 pack 70	https://www.amazon.com/Aluminum-Muffin-Cupcake-Ramekin-Disposable/dp/B00JMTDRXM/ref=redir_mobile_desktop?ie&plnSite=1	9.98
4	large aluminum trays 1 pack/30	https://www.amazon.com/DOBI-30-Pack-Chafing-Pans-Disposable/dp/B073Z1CZ4G/ref=sr_1_3_a_it?ie=UTF8&qid=1520546603&sr=8-3&keywords=aluminum%2Btrays%2Bdisposable&th=1	17.99
4	lamps or grow lights	Carolina 974254	21.95ea
6	electronic balances (.01g) (349ea)	Carolina 702010	2094
	miracle gro	grocery store	9.00
24 (2 sleeve/20)	petri dish sleeve /20	Carolina 741252	10.95ea
1	bromothymol blue bottle /500 ml	Carolina 849165	6.00
12	plastic container with tight snap lid	https://www.shopworldkitchen.com/airtight-food-storage-29-cup-rectangular-container-w--handle/1098436.html or similiar(Walmart, Grocery store)	9.09
1 pkg	heavy black plastic bags	grocery store	9.00
1pk/100	aluminum weigh dish or envelops	Flinn AP6390	10.80
	Learning Sequence 5		
1	Carbon cycle adventure kit	FLinn Scientific #: FB2206	19.95
1	Unit Elodea or Anacharis or other aquatic plant	Carolina Biological #162101	9.75
1	feeder guppy	local pet store	.10
1-3	pond snails (may come on Elodea, if purchased in a pet store)	Carolina Biological #141212	14.50
	empty 2 liter bottle, gravel, tap water (dechlorinated)		
	poster paper, markers		