Stanford NGSS Integrated Curriculum
An Exploration of a Multidimensional World

UNIT 3

Mimicking Nature's Design

How does energy and matter flow within natural and designed systems?

SCALE
Stanford Center for Assessment, Learning & Equity

Stanford NGSS Integrated Curriculum: An Exploration of a Multidimensional World
Unit 3: Mimicking Nature's Design

Essential Question: How does energy and matter flow within natural and designed systems?

Total Number of Instructional Days: 34 – 35

Lift-Off Task:	Task 1:	Task 2:	Task 3:	Task 4:	Task 5:
Changing Rivers	Types of Changes	Matter Moves You	Cycling Matter Through Living Things	Cycling Matter Through Rocks	Design a Thermal Device

Connect to the Culminating Project using the Project Organizer

Group Culminating Project:
Create an aquaponics system that mimics a natural ecosystem

Individual Culminating Project
Write an instruction manual for your aquaponics system

Unit 3 Pop-Out
How Science Works
(*Implement anytime during unit*)

Storyline for Unit 3

Environments contain a variety of different living and non-living parts that all interact to make the environment function as a whole. In this unit, students explore how natural ecosystems function in order to design an artificial ecosystem, known as an aquaponics system, for their culminating project.

In the Lift-Off Task, students are introduced to a changing river environment, shown in an image from 200 years ago as well as an image from the present. After making their own observations, they are asked to generate a list of questions they would ask in order to learn more about how and why this river environment has changed over time. Students will return to this phenomenon and these questions throughout the unit as they seek to form a more cohesive understanding of how ecosystems function.

As students noticed changes that occurred over hundreds of years in the river environment, they were implicitly beginning to think about the chemical and physical processes involved in environmental change. In Task 1, students dig into the science behind some of these changes by learning about both physical and chemical changes. Through data analysis, they will find that looking at the properties of substances before and after the change is key to determining what type of change it is. By the end of this task, students will be able to use their scientific understanding of physical and chemical changes to help them explain real phenomena in river environments, thus paving the way to apply this knowledge in a designed setting, like their aquaponics system.

In Task 2, students continue their exploration of chemical changes with a few example reactions—combustion and cellular respiration. By analyzing these chemical reactions as molecular models, students begin to see that when molecules are broken down, they don't just disappear; rather matter is conserved, molecules are rearranged, and energy is released in the process. This is one way matter and energy move through ecosystems. Armed with understanding of this chemical reaction, students will be able to first decide what components are needed in their aquaponics system, and then begin to conceptualize what the cycling of energy and matter looks like in their system.

Task 3 builds on ideas from Task 1 by introducing another critical chemical reaction that plays a role in the cycling of matter and flow of energy in all environments—photosynthesis. Students conduct investigations that show how photosynthesis and cellular respiration interact to allow matter to cycle and energy to flow through living organisms. By the end of this task, students should have a clear model of this cycling, so they may apply this knowledge to the design of their aquaponics system.

However, photosynthesis and cellular respiration are not the only ways matter is cycled in an ecosystem. In Task 4, students find that Earth's materials can also be cycled through non-living components, like rocks, creating some of the changes students originally observed in the river environment in the Lift-Off Task. After simulating the rock cycle, students model the different processes that cycle Earth's materials, including how energy drives this process. By the end of this task, students are equipped to consider how the rock cycle may play a role in their aquaponics system.

Throughout this unit, students have seen heat being absorbed and released in the chemical reactions they observed. In Task 5, students use this knowledge to approach a design problem: How can they heat a pool in the river environment so blue catfish are able to spawn? Students will use hot packs and cold packs as their inspiration, testing which chemical reactions absorb or release heat. They will then engage in the complete engineering and design process to design a heat-regulation device, which will be modified and used in their aquaponics system design.

Once students are complete with all learning tasks, they are ready to complete their culminating project. In this culminating project, the students' job is to use what they learn about how matter cycles and energy flows through organisms and rocks in order to build a sustainable aquaponics system that mimics the properties of a river environment. After groups build their aquaponics system, students individually create an instruction manual, containing a visual model to explain how their aquaponics system functions.

7th Grade Science Unit 3: Mimicking Nature's Design
Unit Overview

Three-Dimensional Breakdown of the Performance Expectations

This unit was developed to align with, teach, and assess students' understanding and skills related to these Performance Expectations. Below, we have mapped out the disciplinary core ideas, crosscutting concepts, and science and engineering practices addressed in this unit. Aspects of the dimensions that are not explicitly addressed in this unit are crossed out.

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]	**Constructing Explanations** • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • 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. **PS3.D: Energy in Chemical Processes and Everyday Life** • The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (ie. from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen (*secondary*).	**Energy and Matter** • Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
MS-LS1-7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [Clarification Statement:	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • Within individual organisms, food moves through a series of chemical reactions in which it is broken down	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes.

Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.]		and rearranged to form new molecules, to support growth, and to release energy. **PS3.D: Energy in Chemical Processes and Everyday Life** • 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 (*Secondary*).	
MS-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [Assessment Boundary: Assessment does not include the identification and naming of minerals.]	**Developing and Using Models** • Develop and use a model to describe phenomena.	**ESS2.A: Earth's Materials and Systems** • 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.	**Stability and Change** • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.
MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [Assessment Boundary: Assessment is limited to analysis of the following properties:	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings.	**PS1.A: Structure and Properties of Matter** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **PS1.B: Chemical Reactions** • Substances react chemically in characteristic ways. In a chemical process, the	**Patterns** • Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

density, melting point, boiling point, solubility, flammability, and odor.]		atoms that make up the original substances are regrouped into different molecules and these new substances have different properties from those of the reactants.	
MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.]	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**PS1.B: Chemical Reactions** • 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.	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes.
MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.* [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.]	**Designing Solutions** • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific criteria and constraints.	**PS1.B: Chemical Reactions** • Some chemical reactions release energy, others store energy.	**Energy and Matter** • The transfer of energy can be tracked as energy flows through a designed or natural system.
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and	**ETS1.B: Developing Possible Solutions** • There are systematic processes for evaluating solutions with respect	**N/A**

can be combined into a new solution to better meet the criteria for success.	differences in findings.	to how well they meet the criteria and constraints of a problem. • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. **ETS1.C: Optimizing the Design Solution** • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process – that is, some of the characteristics may be incorporated into the new design.	
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	**Developing and Using Models** • Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	**ETS1.B: Developing Possible Solutions** • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. • Models of all kinds are important for testing solutions. **ETS1.C: Optimizing the Design Solution** • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	**N/A**

7th Grade Science Unit 3: Mimicking Nature's Design
Unit Overview

Connections to Common Core Math and ELA Standards:

Over the course of this unit, students will gain knowledge and skills in science, as well as in math and English-language arts. Below we list the Common Core ELA and Math standards for middle school and 7th grade that are relevant to the curriculum tasks in this unit. Within the curriculum, there are opportunities to incorporate components of the following ELA and Math Standards:

Middle School Common Core ELA Standards		Unit Task
Key Ideas and Details	CCSS.ELA-Literacy.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.	Task 3 Project
	CCSS.ELA-Literacy.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.	Task 3
	CCSS.ELA-Literacy.RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	Task 3 Task 4 Task 5
Integration of Knowledge and Ideas	CCSS.ELA-Literacy.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).	Task 1 Task 2 Project
	CCSS.ELA-Literacy.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.	Task 3
Text Types and Purposes	CCSS.ELA-Literacy.WHST.6-8.2: Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.	Task 5 Project
Research to Build and Present Knowledge	CCSS.ELA-Literacy.WHST.6-8.9: Draw evidence from informational texts to support analysis, reflection, and research.	Task 3 Project
Presentation of Knowledge and Ideas	CCSS.ELA-Literacy.SL.8.5: Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.	Task 2 Project

Middle School and 7th Grade Common Core Math Standards		Unit Task
Mathematical Practice	CCSS.MATH.MP.2: Reason abstractly and quantitatively.	Task 1 Task 2 Task 5 Project
	CCSS.MATH.MP.4: Model with mathematics.	Task 2 Project

Connections to English Language Development (ELD) Standards:

We acknowledge that language development is a key component of disciplinary understanding and helps to support more rigorous and equitable outcomes for diverse students. This curriculum thus takes into account both the receptive and productive language demands of the culminating projects and strives to increase accessibility by including scaffolds for language development and pedagogical strategies throughout learning tasks. We aim to support language acquisition through the development of concept maps; utilizing sentence frames; implementing the Critique, Correct, and Clarify technique; employing the Stronger Clearer strategy; and fostering large and small group discussions.

The California ELD Standards are comprised of two sections: the standards and a rubric. Outlined below are the standards from Section One that are met within this curriculum. For additional information, please refer to: https://www.pausd.org/sites/default/files/pdf-faqs/attachments/SS_ELD_7.pdf.

Eighth Grade ELD Standards		
Part I: Interacting in Meaningful Ways	A: Collaborative	1.Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics
		2. Interacting with others in written English in various communicative forms (print, communicative technology, and multimedia)
		3. Offering and justifying options, negotiating with and persuading others in communicative exchanges
		4. Adapting language choices to various contexts (based on task, purpose, audience, and text type)
	B: Interpretive	5. Listening actively to spoken English in a range of social and academic contexts
		6. Reading closely literary and informational texts and viewing multimedia to determine how meaning is conveyed explicitly and implicitly through language
		7. Evaluating how well writers and speakers use language to support ideas and arguments with details or evidence depending on modality, text type, purpose, audience, topic, and content area
		8. Analyzing how writers and speakers use vocabulary and other language resources for specific purposes (to explain, persuade, entertain, etc.) depending on modality, text type, purpose, audience, topic, and content area
	C: Productive	9. Expressing information and ideas in formal oral presentations on academic topics
		10. Writing literary and informational texts to present, describe, and explain ideas and information, using appropriate technology
		11. Justifying own arguments and evaluating others' arguments in writing
		12. Selecting and applying varied and precise vocabulary and other language resources to effectively convey ideas
Part II: Learning About How English	A: Structuring Cohesive Texts	1. Understanding text structure
		2. Understanding cohesion
	B: Expanding and Enriching Ideas	3. Using verbs and verb phrases
		4. Using nouns and noun phrases

Works		5. Modifying to add details
	C: Connecting and Condensing Ideas	6. Connecting ideas
		7. Condensing ideas

Connections to Environmental Awareness:

Over the course of this curriculum, students will explore content related to various environmental principles and concepts that examine the interactions and interdependence of human societies and natural systems. In accordance with the *Education and the Environment Initiative (EEI),* tasks throughout this curriculum explore many of *California's Approved Environmental Principles and Concepts.* The principles relevant to this unit are outlined in the chart below:

Unit Task	**EEI Principle**	**EEI Concept**
Task 2 Task 3 Project	Principle I: The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.	Concept B: The ecosystem services provided by natural systems are essential to human life and to the functioning of our economies and cultures.
Task 1 Task 2 Task 3 Task 4 Project	Principle III: Natural systems change in ways that people benefit from and can influence.	Concept A: Natural systems proceed through cycles and processes that are required for their functioning.

7th Grade Science Unit 3: Mimicking Nature's Design
Teacher Materials List

Unit Essential Question: *How does energy and matter flow within natural and designed ecosystems?*

Overall Unit – All Tasks
- Unit 3, Task Cards Student Version, Lift-Off and Tasks 1 through 5
- Culminating Project Student Task Card
- Project Organizer
- Projector with Audio (for video or images, whenever needed)

Lift-Off Task (2 days)

Per Student
- Task Card Student Version: Lift-Off
- Optional: Printed sets of River Environment Images
- Post-Its (Optional)
- Task Card Student Version: Culminating Project
- Project Organizer

Per Group
- Poster paper and markers

Whole Class
- Poster paper and markers
- Optional: Projector to project River Environment Images
- *See Instructions in Lift-Off for other optional materials to use for the class concept map

Task 1 (3 Days)

Per Student
- Task Card Student Version: Task 1
- Project Organizer

Task 2 (4 Days)

Per Student
- Task Card Student Version: Task 2
- Project Organizer
- Optional: "The Science Behind It" Resource Card

Per Group
- Balancing scale or 2 normal scales
- Atom "Pieces": These can be a modeling kit, unifix cubes, colored beads, legos, jelly beans, or any materials available in three colors
    - 6 for Carbon
    - 12 for Hydrogen
    - 18 for Oxygen
- Colored pencils or crayons

Whole Class
- Candle

- Match or lighter
- Large Clear Jar

Task 3 (4.5 Days)

Per Student

- Task Card Student Version: Task 3
- Project Organizer

Per Group

- Small Beaker 1/3 filled with Bromothyml Blue Solution
- Straw
- Investigation Card in sheet protectors for each table group
- 2 Test Tubes or Baby Food Jars
    - If using Test tubes, need test tube racks
- Small Graduated Cylinder (to retrieve BTB solution from teacher)
- 1-2 Sprigs Elodea Plant (available at most local aquariums)
- Straw
- Masking Tape
- Optional: If students actually want to run the experiment described, follow the same instructions as the other jars, except add a sea snail or small fish. Be sure to use distilled water or the snail/fish will likely die before data can be collected.

Whole Class

- Empty Oatmeal Containers or Large Cardboard Box (For dark environment)
- 2 Sun Lamps
- Bromothyol blue solution
    - 1 g bromothymol blue
    - 1 L distilled water
    - 18 drops of 1M sodium hydroxide (Optional: makes it more blue)

Task 4 (4.5 Days)

Per Student

- Task Card Student Version: Task 4
- Project Organizer

Per Pair

- Critique, Correct, Clarify – Rock Cycle Model

Per Group

- Modeling the Rock Cycle with Crayons Card (in a sheet protector)
- Crayons (at least two different colors)
- Source of very hot water in container
- Tweezers or small tongs
- Aluminum foil square
- Plastic knives
- Optional: Bring in real rocks as examples of the different types of rocks in the rock cycle

7th Grade Science Unit 3: Mimicking Nature's Design

Teacher Materials List

Task 5 (5.5 – 6.5 Days)

Per Student

- Task Card Student Version: Task 5
- Project Organizer

Per Group

- Thermal Chemical Reactions Investigation Card (in sheet protector)
- Calcium chloride (used to melt ice on driveways in winter)
- Potassium chloride (e.g., Morton Lite™)
- Sodium bicarbonate (baking soda)
- Vinegar
- 10 sandwich-size zip-lock bags (thick and thin options)
- Tablespoon measuring spoons
- 100 ml graduated cylinder
- 2 500 ml beakers
- Water (Cold and Warm)
- Ice
- Sharpie
- 2 Thermometers
- Additional material choices for building and modification of prototypes (ie. plastic wrap, foil, tape, cloth, felt, containers of different materials and sizes)

Culminating Project (7 days)

Per Group: Option A, Aquaponics System

*Because it is very expensive to provide materials for every group to make a true aquaponics system, students will use a combination of recycled and household materials to make a cheaper version.

- 2 large soda bottles
- String (acts as "water pump" to bring water from fish tank up to soil)
- Gravel
- Growing medium (pea gravel, perlite, peat moss, etc)
- De-chlorinated water
- Fish
- Plants
- Other organisms (based on student choice)
- Scissors
- Electrical Tape
- Materials from Task 5 for heating devices (See Task 5 section above)

Per Class: Option B, Aquaponics System

*You may choose to gather these materials on your own or purchase an aquaponics "kit," available online or large hardware stores. Search for aquaponics system building instructions online for more details.

- Glass or plastic tank for the fish (3-20 gallon recommended)
- Gravel (2.5 lbs per 5 gallons of water in fish tank)

- Small circulation or fountain water pump (3-4 watt) to pump water from fish tank to grow bed
- Grow bed (must be able to sit on top of fish tank, 3-8 inches deep, with holes to drain into fish tank)
- Growing medium (pea gravel, perlite, peat moss, etc)
- Aquarium air pump
- De-chlorinated water
- Fish
- Plants
- Other organisms (based on student choice)
- Optional:
    - Plastic tubing
    - Supports for grow bed, if necessary
- Scissors
- Electrical Tape
- Drill
- Materials from Task 5 for heating devices (See Task 5 section above)

Per Student: Aquaponics System Instruction Manuel
- Optional: Instruction Manual Template
- Computer with word processing OR
- Blank computer paper and colored pencils/markers for final draft

Unit 3 Pop-Out (3.5 days)
Per Student
- Student Version: Unit 3 Pop-Out

Per Group
- Series of 16 checks in an envelope – 2 options available in Resource provided

7th Grade Science Unit 3: Mimicking Nature's Design
Building on Prior Knowledge

Unit 3 continues to integrate all three disciplines—life science, physical science, and earth science—but now incorporates some engineering and design components as well. In this unit, students use what they already know about ecosystems to explore how matter cycles and energy flows within them, keeping them healthy and functioning. Students are then able to use these concepts and mimic a natural ecosystem in the design of their own aquaponics system.

The integrated model requires students to access and use a wide range of ideas from prior grades. This content knowledge spans seven different Disciplinary Core Ideas: LS1.C. Organization for Matter and Energy Flow in Organisms, PS3.D: Energy in Chemical Processes and Everyday Life, ESS2.A. Earth's Materials and Systems, PS1.A. Structure and Properties of Matter, PS1.B. Chemical Reactions, ETS1.B. Developing Possible Solutions, and ETS1.C. Optimizing the Design Solution.

As students explore these core ideas, they build on their skills in the following science and engineering practices: Developing and Using Models, Analyzing and Interpreting Data, and Constructing Explanations and Designing Solutions. In addition to science and engineering practices, students also continue to build on their knowledge of the following crosscutting concepts: Patterns, Energy and Matter, and Stability and Change.

*This summary is based on information found in the NGSS Framework.

K-8 Progression of Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts for Unit 3

Disciplinary Core Ideas	K-2	3-5	6-8
LS1.C Organization for Matter and Energy Flow in Organisms	Animals obtain food they need from plants or other animals. Plants need water and light.	Food provides animals with the materials and energy they need for body repair, growth, warmth, and motion. Plants acquire material for growth chiefly from air, water, and process matter and obtain energy from sunlight, which is used to maintain conditions necessary for survival.	Plants use energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through a series of chemical reactions that rearrange molecules and release energy.
PS3.D Energy in Chemical Processes and Everyday Life	Sunlight warms Earth's surface.	Energy can be "produced", "used", or "released" by converting stored energy. Plants capture energy from sunlight, which can later be used as fuel or food.	Sunlight is captured by plants and used in a reaction to produce sugar molecules, which can be reversed by burning those molecules to release energy.
ESS2.A Earth's Materials and Systems	Wind and water change the shape of the land.	Four major Earth systems interact. Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, organisms, and gravity break rocks, soils, and sediments into smaller pieces and move them around.	Energy flows and matter cycles within and among Earth's systems, including the sun and Earth's interior as primary energy sources. Plate tectonics is one result of these processes.
PS1.A. Structure and Properties of Matter	Matter exists as different substances that have observable different	Because matter exists as particles that are too small to see, matter is always conserved even if it	The fact that matter is composed of atoms and molecules can be used to explain the properties of

	properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.	seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.	substances, diversity of materials, states of matter, phase changes, and conservation of matter.
PS1.B Chemical Reactions	Heating and cooling substances cause changes that are sometimes reversible and sometimes not.	Chemical reactions that occur when substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.	Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy.
ETS1.B Developing Possible Solutions	Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people.	Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved.	A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. Models of all kinds are important for testing solutions.
ETS1.C Optimizing the Design Solution	Because there is always more than one possible solution to a problem, it is useful to compare and test designs.	Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Science and Engineering Practices	K-2	3-5	6-8
Developing and Using Models*	Modeling in K–2 builds on prior experiences and progresses to include using	Modeling in 3–5 builds on prior experiences and progresses to building and revising simple	Modeling in 6–8 builds on prior experiences and progresses to developing, using, and revising models

	and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions. • Develop and/or use a model to represent amounts, relationships, relative scales (bigger/smaller) and/or patterns in the natural and designed world(s). • Develop a simple model based on evidence to represent a proposed object or tool.	models and using models to represent events and design solutions. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena. • Develop a diagram or simple physical prototype to convey a proposed object, tool, or process. • Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	to describe, test, and predict more abstract phenomena and design systems. • Develop and use a model to describe phenomena. • Develop a model to describe unobservable mechanisms. • Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.
Analyzing and Interpreting Data*	Analyzing data in K-2 builds on prior experiences and progresses to collecting, recording, and sharing observations. • Compare predictions (based on prior experiences) to what occurred (observable events). .	Analyzing data in 3-5 builds on prior experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings. • Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.	Analyzing data in 6-8 builds on prior experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to determine similarities and differences in findings.

7th Grade Science Unit 3: Mimicking Nature's Design
Building on Prior Knowledge

Constructing Explanations*	Constructing Explanations in K-2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena. • Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.	Constructing Explanations in 3-5 builds on prior experiences and progresses to the use of evidence and ideas in constructing explanations that specify variables that describe and predict phenomena. • Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.	Constructing Explanations in 6-8 builds on prior experiences and progresses to include constructing explanations supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.
Designing Solutions*	Designing solutions in K-2 builds on prior experiences and progresses to the use of evidence and ideas in designing solutions. • Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem.	Designing solutions in 3-5 builds on prior experiences and progresses to the use of evidence in designing multiple solutions to design problems. • Apply scientific ideas to solve design problems.	Designing solutions in 6-8 builds on prior experiences and progresses to include designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

*These SEPs are summatively assessed using the Culminating Project.

Crosscutting Concepts	K-2	3-5	6-8
Patterns*	Students recognize that patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. • Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	Students identify similarities and differences in order to sort and classify natural objects and designed products. They identify patterns related to time, including simple rates of change and cycles, and to use these patterns to make predictions. • Patterns can be used as evidence to support an explanation.	Students recognize that macroscopic patterns are related to the nature of microscopic and atomic-level structure. They identify patterns in rates of change and other numerical relationships that provide information about natural and human designed systems. They use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data. • Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

7th Grade Science Unit 3: Mimicking Nature's Design
Building on Prior Knowledge

Energy and Matter*	Students observe objects may break into smaller pieces, be put together into larger pieces, or change shapes. • Objects may break into smaller pieces, be put together into larger pieces, or change shapes.	Students learn matter is made of particles and energy can be transferred in various ways and between objects. Students observe the conservation of matter by tracking matter flows and cycles before and after processes and recognizing the total weight of substances does not change. • Matter is made of particles. • Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. • Energy can be transferred in various ways and between objects.	Students learn matter is conserved because atoms are conserved in physical and chemical processes. They also learn that within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Matter is conserved because atoms are conserved in physical and chemical processes. • The transfer of energy can be tracked as energy flows through a natural system.
Stability and Change*	Students observe some things stay the same while other things change, and things may change slowly or rapidly. • Some things stay the same while other things change.	Students measure change in terms of differences over time, and observe that change may occur at different rates. Students learn some systems appear stable, but over long periods of time they will eventually change. • Change is measured in terms of differences over time and may occur at different rates.	Students explain stability and change in natural or designed systems by examining changes over time, and considering forces at different scales, including the atomic scale. Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time. • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.

*These CCCs are summatively assessed using the Culminating Project.

7th Grade Science Unit 3: Mimicking Nature's Design
Building on Prior Knowledge

Progression of Knowledge from Kindergarten – 8th grade

LS1.C. Organization for Matter and Energy Flow in Organisms: In Kindergarten – second grade, students make observations to begin to understand the core content of this DCI—what plants and animals need to live and grow and how this is all related. In fifth grade, students explore these relationships a bit deeper by making connections between plants and animals as it relates to matter and energy flow. Students first gather evidence that plants get their matter from air and water, and then use models to describe that this matter also holds energy that plants harvested from the sun. Since animals eat plants, this original energy from the sun is what gives animals the energy they need for everyday life and growth. By the time students get to this seventh grade unit, they already understand the mechanisms at a macroscopic level and thus are well prepared to learn about the detailed underlying mechanisms of photosynthesis and cellular respiration. While in the K-2 band, students are focused on Patterns and Analyzing and Interpreting Data as they begin their exploration with real-life observations, the later grade bands focus entirely on the lens of Energy and Matter as students consider the connections between plants and animals and within an ecosystem as a whole. In line with this shift, students also move towards the science and engineering practices of Developing and Using Models and using evidence as they engage in Constructing Explanations and Engaging in Argument From Evidence.

The following is the progression of the Performance Expectations for this DCI:

K-LS1-1 Use observations to describe patterns of what plants and animals (including humans) need to survive.

5-PS3-1 Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain warmth) was once energy from the sun.

5-LS1-1 Support an argument that plants get the materials they need for growth chiefly from air and water.

MS-LS1-6 Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

MS-LS1-7 Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

PS3.D. Energy in Chemical Processes and Everyday Life: In Kindergarten – second grade, students are not explicitly introduced to this DCI but they do learn that sunlight warms the Earth's surface, which is an essential foundation for the chemical processes they will explore in later grades. In fourth grade, students first engage in this DCI by learning that the expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use. While this Performance Expectation applies the concept to designed systems, rather than the natural systems in other Performance Expectations, it is an essential understanding for all of them. In fifth grade, students begin this exploration of natural systems by studying photosynthesis without explicit reference to the term; they learn that the energy released from food was once energy from the sun captured in a chemical process. In middle school, students dive deeper, constructing explanations and developing models for both photosynthesis and cellular respiration, explaining all components and interactions involved in these chemical reactions. At all grade bands, students are engaging with the crosscutting concept of Energy Matter, but Science and Engineering practices range from Designing Solutions to Developing and Using Models to Constructing Explanations.

The following is the progression of the Performance Expectations for this DCI:

4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

5-PS3-1 Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain warmth) was once energy from the sun.

MS-LS1-6 Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

MS-LS1-7 Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

<u>ESS2.A. Earth's Materials and Systems:</u> In Kindergarten – second grade, students begin with the basic idea that wind and water can change the shape of the land and use this knowledge to compare solutions that might prevent this from happening. In fourth grade, students build on this knowledge to investigate other factors, such as water, ice, wind, living organisms, and gravity that might also cause weathering and erosion. At both of these grade levels, students have been implicitly engaging with the idea that different earth systems interact in these particular ways. In fifth grade, students explore this idea at a broad level, developing a model that shows an example of the geosphere, biosphere, hydrosphere, and/or atmosphere interacting. This sets the stage for this seventh grade unit in which students learn that all Earth processes are the result of energy flowing and matter cycling within and among the Earth systems that they modeled in fifth grade. In the next unit in this seventh grade curriculum, students will focus on these interactions between Earth systems at different scales to think about how they have shaped Earth's history and will determine its future.

The following is the progression of the Performance Expectations for this DCI:

2-ESS2-1 Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.

4-ESS2-1 Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.

5-ESS2-1 Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

MS-ESS2-1 Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

<u>PS1.A. Structure and Properties of Matter</u>: In Kindergarten - second grade, students begin their initial exploration of matter by beginning to observe and analyze tangible materials and their properties. They also explore how an object made of small pieces can be disassembled and made into a new object, a concept that will be crucial as they begin to

think about atoms, molecules, chemical reactions, and conservation of matter in later grade bands. In third-fifth grade, they build on explorations from second grade to identify specific materials based on their properties. They also use experiments to gather evidence of the law of conservation of matter, a schema they started to develop in second grade. At this point, students are moving past observations of matter they can see and towards developing an understanding that matter is made of particles too small to be seen. Thus, by Unit 2 of this seventh grade curriculum, they were able to develop models of unseen particles, such as the atomic composition of various molecules and the movement of particles in different states of matter. In this unit, students delve deeper into chemical reactions, learning how to determine when a chemical reaction has occurred. In a later unit, students will apply this knowledge to the processes that transform natural resources to synthetic materials. Because of the vast number of Performance Expectations related to this DCI, students engage with a large range of science and engineering practices and crosscutting concepts.

The following is the progression of the Performance Expectations for this DCI:

2-PS1-1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

2-PS1-2 Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

2-PS1-3 Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object.

5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen.

5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.

5-PS1-3 Make observations and measurements to identify materials based on their properties.

MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

PS1.B. Chemical Reactions: In Kindergarten - second grade, students gather evidence to argue that some changes caused by heating or cooling can be reversed and some cannot. In doing so, they begin to experience chemical reactions without knowing that is what they are observing. In fifth grade, students take this a bit further by investigating that when substances are mixed, a new substance with different properties may be formed. At this grade level, students are also beginning to engage with the idea of conservation of matter by gathering evidence that total weight of matter is conserved in any type of change. All of this evidence prepares students for the middle school level in which they are finally asked to explicitly engage with the definition of a chemical reaction. In this seventh grade unit, students learn that in chemical reactions, the atoms that make up the original substances are regrouped into different molecules and these new substances have different properties. They are able to use their investigation skills from 5th grade to again analyze properties of substances, but this time to determine whether a chemical reaction has occurred. Students also model the law of conservation of matter at the atomic level, which builds on the evidence they gathered of this phenomenon in fifth grade and revisits a Performance Expectation from Unit 2. Lastly, students learn that some chemical reactions release energy and others store energy and use this knowledge to design a thermal-absorbing or thermal-releasing device. Again, because of the vast number of Performance Expectations related to this DCI, students engage with a large range of science and engineering practices and crosscutting concepts. You will also notice that this DCI has many parallels to the DCI above—PS1.A. Structure and Properties of Matter—as they are often both identified within a PE.

The following is the progression of the Performance Expectations for this DCI:

2-PS1-4 Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.

5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.

5-PS1-4 Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

MS-PS1-5 Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

MS-PS1-6 Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

ETS1.B. Developing Possible Solutions: During Kindergarten through second grade, students begin communicating multiple designs in the form of diagrams and sketches. By third to fifth grade, students move from mere drawings to actually testing out their designs to see how they perform under different conditions. Students then use this data to make improvements. Like in Kindergarten through second grade, there is still the idea that communication of designs with peers is an essential part of the design process. In this seventh grade unit, students move towards more systematic processes to evaluate solutions for how well they meet criteria and constraints. There is also a much greater emphasis on using the data to inform improvements, focusing on the idea that parts of different solutions can be used to make an even better solution. At the different grade levels, students engage in a variety of different science and engineering practices: Developing Models in K-2, Designing Solutions (specifically comparing solutions) in 3-5, and Engaging in

Argument From Evidence in 6-8. This is representative of the different practices students are engaging with, described above.

The following is the progression of the Performance Expectations for this DCI:

K-2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

ETS1.C. Optimizing the Design Solution: In Kindergarten to second grade, students begin to understand that because there are always multiple solutions to a problem, it is useful to compare and test designs. Students in third through fifth grade take this skill and use findings from those tests to determine which solution best meets criteria and constraints that they identified through ETS1.A. In accordance with the progression students follow in middle school for ETS1.B, students in this seventh grade unit move towards developing and testing models, and analyzing data to identify best characteristics that inform a new and better solution. Thus, it makes sense that at all grade levels, students focus on Science and Engineering Practices related to testing and analyzing: Developing and Using Models, Planning and Carrying Out Investigations, and Analyzing and Interpreting Data.

The following is the progression of the Performance Expectations for this DCI:

K-2-ETS1-3 Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

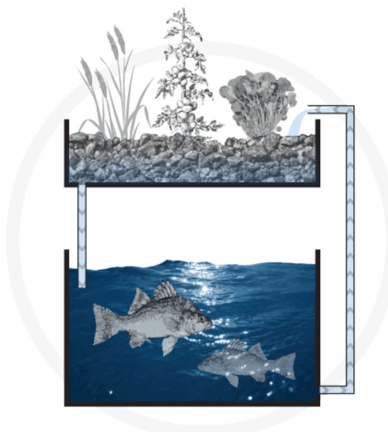
MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

7th Grade Science Unit 3: Mimicking Nature's Design
Culminating Project

Unit Essential Question: *How does energy and matter flow within natural and designed systems?*

Introduction

Real ecosystems, like the river environment students saw in the Lift-Off, have natural cycles that keep them functioning and healthy all on their own. By studying real ecosystems, we can learn how to replicate these cycles in artificial environments of our own making. Aquaponics systems, like the one shown to the right, use our understanding of real ecosystems to create an environment that sustains itself. Matter and energy flow within and between the garden on top and the fish tank below, providing each environment with the factors it needs to thrive.



For this unit's project, each group's task is to use what they learn about how energy and matter flow through ecosystems in order to design and build a sustainable aquaponics system that mimics the properties of a river environment. Individually, students will then write an instruction manual that describes their aquaponics system and explains the science behind how it functions.

3-Dimensional Assessment

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms
- Plants and many microorganisms use the energy from light to make sugars from carbon dioxide and water through the process of photosynthesis, which also releases oxygen.
- Within organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth and release energy.

PS3.D: Energy in Chemical Processes and Everyday Life
- In the chemical reaction by which plants produce food molecules, energy input is required to combine carbon dioxide and water in order to form carbon-based organic molecules and release oxygen.
- In cellular respiration, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.

ESS2.A: Earth's Materials and Systems
- 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.

PS1.A: Structure and Properties of Matter
- Each pure substance has characteristic physical and chemical properties that can be used to identify it.

PS1.B: Chemical Reactions
- 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.

Science and Engineering Practices

Developing and Using Models
- Develop and use a model to describe phenomena.
- Develop a model to describe unobservable mechanisms.

Analyzing and Interpreting Data
- Analyze and interpret data to determine similarities and differences in findings.

Constructing Explanations
- Construct a scientific explanation based on valid and reliable evidence obtained from sources 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.

Designing Solutions
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific criteria and constraints.

Crosscutting Concepts

Patterns
- Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Energy and Matter
- Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
- Matter is conserved because atoms are conserved in physical and chemical processes.
- The transfer of energy can be tracked as energy flows through a natural or designed system.

Stability and Change
- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.

7th Grade Science Unit 3: Mimicking Nature's Design
Culminating Project

Time Needed (Based on 45-Minute Periods)
7 Days at end of unit

- Group Project: 3 periods
- Individual Project: 4 periods
    - First draft: 2 periods
    - Feedback: 1 period
    - Revision: 1 period

Materials
Option A - Group Aquaponics System: Because it is very expensive to provide materials for every group to make a true aquaponics system, students will use a combination of recycled and household materials to make a cheaper version.

- 2 large soda bottles
- String (acts as "water pump" to bring water from fish tank up to soil)
- Gravel
- Growing medium (pea gravel, perlite, peat moss, etc)
- De-chlorinated water
- Fish
- Plants
- Other organisms (based on student choice)
- Scissors
- Electrical Tape
- Materials from Task 5 for heating devices (See Task 5 Teacher Version)

Option B - Class-wide Aquaponics System: You may choose to gather these materials on your own or purchase an aquaponics "kit," available online or in large hardware stores. Search for aquaponics system building instructions online for more details.

- Glass or plastic tank for the fish (3-20 gallon recommended)
- Gravel (2.5 lbs per 5 gallons of water in fish tank)
- Small circulation or fountain water pump (3-4 watt) to pump water from fish tank to grow bed
- Grow bed (must be able to sit on top of fish tank, 3-8 inches deep, with holes to drain into fish tank)
- Growing medium (pea gravel, perlite, peat moss, etc)
- Aquarium air pump
- De-chlorinated water
- Fish
- Plants
- Other organisms (based on student choice)
- Optional:
    - Plastic tubing
    - Supports for grow bed, if necessary
- Scissors
- Electrical Tape
- Drill
- Materials from Task 5 for heating devices (See Task 5 Teacher Version)

7th Grade Science Unit 3: Mimicking Nature's Design

Culminating Project

Instruction Manual
- Optional: Instruction Manual Template
- Blank Paper for final draft
- Optional: Colored pencils or markers

Instructions for the Culminating Project

1. Introduce the Culminating Project at the end of the Lift-Off task, including both group and individual components outlined in the Challenge.

2. Read over the Culminating Project Task Card with the students. We recommend only reading the Challenge and Group Project Criteria for Success at this time in order to not overwhelm students with information.
   - Take questions for clarification.
   - Optional: Show the following video to introduce students to aquaponics: https://www.youtube.com/watch?v=n-SXRtNoEkI
   - We highly recommend showing a few examples of different types of aquaponics systems so students get a general idea of what they look like. There are many examples online, but this student manual has some good diagrams on pg 10 and 12: http://northhuronag.weebly.com/uploads/1/1/2/8/11286496/aquaponics_curriculum_student_manual.unlocked.pdf. You will likely need to remind students of the structure of an aquaponics system for the first few tasks of this unit.
   - Provide students with a list of relevant materials they will have available to build, as this will impact their system design for the rest of the unit.

3. Remind students that as they go through the Project Organizer, they will be planning parts of their aquaponics system and recording information they may need for their individual project. However, there is nothing wrong with going back and changing their ideas over the course of the unit. The students won't fully design their system until the end of the unit, so change is acceptable and often experienced.

4. Make sure students fill out the Project Organizer after each task, which will help them think about the science behind their aquaponics system along the way. This process allows students to both apply and document relevant scientific concepts as they move throughout the unit. This will inform both their group and individual projects.
   - We recommend that students complete the Project Organizer individually. They might discuss ideas first as a group, but should then respond individually. This allows students time to process concepts on their own and generate their own ideas, which can be used later when it comes to developing their group project.

5. The table below summarizes how the Project Organizer guides students through developing different components of their aquaponics system and instruction manual.

Task	Project Organizer	Group and Individual Culminating Project
Lift Off Changing Rivers	• What did you see in the pictures that you might also want to include in your aquaponics system (garden and	• Aquaponics system includes essential living and non-living parts of an ecosystem

	tank)?	• Instruction manual contains a diagram that includes and labels all living and non-living parts
Task 1 Types of Changes	• Draw a before and after picture of your aquaponics system for each physical and chemical change, writing a caption explaining each. • What data explains how you know what type of change it is? • Do the changes represent a threat to your aquaponics system? If so, what are some potential solutions?	• Instruction manual identifies and explains one physical and one chemical change that occurs in the aquaponics system, using data to explain how macroscopic properties allow them to determine the type of change
Task 2 Matter Moves You	• What organisms in your aquaponics system do cellular respiration? • What molecules are used and created in this process? How will the system provide these reactants and use up these products? • Draw a model of cellular respiration.	• Aquaponics system includes an organism that does cellular respiration • Instruction manual models and explains cellular respiration, including how matter is conserved in this process
Task 3 Cycling Matter Through Living Things	• What organisms in your aquaponics system do photosynthesis? • What molecules are used and created in this process? How will the system provide these reactants and use up these products? • Draw a model of photosynthesis. • How do the plant and animal (from Task 2) work together to cycle matter and keep energy flowing through the system?	• Aquaponics system includes an organism that does photosynthesis • Instruction manual models and explains photosynthesis, including how energy drives the cycling of matter in this process
Task 4 Cycling Matter Through Rocks	• How is matter cycled in the system? • Which processes of the rock cycle might occur over time in your aquaponics system and how would this affect the system?	• Instruction manual models and describes the processes of the rock cycle that might occur in the aquaponics system over time, including why other rock cycle processes are not identified
Task 5 Design a Thermal Device	• Draw the final heat-regulation device you will use to maintain the temperature of the fish tank. • Label the materials used and explain how it works.	• Aquaponics system includes a heat-regulation device to maintain the temperature of the fish tank • Instruction manual contains a diagram that shows and explains how the heat-regulation device works, including the design process that led to the final product

6. After all the learning tasks are completed, and all sections of the Project Organizer are completed, the students can start to design their aquaponics system. The Project Organizer and Group Project Criteria for Success should be used as reference for the students to remind them of all parts to include in their system.
    - We recommend the use of group roles for Culminating Project work time (See "How to Use This Curriculum" document for details). We recommend changing the roles every workday.

7. As shown in the materials section, you have two options for completion of the Group Culminating Project.
    - Option A: Have students use the cheaper materials list to make Biobottle Aquaponics Systems in groups. Note: These may not function as well or be as long-lasting as the option below.
    - Option B: Because building aquaponics systems are material and time-intensive, we offer the option of students designing their aquaponics system as a visual poster model. All of the group posters would then be used to inform a class-wide build of one aquaponics system. After creating consensus, we recommend assigning each group part of the aquaponics system to build.
    - For more information on aquaponics systems, the following websites might be helpful:
        - https://aquaponics.com/build-a-mini-aquaponic-system/
        - http://www.homesteadandprepper.com/diy-aquaponics-projects-for-beginners/
        - https://besurvival.com/tips-and-tricks/diy-beginner-aquaponics-projects

8. Optional: If using Option A, after students have built their aquaponics systems, conduct a gallery walk so students can observe other groups' designs.
    - For a more interactive gallery walk, give each student a few post-its that they must write positive or constructive comments on to leave at various groups' tables.

9. Once the aquaponics systems are built, students are ready to move on to their individual project. Students will create an instruction manual that models and explains all the parts of their aquaponics system and meets all the criteria in the student handout.
    - We recommend providing a template to help them organize their instruction manual. This only provides them with a structure, so this should be used in conjunction with the Individual Project Criteria for Success checklist to ensure students include all parts required. An option is provided at the end of this teacher guide.

10. Conduct a peer review of the instruction manuals after students have completed a first draft.
    - Copy the Instruction Manual Peer Review Feedback form found in the Student Instructions. Another option is to use the Student 3-Dimensional Individual Project Rubric.
    - Assign each student a partner, preferably a partner from a different group.
    - Students switch drafts and assess them using the peer review feedback form.
        - Remind each student to give one positive comment and one constructive comment for each section on the checklist.
        - Allow students time to present their feedback to their partner, so their partner may ask clarifying questions if needed.

11. After receiving feedback, allow students time to complete a final draft based on the feedback they received.

7th Grade Science Unit 3: Mimicking Nature's Design

Culminating Project

Assessment

The Project Organizer can be formatively assessed using:

- *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix from the Unit Overview to inform your criteria.

The Group Culminating Project will be summatively assessed using:

- The *Group Project Criteria for Success* Checklist

The Individual Culminating Project will be summatively assessed using:

- The *3-Dimensional Individual Project Rubric*.
- Keep in mind that the Proficient level indicates that the student has successfully demonstrated understanding of the criteria. Because we are in the early stages of NGSS adoption, it may take multiple opportunities throughout the course of the year for students to reach Proficient.
- If you wish to give students a numeric score, you could take the average score of all of their rubrics or add up rubric scores to give students a summation out of the total. Because of the note above, this scoring may not correlate to traditional grading systems.
- While we recommend scoring all of the project criteria with the rubrics for each student, we understand the burden of that level of scoring.
    - One option is to select the rubrics that you wish to focus on for this project and use those to assess each student's individual project.
    - Another option is to review the Proficient level of each of the project's rubrics and use the descriptions to generally analyze all student work for trends.

Aquaponics System Instruction Manual Template

Title

Introduction to Manual

Diagram of Aquaponics System

How Aquaponics Systems Sustain Themselves	
Cellular Respiration	Photosynthesis

Possible Changes to Your Aquaponics System Over Time	
Rock Cycle	Physical and Chemical Changes

How to Regulate Temperature in Your Aquaponics System

Benefits and Limitations of an Aquaponics System

7th Grade Science Unit 3: Mimicking Nature's Design

3-Dimensional Individual Project Rubric

Overview: The following rubrics can be used to assess the individual project: the aquaponics system instruction manual. Each rubric is aligned to one section of the *Individual Project Criteria for Success*, located on the Culminating Project Student Instructions. *If student provides no assessable evidence (e.g., "I don't know" or leaves answer blank), then that student response cannot be evaluated using the rubric and should be scored as a zero.

Below we provide an alignment table that details the dimensions assessed for each criterion.

	Student Criteria for Success	Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
1	❒ Identify at least one organism that does cellular respiration in your aquaponics system ○ Model and describe the process of cellular respiration (using pictures, labels, arrows, and captions)	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • 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, and to release energy. **PS3.D: Energy in Chemical Processes and Everyday Life** • 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 (*secondary*).	**N/A**
2	○ In your model, make sure to show and explain how matter is conserved in this chemical reaction	**N/A**	**PS1.B: Chemical Reactions** • 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 than those of the reactants. • The total number of each type of atom is conserved, and thus the mass does not change.	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes.

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3	❒ Identify at least one organism that does photosynthesis in your aquaponics system ○ Model and explain the process of photosynthesis (using pictures, labels, arrows, and captions) ○ In your model, make sure to show all forms of energy and matter involved ○ Cite evidence from Task 3 to support your explanation	**Constructing Explanations** • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • 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. **PS3.D: Energy in Chemical Processes and Everyday Life** • The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (ie. from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen (*secondary*).	**Energy and Matter** • Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
4	❒ Model and describe which processes of the rock cycle might occur in your aquaponics system over time ○ Identify the flow of energy that drives the processes you identify	**Developing and Using Models** • Develop and use a model to describe phenomena.	**ESS2.A: Earth's Materials and Systems** • 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.	**N/A**
5	○ Explain why some of the rock cycle processes you explored in Task 4 will not occur in your aquaponics system and are not seen in short time periods	**N/A**	**ESS2.A: Earth's Materials and Systems** • 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	**Stability and Change** • Explanations of stability and change in natural and designed systems can be constructed by examining the changes over time and

			energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.	processes at different scales, including the atomic scale.
6	❒ Identify and explain one physical and one chemical change that will occur in your aquaponics system ○ Use data from Task 1 to explain how looking at macroscopic properties of matter can help you determine whether physical or chemical changes are happening at the microscopic level	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings.	**PS1.A: Structure and Properties of Matter** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **PS1.B: Chemical Reactions** • 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 than those of the reactants.	**Patterns** • Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
7	❒ Draw a diagram of the heat-regulation device you designed and explain how it will work in your aquaponics system ○ Describe the design process that led you to your final product	**Designing Solutions** • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific criteria and constraints.	**PS1.B: Chemical Reactions** • Some chemical reactions release energy, others store energy.	**Energy and Matter** • The transfer of energy can be tracked as energy flows through a designed or natural system.

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3-Dimensional Individual Project Rubric

Rubric 1: Student develops a model to describe the process of cellular respiration that occurs within an animal in their aquaponics system, including all matter and energy involved.

- Dimensions Assessed: SEP – Developing and Using Models, DCIs – LS1.C: Organization for Matter and Energy Flow in Organisms and PS3.D: Energy in Chemical Processes and Everyday Life

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student develops an **incomplete** model to describe the process of cellular respiration that occurs within an animal in their aquaponics system. OR Student develops **a partial written explanation** to describe the process of cellular respiration that occurs within an animal in their aquaponics system.	Student develops a **partial** model to describe the process of cellular respiration that occurs within an animal in their aquaponics system. OR Student develops **a complete written explanation** to describe the process of cellular respiration that occurs within an animal in their aquaponics system, including all matter and energy involved.	Student develops a **complete** model to describe the process of cellular respiration that occurs within an animal in their aquaponics system, including all matter and energy involved.	Student develops a **complete** model to describe **in detail** the process of cellular respiration that occurs within an animal in their aquaponics system, including all matter and energy involved.
Look Fors: • Student's model consists of pictures and labels that show limited components of cellular respiration (ie. only the transformation from food to energy is modeled). Thus any arrows and captions only offer an incomplete explanation of cellular respiration. OR • Student writes an explanation that partially describes cellular respiration, but no model is present.	**Look Fors:** • Student's model consists of pictures and labels that show some components of cellular respiration (ie. the energy component is missing). Thus any arrows and captions only partially explain cellular respiration. OR • Student writes an explanation that completely describes cellular respiration (See Advanced Look-Fors), but no model is present.	**Look Fors:** • Student's model consists of pictures and labels that show all components of cellular respiration (ie. animal, oxygen, glucose or food, water, carbon dioxide, and ATP or energy). • The model has arrows that show all interactions, but captions are limited to explain these interactions. For example, arrows show: glucose and oxygen entering the animal, releasing energy and creating carbon dioxide and water as byproducts.	**Look Fors:** • Student's model consists of pictures and labels that show all components of cellular respiration (ie. animal, oxygen, glucose or food, water, carbon dioxide, and ATP or energy). • The model has captions and arrows that show and explain all interactions. For example, arrows and captions show: glucose and oxygen enter the animal, bonds are broken and energy is released, and carbon dioxide and water are created as byproducts.

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3-Dimensional Individual Project Rubric

Rubric 2: Student describes that matter is conserved, specifically within the context of the cellular respiration chemical reaction.

- Dimensions Assessed: DCIs – LS1.C: Organization for Matter and Energy Flow in Organisms and PS3.D: Energy in Chemical Processes and Everyday Life, CCC – Energy and Matter

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student uses a model to describe that matter is **not** conserved within the context of the cellular respiration chemical reaction.	Student **explicitly** describes that matter is conserved, **but not** specifically within the context of the cellular respiration chemical reaction.	Student **implicitly** describes that matter is conserved, specifically **within the context** of the cellular respiration chemical reaction.	Student **explicitly** describes that matter is conserved, specifically **within the context** of the cellular respiration chemical reaction.
Look Fors: • Student inaccurately describes that matter is not conserved in cellular respiration.	**Look Fors:** • Student explicitly states that matter is conserved in cellular respiration, but does not explain how they know.	**Look Fors:** • Student uses their model to implicitly show how matter is conserved in cellular respiration. For example, student may show the number of each type of atom in the reactants and products, but does not explicitly compare the two or state that matter is conserved.	**Look Fors:** • Student uses their model to explicitly show how matter is conserved in cellular respiration. For example, student may show that the number of each type of atom in the reactants and products is equal. Then the student compares the reactants and products and discusses how atoms in the reactants were rearranged into the products, and thus matter is conserved.

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3-Dimensional Individual Project Rubric

Rubric 3: Student describes photosynthesis, explaining how energy drives the cycling of matter and supporting the explanation with evidence from the tasks.

- Dimensions Assessed: SEP – Constructing Explanations, DCIs – LS1.C: Organization for Matter and Energy Flow in Organisms and PS3.D: Energy in Chemical Processes and Everyday Life, CCC – Energy and Matter

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student **partially** describes photosynthesis, but **does not** support the explanation with evidence from the tasks.	Student **partially** describes photosynthesis, supporting the explanation with evidence from the tasks.	Student **completely** describes photosynthesis, **implicitly** explaining how energy drives the cycling of matter and supporting the explanation with evidence from the tasks.	Student **completely** describes photosynthesis, **explicitly** explaining how energy drives the cycling of matter and supporting the explanation with evidence from the tasks.
Look Fors: • Student's explanation of photosynthesis is partial, describing some components and interactions. For example, student discusses how sunlight is used to create glucose in plants. This response omits many components of the photosynthesis reaction. • Student does not support this explanation with evidence from the Task 3 lab.	**Look Fors:** • Student's explanation of photosynthesis is partial, describing some components and interactions. For example, student discusses how carbon dioxide and water are used to create glucose and oxygen. In this response, student doesn't discuss how energy drives the cycling of matter. • Student supports this explanation with evidence from the Task 3 lab. For example, student discusses how in the experiment, there was evidence of photosynthesis because the water turned blue, meaning the plant took in some carbon dioxide to do photosynthesis.	**Look Fors:** • Student's explanation of photosynthesis is complete, describing all components and interactions. For example, student discusses how carbon dioxide, water, and sunlight are used to create glucose and oxygen. While implicit, student doesn't explicitly discuss how the Sun's energy drives the cycling of matter. • Student supports this explanation with evidence from the Task 3 lab. For example, student discusses how in the experiment, there was evidence of photosynthesis because the water turned blue, meaning the plant took in some carbon dioxide to do photosynthesis.	**Look Fors:** • Student's explanation of photosynthesis is complete, describing all components and interactions, including how energy drives the cycling of matter. For example, student discusses how plants combine carbon dioxide and water to create glucose and oxygen. This process is only possible with the presence of sunlight to provide energy to break the bonds. • Student supports this explanation with evidence from the Task 3 lab. For example, student discusses how in the experiment, only the Elodea in the light did photosynthesis. They know this because the water turned blue, meaning the plant took in some carbon dioxide to do photosynthesis.

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3-Dimensional Individual Project Rubric

Rubric 4: Student develops a model to show the cycling of Earth's materials in the aquaponics system and describes the flow of energy that drives this process.

- Dimensions Assessed: SEP – Developing and Using Models, DCI – ESS2.A Earth's Materials and Systems

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student develops a **partial** model to show the cycling of Earth's materials in the aquaponics system with no descriptions.	Student develops a **partial** model to show the cycling of Earth's materials in the aquaponics system and **partially** describes the flow of energy that drives this process.	Student develops an **accurate** model to show the cycling of Earth's materials in the aquaponics system and **partially** describes the flow of energy that drives this process.	Student develops an **accurate** model to show the cycling of Earth's materials in the aquaponics system and **completely** describes the flow of energy that drives this process.
Look Fors: ● Student model depicts either sedimentation or weathering/erosion, but not both processes. For an aquaponics system, this could mean showing soil erosion or a buildup of sediments over time. No descriptions about flow of energy are present.	**Look Fors:** ● Student model depicts and explains either sedimentation or weathering/erosion, but not both processes. For an aquaponics system, this could mean showing soil weathering/erosion or a buildup of sediments over time. Description partially describes the flow of energy with one or more components. For example, a response like "Wind and rain causes weathering," skips the fact that the energy from the sun causes wind and rain, which result in weathering.	**Look Fors:** ● Student model depicts and explains both sedimentation and weathering/erosion. For an aquaponics system, this could mean showing soil weathering/erosion and a buildup of sediments over time. Description partially describes the flow of energy with one or more components. For example, a response like "Energy from the sun causes wind and rain, which result in weathering and erosion" does not include the process of sedimentation.	**Look Fors:** ● Student model depicts and explains both sedimentation and weathering. For an aquaponics system, this could mean showing soil weathering/erosion and a buildup of sediments over time. Description completely describes the flow of energy for the processes identified. For example, a response like "Energy from the sun causes wind and rain, which result in weathering. This also erodes rock and deposits it other places, and the pressure of gravity eventually leads to sedimentation. "

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3-Dimensional Individual Project Rubric

Rubric 5: Student explains why some rock cycle processes will not occur in their aquaponics system by examining each process at different time scales.

- Dimensions Assessed: DCI – ESS2.A Earth's Materials and Systems, CCC – Stability and Change

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student **inaccurately** explains why some rock cycle processes will not occur in their aquaponics system.	Student explains why some rock cycle processes will not occur in their aquaponics system **but does not** examine each process at different time scales.	Student **partially** explains why some rock cycle processes will not occur in their aquaponics system by examining each process at different time scales.	Student **completely** explains why some rock cycle processes will not occur in their aquaponics system by examining each process at different time scales.
Look Fors: • Student inaccurately explains that weathering/erosion will not happen in their aquaponics system because there is no wind.	**Look Fors:** • Student explains that crystallization and/or deformation will not happen in their aquaponics system because there is no geothermal energy input. Student does not specifically reference time scales in their explanation.	**Look Fors:** • Student explains that crystallization or deformation (instead of both) will not happen in their aquaponics system because there is no geothermal energy input. They also specifically reference time scales by explaining that this process also takes a very long time, so they wouldn't be visible over our lifetime anyways.	**Look Fors:** • Student explains that crystallization and deformation will not happen in their aquaponics system because there is no geothermal energy input. They also specifically reference time scales by explaining that these two processes also take a very long time, so they wouldn't be visible over our lifetime anyways.

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3-Dimensional Individual Project Rubric

Rubric 6: Student identifies a physical and chemical change that occurs in their aquaponics system, supporting identifications with an explanation of how macroscopic patterns allow them to determine the microscopic structure for each change.

- Dimensions Assessed: SEP – Analyzing and Interpreting Data, DCIs – PS1.A Structures and Properties of Matter and PS1.B Chemical Reactions, CCC – Patterns

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student identifies **at least one accurate** physical and/or chemical change that occurs in their aquaponics system, **with no explanation**.	Student identifies **at least one accurate** physical and/or chemical change that occurs in their aquaponics system, supporting identifications with an explanation of macroscopic patterns **OR** microscopic patterns.	Student **accurately** identifies a physical and chemical change that occurs in their aquaponics system, supporting identifications with an **implicit** explanation of how macroscopic patterns allow them to determine the microscopic structure for each change.	Student **accurately** identifies a physical and chemical change that occurs in their aquaponics system, supporting identifications with an **explicit** explanation of how macroscopic patterns allow them to determine the microscopic structure for each change.
Look Fors: • Student accurately identifies at least one physical and chemical change in their aquaponics system. For example, photosynthesis is a chemical change and evaporating water is a physical change. • No supporting explanation is provided.	**Look Fors:** • Student accurately identifies at least one physical and chemical change in their aquaponics system. For example, photosynthesis is a chemical change and evaporating water is a physical change. • Student supports the identifications with macroscopic OR microscopic patterns, but not both. For example, the properties of reactants and products are different for photosynthesis and the same for evaporating water. This means photosynthesis is a chemical change and evaporating water is a physical change.	**Look-Fors** • Student accurately identifies a physical and chemical change in their aquaponics system. For example, photosynthesis is a chemical change and evaporating water is a physical change. • Student supports the identifications with macroscopic and microscopic patterns, but does not explicitly connect the two. For example, the properties of reactants and products are different for photosynthesis and the same for evaporating water. The reactants and products for photosynthesis are also different, but the same for evaporating. This means photosynthesis is a chemical change and evaporating water is a physical change.	**Look Fors:** • Student accurately identifies a physical and chemical change in their aquaponics system. For example, photosynthesis is a chemical change and evaporating water is a physical change. • Student supports the identifications with macroscopic and microscopic patterns, explicitly connecting the two. For example, the properties of reactants and products are different for photosynthesis, which shows us that the molecules are different and that it is a chemical change. Meanwhile, the properties of reactants and products are the same for evaporating water, which shows us the molecules are the same and that it is a physical change.

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Rubric 7: Student shows and explains how their design uses a chemical reaction to release heat and describes their design process.

- Dimensions Assessed: SEP –Designing Solutions, DCI – PS1.B Chemical Reactions, CCC – Energy and Matter

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student **partially** shows and explains how their design uses a chemical reaction to release heat and **partially** describes their design process. OR Student **accurately** shows and explains how their design uses a chemical reaction to release heat and **does not** describe their design process.	Student **accurately** shows and explains how their design uses a chemical reaction to release heat and **partially** describes their design process.	Student **accurately** shows and explains how their design uses a chemical reaction to release heat and **mostly** describes their design process.	Student **accurately** shows and explains how their design uses a chemical reaction to release heat and **completely** describes their design process.
Look Fors: ● Student's diagram partially shows a device that uses a chemical reaction to release heat. Labels and/or captions to describe how the device works may be missing information; for example, the specific chemical reaction that releases heat. Student describes their design process, but it is very limited. OR ● Student's diagram accurately shows a device that uses a chemical reaction to release heat. Labels and/or captions describe how the device works, including the chemical reaction that releases heat. No description of design process is present.	**Look Fors:** ● Student's diagram accurately shows a device that uses a chemical reaction to release heat. Labels and/or captions describe how the device works, including the chemical reaction that releases heat. ● Student describes their design process, but it is very limited. For example, student only discusses testing their device and making modifications.	**Look Fors:** ● Student's diagram accurately shows a device that uses a chemical reaction to release heat. Labels and/or captions describe how the device works, including the chemical reaction that releases heat. ● Student describes their design process, including most of the following: identifying criteria/constraints, developing models, testing, modifying with others' ideas, and final testing. For example, they leave out identifying criteria/constraints.	**Look Fors:** ● Student's diagram accurately shows a device that uses a chemical reaction to release heat. Labels and/or captions describe how the device works, including the chemical reaction that releases heat. ● Student describes their design process, including all of the following: identifying criteria/constraints, developing models, testing, modifying with others' ideas, and final testing.

Additional Notes:

- The first and last bullet points of the Individual Project Criteria for Success does not have rubrics as they are merely meant for students to tie together pieces of their project.
- Two additional rubrics are provided in Task 5 to assess the Engineering and Design Performance Expectations (MS-ETS1-3 and MS-ETS1-4); these PEs are not assessed explicitly in this Culminating Project.

7th Grade Science Unit 3: Mimicking Nature's Design

Project Organizer

Unit Essential Question: *How does energy and matter flow within natural and designed ecosystems?*

You will be creating a sustainable aquaponics system that mimics the properties of a river environment. After each task, you will return to the table below to organize what you learn as you go through the unit. By the end of the five tasks, you will have all this information to use for your culminating project. For each activity, be sure to include answers to **ALL** the questions provided.

Lift-Off Task: Changing Rivers	What did you see in the pictures that you might also want to include in your aquaponics system (garden and tank)?

7th Grade Science Unit 3: Mimicking Nature's Design
Project Organizer

Task 1: Types of Changes	Now that you understand physical and chemical changes on the molecular level, identify one physical change and one chemical change that you anticipate may occur in your aquaponics system. ❒ Draw a before and after picture of your aquaponics system for each change and write a caption explaining each. ○ Use data from this task, or research the properties of your own environmental change, to explain how you know what type of change it is. ❒ For each change, decide if it represents a threat to your aquaponics system. If it is a threat, describe a potential solution to prevent it.

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Project Organizer

Task 2: Matter Moves You	Identify or add an organism to your aquaponics system that does cellular respiration. ❒ Identify what molecules the organism requires for cellular respiration. How will your system provide these molecules? ❒ Identify what molecules the organism will create through this process. How will your system use up the products that it creates? ❒ Draw a picture of your organism and the molecules identified. Use arrows to show which molecules enter or leave the organism.
Task 3: Cycling Matter Through Living Things	Identify or add an organism to your aquaponics system that does photosynthesis. ❒ Identify what molecules it will need to have in order to do photosynthesis. How will your system provide what the organism needs? ❒ Identify what molecules it will create through this process. How will the system use up the products that it creates? ❒ Draw a picture of your organism and the molecules identified, using arrows to show whether the molecules enter or leave the organism. ❒ Make connections to the organism you chose after Task 2: How do the plant and animal work together to cycle matter and keep energy flowing through the system?

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Project Organizer

Task 4: Cycling Matter Through Rocks	Look back at the design sketch for your aquaponics system from Task 1: ❒ How might cycling of matter come into play in your aquaponics system? ❒ Describe which process(es) of the rock cycle might occur in your aquaponics system over time. ❒ What will the effects be on your system?
Task 5: Design a Thermal Device	Now that you have designed a heat-regulation device to help maintain river water temperature, you can use this knowledge to design your own heat-regulation devices that will work to maintain the temperature of your aquaponics fish tank. ❒ Draw the final heat-regulation device. ○ Label the materials used and explain how it works. ❒ Describe how you combined best characteristics of different designs to create a device that best meets the criteria and constraints. ○ Cite the data that supported your decisions.

7th Grade Science Unit 3: Mimicking Nature's Design
Lift-Off Task: Changing Rivers

<u>Unit Essential Question</u>: *How does energy and matter flow within natural and designed ecosystems?*

Introduction

Every environment is made up of many different living and nonliving components, all of which play a very important role in the functioning of an ecosystem as a whole. Because environments share common characteristics and interactions, we can learn from one environment to teach us about how other environments might work. In this Lift-Off Task, students are introduced to a changing river environment, shown in an image from 200 years ago as well as an image from the present. After making their own observations, they are asked to generate a list of questions they would ask in order to learn more about how and why this river environment has changed over time. Students will return to this phenomenon and these questions throughout the unit as they seek to form a more cohesive understanding of how ecosystems function. This will help inform their culminating project—to build an aquaponics system that mimics the properties of an environment, like this changing river.

Alignment Table

Because the Lift-Off tasks focus on student-generated questions, we do not identify specific Disciplinary Core Ideas or Science and Engineering Practices in this table.

Crosscutting Concepts (*depending upon student-generated questions)
• Patterns
  ○ Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
• Energy and Matter
  ○ Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
  ○ Matter is conserved because atoms are conserved in physical and chemical processes.
  ○ The transfer of energy can be tracked as energy flows through a designed or natural system.
• Stability and Change
  ○ Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.

Equity and Groupwork • Share and listen to broad and diverse student contributions. • Make connections between each other's ideas. • Work together to co-construct a concept map.
Language • Use connector words to link ideas. • Generate and write questions about the phenomenon. • Organize key questions in a concept map.

Learning Goals

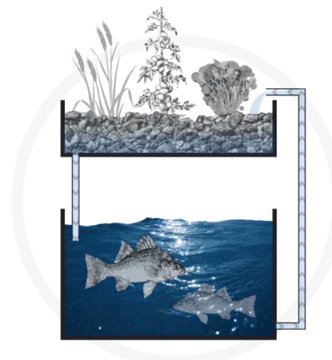
This learning task introduces students to the phenomenon of the changing river environment and asks them to begin generating questions that will guide them through the unit. More specifically, the purpose is to:

- Individually analyze past and present images of a river environment and generate a list of questions.
- Make connections between related questions.
- Generate possible answers to questions, using prior knowledge.

- Apply prior knowledge of ecosystems and observations from images to make a list of what they might want to include in their aquaponics system.

Content Background for Teachers

Every environment is made up of an abundance of living and nonliving things. Nonliving things include things like sunlight, temperature, soil, water, rocks, and air. Living things include plants, animals, fungus, and bacteria. All of this matter is constantly cycling, as energy flows between living and non-living things, allowing the environment to function properly. This is the premise for an aquaponics system, as shown to the right.



In this task, students engage their prior knowledge of environmental factors as they analyze pictures of a river environment. While identifying differences between the past and present river environment may be easy, the reasons for the differences may be new for students. As students identify differences they see in the river environment photos, they are beginning their exploration of deeper chemical and physical processes that they will learn more about in later tasks. For example, they may notice changes in the size of rocks, the size of the river, the size of living things like trees, or the presence/absence of living things like deer. These are all the result of various processes, such as growth due to photosynthesis, erosion, feeding, decomposition, etc. This will be essential knowledge to apply as they design their aquaponics system throughout the unit.

In this task, students create a concept map, which is a graphical tool that helps to organize and represent knowledge and questions, and is a successful academic language instruction tool. As students learn more about the reasons behind these environmental changes, they will add more questions and ideas to this concept map. If your students have not had previous experience making concept maps, please see the instructions in Part B below for strategies on teaching this skill.

Academic Vocabulary

- Environment
- Ecosystem
- Artificial
- Aquaponics System
- Sustainable
- Energy
- Matter
- Flow
- Cycle
- Properties

*Additional academic vocabulary will vary by class

7th Grade Science Unit 3: Mimicking Nature's Design
Lift-Off Task: Changing Rivers

Time Needed (Based on 45-Minute Periods)
2 Days
- Introduction, Part A and Part B: 1 period
- Class Concept Map, Project Overview, and Project Organizer: 1 period

Materials
- Unit 3, Lift-Off Task Student Version
- Optional: Projector to project River Environment Images or printed sets of River Environment Images for each student

Part B
- Poster paper and markers
- Post-Its (Optional)

Part C
- Class Poster Paper and markers
- *See Instructions below for other optional materials to use for the class concept map

Connecting to the Culminating Project
- Culminating Project Handout
- Project Organizer Handout

Instructions
1. Introduce students to the unit by reading or projecting the Unit Essential Question aloud.

2. Read the introduction on page 1 of the student guide aloud, which introduces the phenomenon for the unit: the changing river environment. Then have students analyze the past and present images of the river environment and make observations of what they notice.
   - You may want to project the images as a class or provide each student an enlarged set of the images to keep as a reference throughout the unit.

Part A
1. In this Lift-Off task, students will be generating questions to help them make sense of the phenomenon.

2. Have students complete this section individually in their student guide.
   - For students who need more support, encourage them to look at specific places where the images look different and consider any questions they have.
   - Here is a list of some potential questions students might generate: "What is different between the two environments? What other differences are there that I can't see in the picture? What is the climate in the region? What kinds of plants and animals live there? Why is there a deer in the first photo but not the second? Why are there birds in one photo but not the other? What happened to the tree? Why do plants seem to move? Why do the sizes of things seem to change (plants, animals, river, rocks)?"

Part B:
1. In this part of the task, students create a concept map as a group.

- Remind students to refer to the directions on their student guide to help them make their concept map. First, students should compare each member's list of questions and record/connect key questions on a piece of poster paper. They will then draft possible answers to the questions, using prior knowledge.
- Remind students that there are no right or wrong questions or predictions, so students feel encouraged to contribute any and all questions and ideas they think of.
- Because this is a collaborative task, it is recommended that you remind students of group work norms and assign group roles, such as Resource Manager, Facilitator, Recorder, and Harmonizer (See "How to Use this Curriculum" for more details).

2. Students will post their posters on a wall and then walk around and look at each group's ideas. One suggestion for gallery walks is for students to interact with the posters in some way. For example, students are required to initial or leave post-its on three questions that they are also excited about on other posters.

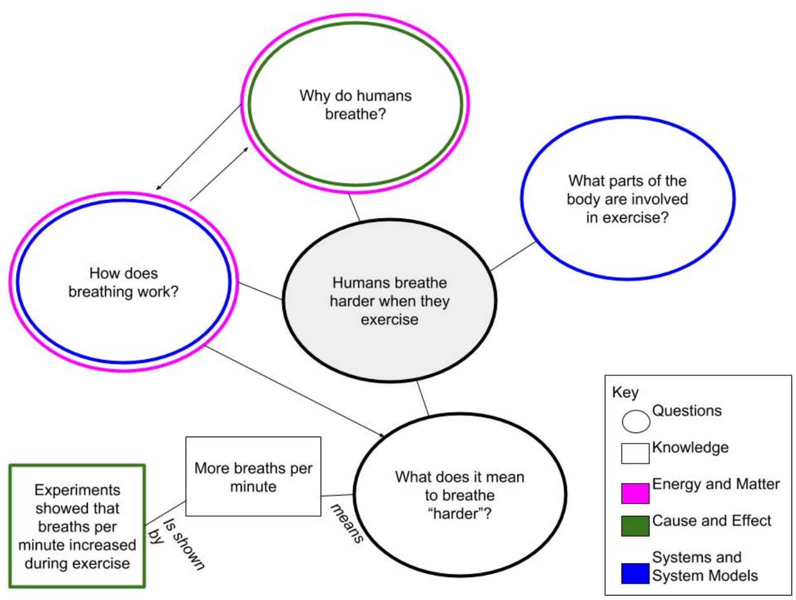
How to Concept Map

For students who have not had a lot of experience making concept maps, we have detailed a strategy below for introducing concept mapping using more familiar content. An example is also provided, but this will vary depending on what your students come up with as you make your own model.

1. Write the phenomenon in the middle of the poster, in this case "Humans breathe harder when they exercise."

2. Ask students to share questions they might ask to make sense of this phenomenon and make a list of these questions on the board.

3. Model the process of reviewing the list and finding similarities amongst the questions.
    - Place these key questions on the concept map poster, modeling how to put similar questions near each other on the poster. Circle these to signify that these are questions, not content knowledge.



4. Ask students to look at the key questions and see if any of the questions are connected: Would answering one question lead to one of the other questions? Model making these connections by drawing arrows

between the circles.

5. In this Lift-Off task, students will only be drafting possible answers to the questions, not actually gathering and recording learned concepts. However, throughout the unit, they will be adding content they have learned. Model this by recording a student's prior knowledge to one of the questions, using boxes to signify that these are pieces of content knowledge rather than questions.
    - Use connector words to identify the relationships between the content boxes (See image above for an example).

6. Optional: To emphasize crosscutting concepts using a concept map, make a key of different colors for the crosscutting concepts emphasized in this unit. Identify questions that clearly show evidence of the different crosscutting concepts and circle them with the corresponding colors. Explain to students how you made that choice by pointing out the language that hints at that crosscutting concept. *Note: not all boxes and circles will necessarily have a crosscutting concept.

Part C

1. Construct a whole-class concept map that begins to help students make sense of the phenomenon of the changing river environment.
    - Start with the phenomenon in the middle.
    - Then ask students to share out the questions that were most common across all the posters in the classroom. As you record questions on the poster, organize them based on connections you see. Draw circles around each question (as you add to the concept map throughout the unit, you'll also be adding concepts learned, which can be written in boxes to distinguish them from the questions).
    - Ask students to identify any connections they see between the questions and record these as lines between the questions.
        - Recommended: Give pairs of students think time to come up with 1-2 connections to add to the class concept map and call on pairs using equity sticks. This encourages more equitable participation in this class-wide activity.
    - The purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.
    - This whole class concept map will be revisited at the end of each subunit, asking students questions like: Are there any new questions you have about the phenomenon? Are there any connections you want to add or change? What is your reason for that addition/revision? Are there more connections we can make between the questions/ideas already on the map? Do you want to add any new ideas/concepts to the map?

2. Because this concept map will be added to and revised throughout the unit, here are some practical options for implementation.

- If you have access to white board paper, we encourage you to use these for class posters since it will allow you and your students to make revisions throughout the unit.
- Another option is to use smaller pieces of paper for each class and project using a document camera; this will save space as opposed to doing large class posters.
- We highly recommend students keep their own version of this concept map in their notebooks, adding questions and concepts as they go through the unit.

3. Once the draft concept map is complete, introduce students to the crosscutting concepts for this unit. We recommend posting posters of each crosscutting concept in your classroom (See beginning of teacher guide for templates).
   - The crosscutting concepts for this unit are: Patterns; Energy and Matter; and Stability and Change. Assign a color for each crosscutting concept that can be used throughout the unit.
   - Have students analyze the class concept map for as many examples of the crosscutting concepts as they can find. Depending on the questions they have, they may be able to find an example of each of the crosscutting concepts or perhaps just some.
   - We recommend modeling this process by picking a question, identifying the crosscutting concept, and tracing the circle in the corresponding color. Explain the key words that helped you identify the crosscutting concept in this question. Some identifying words that students might look for are:
     - **Patterns**: These could be phrases such as, "is the same as", "has in common with", "is similar to", "shares" etc.
     - **Energy and Matter**: These could be phrases such as, "energy is transferred/flows," "is conserved," "is important for," "is needed," etc.
     - **Stability and Change**: These could be phrases such as, "remains the same", "is changed by", "is disrupted by", "changes", "disrupts," etc.

Connecting to the Culminating Project

1. Hand out the Culminating Project Task Card and read the Challenge and Group Project Criteria for Success aloud as a class.
   - Take questions for clarification.

2. Optional: Display some examples of what real aquaponics systems look like.

3. Pass out their Project Organizer and explain that they will complete a section of this after each task in class. Students should independently complete the Lift-Off Task section of the Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.
   - Students have been tasked with creating a sustainable aquaponics system that mimics the properties of the river environment they saw in this task. Their prompt is as follows: What did you see in the pictures that you might also want to include in your aquaponics system?

Reflection

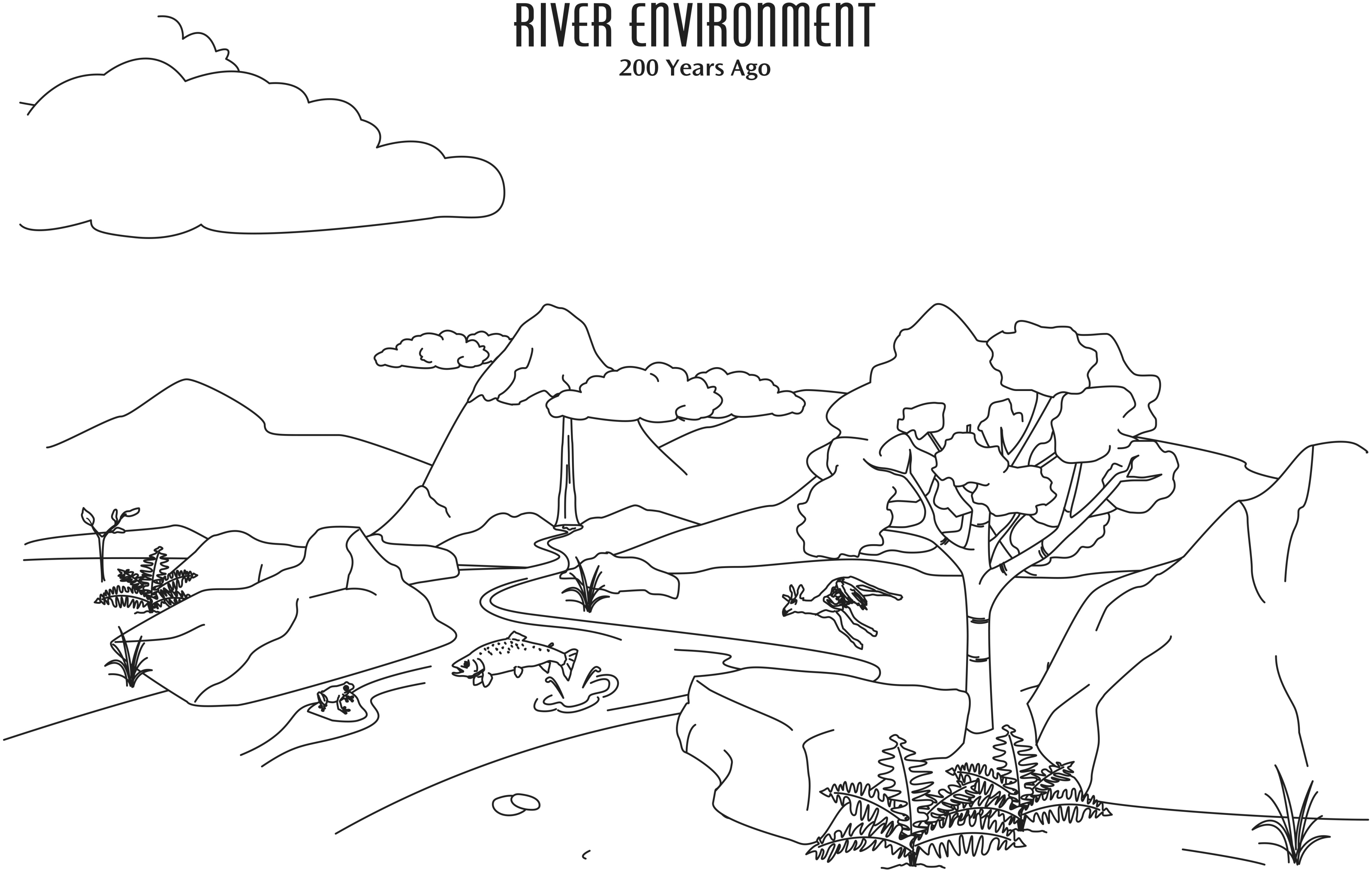
1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:

- At the beginning of this task, you made a list of all the questions you have about the river environment in the past vs. the present. Look back at your list: think about the questions your peers asked that you did not initially write down. How are their questions different from the ones you originally asked?
- In this unit, we will be focusing on three crosscutting concepts: **Patterns**: Macroscopic patterns are related to microscopic structure; **Energy and Matter**: The transfer of energy can be tracked as it flows through a system, is conserved, and drives the cycling of matter; and **Stability and Change**: Stability and change can be explained by looking at changes over time and at different scales. Looking at your class concept map, give one example of how a crosscutting concept came up in today's task.
- Now that you understand what project you'll be working on over the course of this unit, what else do you need to know? What additional questions do you have?

2. There are no right answers, but encourage students to look back at their initial list of questions and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their questions and ideas based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and the gathering of knowledge and skills for their final project.

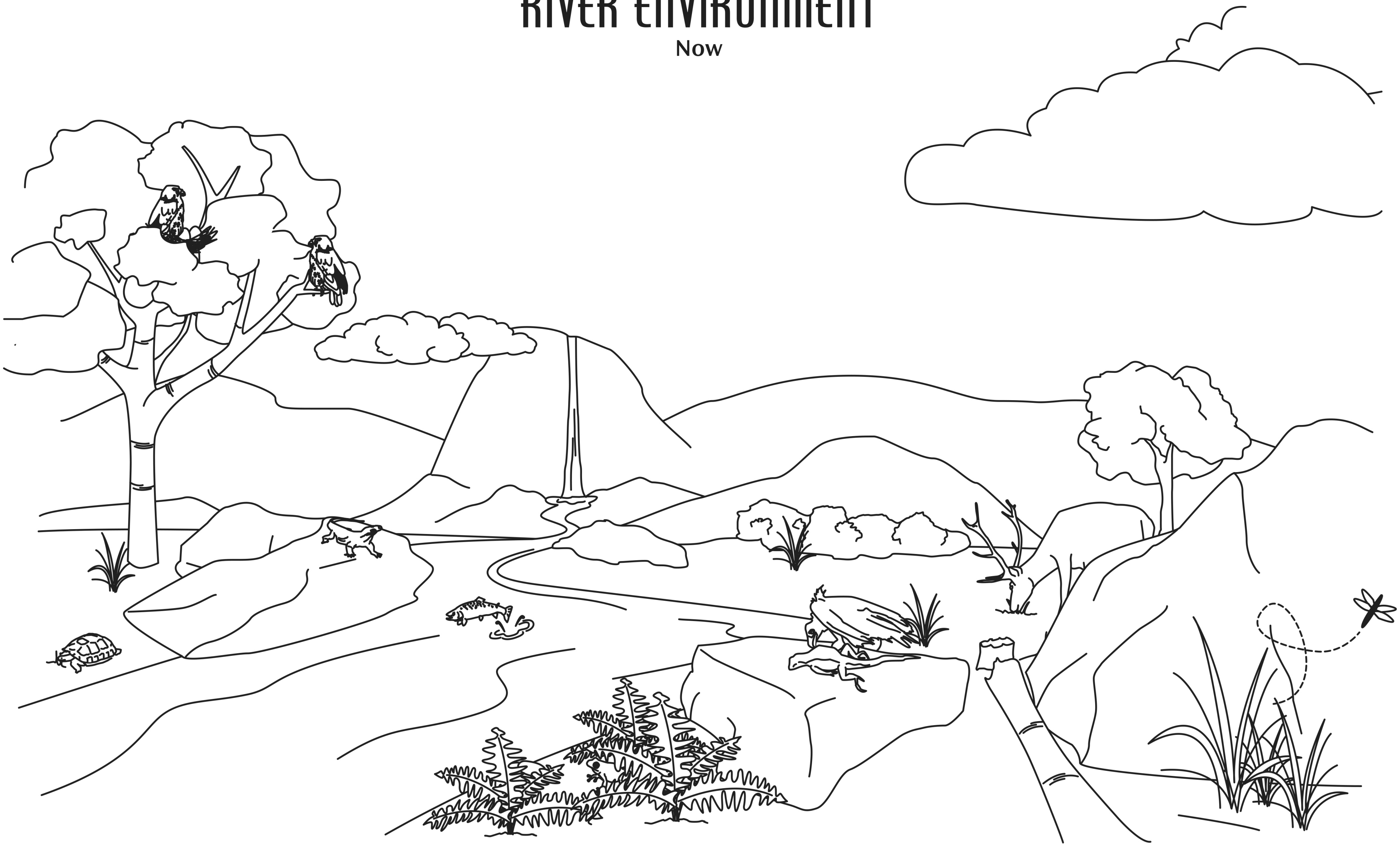
RIVER ENVIRONMENT

200 Years Ago



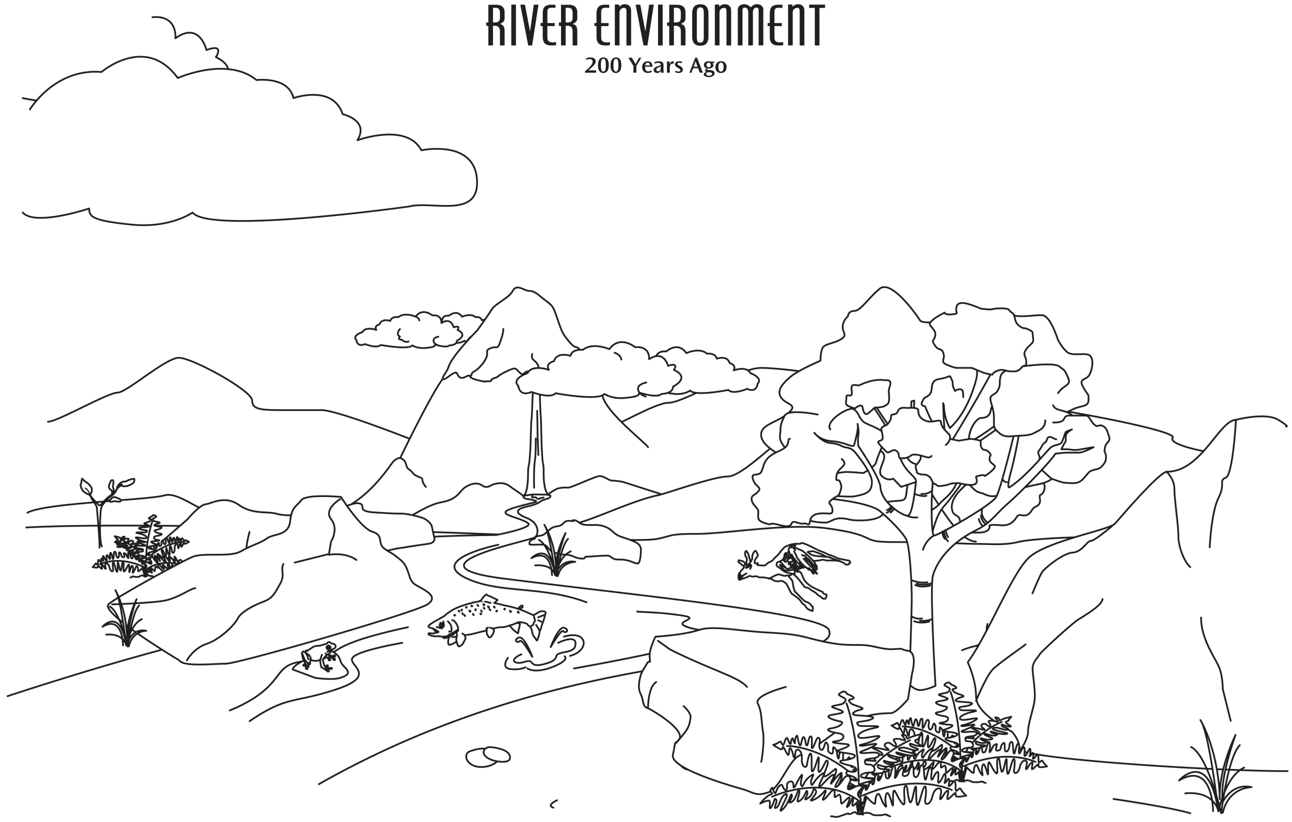
RIVER ENVIRONMENT

Now



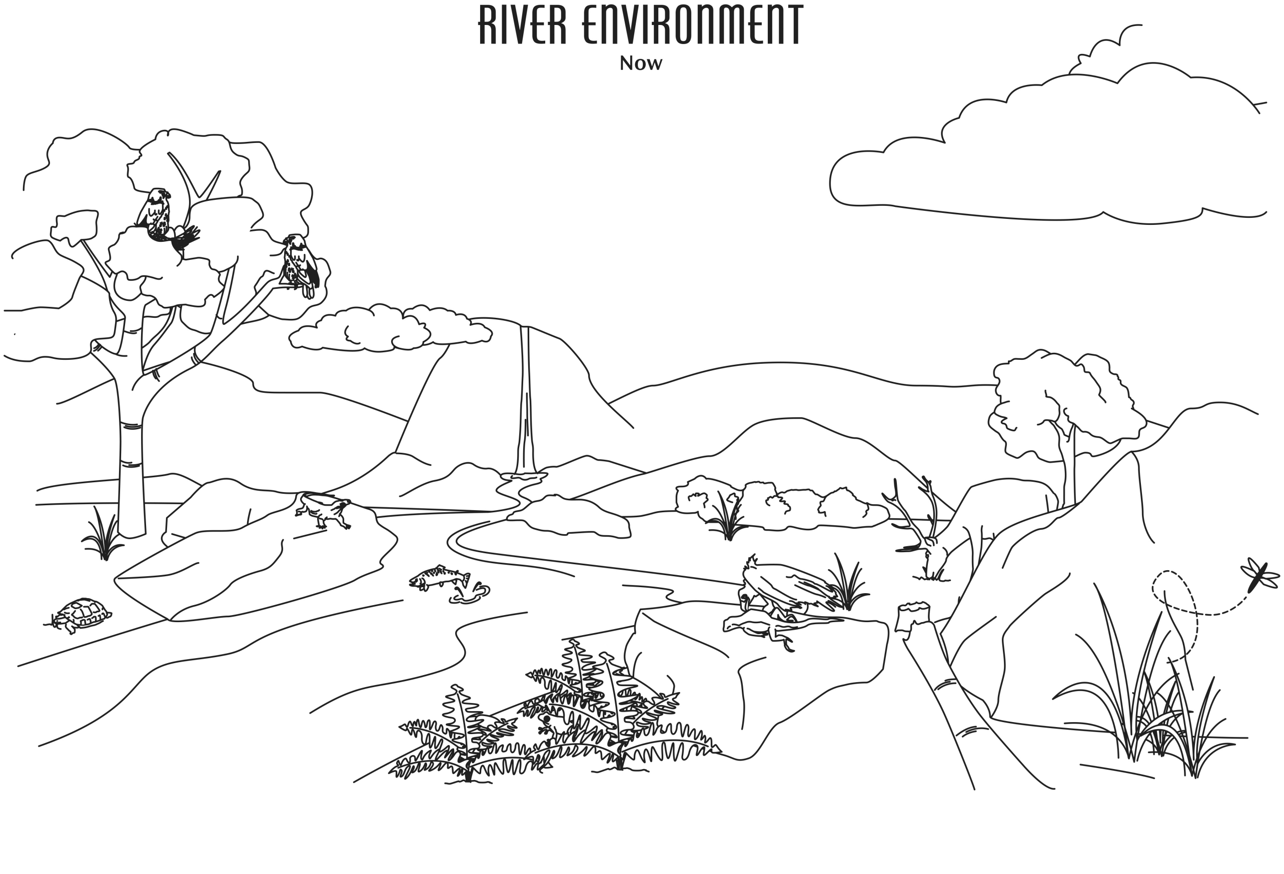
RIVER ENVIRONMENT

200 Years Ago



RIVER ENVIRONMENT

Now



7th Grade Science Unit 3: Mimicking Nature's Design
Task 1: Types of Changes

Unit Essential Question: *How does energy and matter flow within natural and designed ecosystems?*

Introduction

In the Lift-Off Task, students were introduced to environmental changes within the context of a river environment. As they noticed changes that occurred over hundreds of years, they were implicitly beginning to think about the chemical and physical processes involved in environmental change. In this task, students dig into the science behind some of these changes by learning about both physical and chemical changes. They learn that not all changes are the same; in some, the substances remain constant while in others, the substances change entirely. Through data analysis, they will find that looking at the properties of substances before and after the change is key to determining what type of change it is. By the end of this task, students will be able to use their scientific understanding of physical and chemical changes to help them explain real phenomena in river environments, thus paving the way to apply this knowledge in a designed setting, like their aquaponics system.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [Assessment Boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.]	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings.	**PS1.A: Structure and Properties of Matter** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **PS1.B: Chemical Reactions** • 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.	**Patterns** • Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

7th Grade Science Unit 3: Mimicking Nature's Design
Task 1: Types of Changes

Equity and Groupwork
• Work within group roles to successfully analyze data.
Language
• Use models to construct own definitions of physical and chemical changes. • Write conclusions based on data analysis.

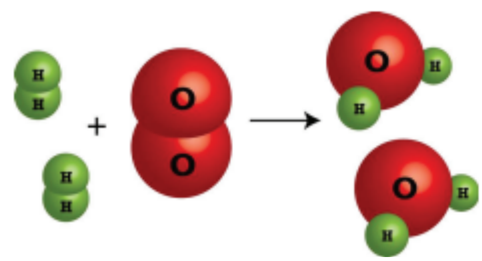
Learning Goals

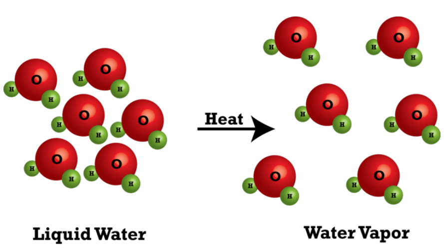
This learning task asks students to observe the differences between a physical and chemical change. More specifically, the purpose is to:

- Use prior knowledge to group types of environmental changes in the river environment.
- Explore data on the properties of substances before and after an environmental change.
- Use models to help identify the above environmental changes as physical or chemical.
- Apply understandings to a process involved in decomposition.
- Apply knowledge of physical and chemical changes to an aquaponics system design.

Content Background for Teachers

In this task, students start to make sense of some of the science behind the changes they see in an environment. In this task, students attempt to separate the changes they see into two categories—physical and chemical changes. The difference between a physical change and a chemical change is composition. In a chemical change, the matter changes into a completely different type of matter, meaning that the original molecules are rearranged into different molecules (see image to the right). In a physical change, the matter stays the same but there is a change in size, shape, state, or appearance (see image below).





Some examples of physical changes are physical manipulations such as ripping paper or changes of state, such as freezing water or melting candle wax. These do not change the internal composition of the item. In chemical changes, however, the composition is changed, and so do the properties of the substances. While students cannot see atoms with the naked eye, there are a number of clues to tell them that a chemical reaction has occurred. To identify a chemical change, they need to look for observable signs, such as color change, bubbling and fizzing, and the presence of light, smoke, heat, and/or odor. This method of identifying chemical reactions should have been explored in earlier grades. Should your students not be familiar with classifying chemical reactions in this way, review some of the ways in which chemical reactions can be identified.

However, students can also identify whether a change is physical or chemical by looking at the properties of the reactants and the products before the change. Even without the chemical composition of the reactants and products, scientists can look at the properties of each. If properties, such as density, boiling point, melting point, and solubility are different between the reactants and the products, that suggests that new molecules were formed, and thus a chemical reaction occurred. This way of identifying chemical reactions will be explored in this task.

Investigating physical and chemical changes are just the starting point for future explorations of chemical reactions to come throughout the unit. Soon, students will begin to explore specific chemical reactions relevant to their study of environmental changes, zooming in to the molecular level and considering conservation of matter in an environmental system. As students work through this introductory task distinguishing physical and chemical changes, it is helpful to keep these connections in mind.

Academic Vocabulary

- Physical Change
- Chemical Change
- Properties
- Reactants
- Products
- Glucose
- Decomposition
- Molecules
- Amino Acid
- Nitrogen

Time Needed (Based on 45-Minute Periods)

3 Days

- Engage: 0.5 period
- Explore: 0.5 period
- Explain: 0.5 period
- Elaborate: 0.5 period
- Evaluate and Reflection: 1 period

Materials

- Unit 3, Task 1 Student Version

Evaluate

- Project Organizer Handout

Instructions

Engage

1. Introduce Task 1: In the Lift-Off Task, you saw images of a river environment 200 years ago and the river environment today. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

7th Grade Science Unit 3: Mimicking Nature's Design
Task 1: Types of Changes

2. Transition to Task 1: You likely observed many differences between the past and present river environment. What processes are behind these differences? In this task, you will investigate the kinds of changes that happen in environments over time.
    - Now pass out the Task 1 student guide.

3. With a partner, have students return to the past and present images of the river environment and make a list of all the differences they observe between the two.
    - Once students generate a list, have pairs of students group the differences into similar types of changes and record those groupings.
    - Recommended: Project the images class-wide and co-construct groupings of similar types of environmental changes. Use equity sticks for more equitable participation (See "How to Use This Curriculum" for details).

Explore

1. In the Engage, students began to think about the different kinds of changes that happen in environments over time. In this activity, students learn more about these environmental changes by analyzing and interpreting data from two common changes—plant growth and fog rising off water.

2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
    - Ask the Facilitator to read the directions and to make sure everyone understands the task.
    - Ask the Materials Manager to handle any resources needed to complete the task, including reading the data sets aloud.
    - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
    - Ask the Recorder to make sure the group is recording their observations in their student guides.

3. Students will examine the properties of the substances before and after each of the environmental changes has occurred. Because students may not know the definitions of some of the properties (ie. density), make it clear to students that they just need to focus on the difference in numbers to understand the difference in properties.
    - This requires students to use the SEP of **Analyzing and Interpreting Data** as they look for similarities and differences between the two data sets.
    - Students will also engage with the CCC of **Patterns** as they begin to notice macroscopic **patterns** in the data (properties of substances), which they will be able to compare to microscopic patterns in atomic-level structures in the next section of this task.

4. The first data set is an example of a chemical change while the second data set is an example of a physical change. Students are not yet introduced to these terms; instead they are asked to investigate the data with guided questions that are intended to help them notice differences or similarities between the properties of substances in both data sets. The last question asks them to compare the two data sets, which will help transition them to the next portion of the task.

   a. Plant Growth: Students should notice that the properties of the reactants are different from the products.
   b. Fog Rising Off Water: Students should notice that the properties of the reactants are the same as the products.
   c. Comparison of Two Data Sets: Students may notice that there is more variation in reactants and products in Data Set 1, but only water in Data Set 2. Students may also notice that the substances don't change in Data Set 2, but they do in Data Set 1.

Explain

1. Now that students have explored the data, it is time to introduce them to the relevant scientific terminology: physical change and chemical change.

2. Rather than giving students the explicit definitions, models are provided for each type of change that students interpret and use to craft their own definitions in pairs.
   - We recommend pausing partner work after this first question and coming to a class consensus on definitions for physical and chemical changes. Keep in mind that it takes time to reach consensus and it is okay if complete consensus is not reached.
   - Students will likely notice that in a physical change, the molecules remain the same while in a chemical change, the molecules change into new molecules.

3. Once students have an understanding of physical vs. chemical changes, they can apply this information to the data sets from the *Explore*. In pairs, students look back at the data, identify each data set as a physical or chemical change, and explain why.
   - This explicitly emphasizes the CCC of **Patterns** as students relate the macroscopic patterns of properties to what is happening at the microscopic level with atomic structure. They are also continuing to **Analyze and Interpret Data** as they did during the *Explore*.

4. Lastly students return to their lists from the *Engage* and make predictions about which changes they think are physical and which are chemical based on what they have learned during this task. These predictions need not be accurate at this point since they don't have all the essential information. However, students should be using their new knowledge of physical and chemical changes as part of their reasoning.

Elaborate

1. This activity asks students to use the knowledge they have gained throughout the task and apply it to another environmental change present in the river environment—the decomposition of the deer.
   - Here students are introduced to a concept they should have learned before—decomposition. For students who are not familiar with this term, we recommend spending some time reviewing it as a class using the information in their student guide.
   - This scenario specifically focuses on a chemical process that converts one form of nitrogen into another more useable form for plants.

2. Similar to the Explore, students are given a data table showing the properties of substances before and after a reaction.

- Again, students are practicing the SEP of **Analyzing and Interpreting Data** and the CCC of **Patterns**, as they analyze similarities and differences in macroscopic patterns to infer changes in microscopic structures.

3. Student responses to this question represent an opportunity for formative assessment. Collect student work to identify trends in students' ability to relate macroscopic patterns to atomic-level structure as they identify this process as a chemical or physical change. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

4. Return to the whole-class concept map from the Lift-Off Task.
   - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
     - Some possible facilitating prompts to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
     - Draw circles around each question and boxes around each concept.
     - Write connector words to describe connections between the concept boxes.
     - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: types of environmental changes (physical vs. chemical).
   - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
     - **Patterns**: These could be phrases such as, "has in common with" "shares," "is also shown in," "is the same as," "looks the same as," etc.
   - Once again, the purpose of this concept map is to facilitate the generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 1 section of the Unit 3 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with creating a sustainable aquaponics system that mimics the properties of the river environment, including any physical and chemical changes that may occur. Their prompt is as follows: Now that you understand physical and chemical changes on a molecular level, identify one physical change and one chemical change that you anticipate may occur in your aquaponics system.
    - Draw a before and after picture for each change and write a caption explaining each.
        - Use data from this task, or research the properties of your own environmental change, to explain how you know what type of change it is.
    - For each factor, decide if it represents a threat to your aquaponics system. If it is a threat, describe a potential solution to prevent it.

3. Since aquaponics systems are likely still new for students, we recommend projecting or providing example images as they complete this section of their project organizer.

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
    - At the beginning of this task, you were asked to group the types of changes you observed in the river environment. Look back at your groupings: are they similar to groupings of physical vs. chemical changes? Explain how they are similar or different.
    - In this task, we focused on the crosscutting concept of **Patterns**: Macroscopic patterns are related to microscopic structure. Where did you see examples of **Patterns** in this task?
    - Now that you have learned more about two types of changes in environments, what questions do you still have?

2. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

Assessment

1. You may collect students' Project Organizer and assess using:
    - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
    - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
    - Students may make changes to their Project Organizer according to your comments OR
    - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

7th Grade Science Unit 3: Mimicking Nature's Design
Task 2: Matter Moves You

Unit Essential Question: *How does energy and matter flow within natural and designed ecosystems?*

Introduction

In the last task, students began to explore chemical changes by looking for changes in properties, implying a molecular change. In this task, students continue their exploration of chemical changes with a few example reactions—combustion and cellular respiration. Students are first engaged with the mystery of the extinguished candle, which allows them to practice modeling a chemical reaction and also helps them to begin to explore the concept of conservation of matter. By analyzing a chemical reaction as a molecular model, students begin to see that when molecules are broken down, they don't just disappear; rather matter is conserved, molecules are rearranged, and energy is released in the process. Students then apply what they have learned to a chemical reaction that is very important to their river environment—cellular respiration. Students create both physical and visual models of this chemical equation to explore the idea that the total number of atoms is conserved and thus mass is conserved. This is one way matter and energy move through ecosystems. Armed with understanding of this chemical reaction, students will be able to first decide what components are needed in their aquaponics system, and then begin to conceptualize what the cycling of energy and matter looks like in their system.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-LS1-7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.]	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • 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, and to release energy. **PS3.D: Energy in Chemical Processes and Everyday Life** • Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes.

		carbon react with oxygen to produce carbon dioxide and other materials (*Secondary*).	
MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.]	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**PS1.B: Chemical Reactions** • 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.	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes.
Equity and Groupwork • Discuss observations of models and experiments. • Work within group roles to co-construct models of different chemical equations. • Use a successive pairing structure to share ideas and feedback.			
Language • Use compare and contrast language to compare the opposite sides of a chemical reaction. • Describe a phenomenon using pictures, arrows, and words. • Practice oral language and refine written language using the Stronger and Clearer Protocol.			

Learning Goals

This learning task asks students to explore how chemical reactions work on an atomic level. More specifically, the purpose is to:

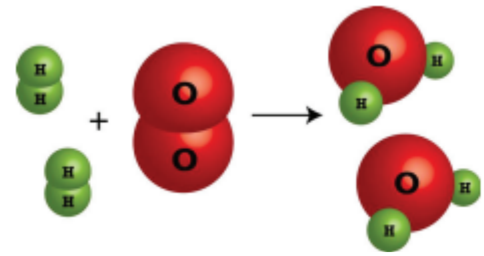
- Engage prior knowledge of chemical changes and use it to analyze a familiar model.
- Explore what happens when you take away a reactant in a chemical reaction.
- Develop a model for cellular respiration that shows conservation of matter.
- Practice explaining a model to peers and revise based on feedback.
- Apply knowledge of cellular respiration to an aquaponics system design.

7th Grade Science Unit 3: Mimicking Nature's Design

Task 2: Matter Moves You

Content Background for Teachers

In this task, students continue to develop their understanding of chemical changes by digging deeper into the molecular level of chemical reactions. Students use experimental demonstrations and chemical equations to develop their own conceptions of conservation of matter.

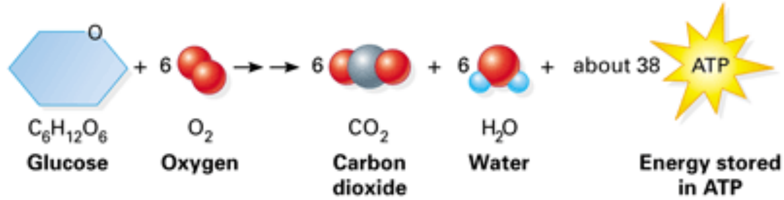


In a chemical equation, the reactants of the chemical reaction are depicted on the left and the products of the chemical reaction are depicted on the right, with an arrow between that represents the reaction. In a chemical reaction, the actual molecules change into new and different molecules. Students were introduced to these concepts and terms in Task 1. Throughout the task, students look at two chemical equations: the chemical equation for burning candle wax and the chemical equation for cellular respiration. In both of these cases, students are analyzing the equations to notice the similarities and differences between reactants and products.

Students should find that the reactants and products are different because the arrangement of atoms is different—in other words, the molecules are different. This is consistent with what they know about chemical changes from Task 1. However, students should also find that the reactants and products are similar in that the number of atoms of each type is the same. This is known as the principle of conservation of matter, which states that atoms cannot be created or destroyed in a chemical reaction. Rather than define this concept for students, students come to this understanding on their own by using models of chemical reactions.

They first use the candle covered by a jar demonstration as the context for discovering conservation of matter. What is happening in this demonstration? The candle wax (a solid) releases the fuel (methane gas) as it melts near the flame and is absorbed into the wick. The fire is evidence of an exothermic reaction between oxygen gas and methane gas (wax vapor). When you cover the jar, it takes away the oxygen, so the reaction can no longer continue. No atoms disappear in this chemical reaction; they are merely rearranged into new substances (carbon dioxide and water). Thus, when you take away oxygen, you cannot create the carbon dioxide and water out of nothing.

This concept of conservation of matter is tested further with an example relevant to the phenomenon of the unit—the changing river environment. In every environment, living organisms eat food (glucose) and breathe in oxygen, which is then converted into energy. Any excess glucose is stored and leads to organism growth. Carbon dioxide and water are created as byproducts in the process of cellular respiration. Students make their own model of this process, using manipulatives of different colors to represent each atom. By weighing each side of the equation on a scale, they will have more proof that the total number of atoms does not change in a chemical reaction, and thus mass is conserved. These ideas can then be represented in their individual visual model and written explanation.



7th Grade Science Unit 3: Mimicking Nature's Design

Task 2: Matter Moves You

By the end of the task, students will be able to relate the concept of conservation of matter to cellular respiration in a way that will help them think about the needs of their Aquaponics System. Drawing a model of what is needed and created by every organism doing cellular respiration will help students decide what to include in their system.

**If you feel like students need more direct instruction around these ideas, you may provide them with "The Science Behind It" Resource Card during the *Explain*, which is located at the end of this teacher guide.

Academic Vocabulary

- Chemical Reaction
- Product
- Reactant
- Molecules
- Atoms
- Cellular Respiration
- Oxygen
- Carbon Dioxide
- Water
- Glucose
- ATP
- Energy
- Matter
- Mass

Time Needed (Based on 45-Minute Periods)

4 Days

- Engage: 0.5 period
- Explore: 1 period
- Explain: 1 period
- Elaborate: 0.5 period
- Evaluate and Reflection: 1 period

Materials

- Unit 3, Task 2 Student Version

Explore

- Candle
- Match or lighter
- Large Clear Jar

Explain (Per Group)

- Optional: If you feel your students need a more traditional pre-teaching of this material, use the resource card at the end of this Teacher Version, entitled "The Science Behind It," as either a reading for students or a resource for your own powerpoint presentation.

- Balancing scale or 2 normal scales
- "Atom Pieces": These can be a modeling kit, unifix cubes, colored beads, legos, jelly beans, or any materials available in three colors
    - 6 for Carbon
    - 12 for Hydrogen
    - 18 for Oxygen
- Colored pencils or crayons

Evaluate

- Project Organizer Handout

Instructions

Engage

1. Introduce Task 2: In Task 1, you investigated different types of changes that happen in an environment—both physical and chemical changes. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 2: When a chemical change, or chemical reaction happens, the initial molecules form new molecules, but we can't see this happening! In this task, you will explore different chemical reactions and develop a model to show what happens when an important chemical reaction in ecosystems occurs.
    - Now pass out the Task 2 student guide.

3. In pairs, ask students to look at the model of a chemical reaction from Task 1. This is their introduction to the SEP of **Developing and Using Models** in this unit, which they will continue to practice extensively throughout this task.
    - Using the discussion questions, students make observations of the model in partners. The purpose of these questions is to create a foundation for students to understand the concept of conservation of matter. Below are some potential observations students may make:
        - For question 1, students may observe a couple different things: there are three molecules on the left and only two on the right. On the left, the colors are separated, whereas on the right they are mixed together, etc.
        - For question 2, the sides of the equation are similar because there is the same number of each atom on each side. In other words, there are four small green circles on each side and 2 large red circles on each side.

4. After pairs discuss, use equity sticks to share out observations in a class-wide discussion (See "How to Use This Curriculum" for more details on how and why to use equity sticks).

7th Grade Science Unit 3: Mimicking Nature's Design

Task 2: Matter Moves You

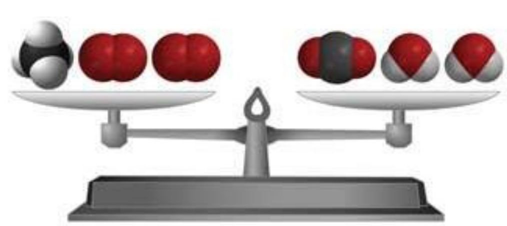
Explore

1. In this Explore, students first experience the phenomenon of a candle extinguishing when covered with a jar and then use a model to try to explain what is happening. In the process, students are not only getting comfortable with modeling chemical reactions, but are also implicitly gathering more evidence for the concept of conservation of matter.
2. Read the paragraph from the Student Guide aloud to set the context for the demonstration: Let's investigate chemical reactions with a familiar example—a burning candle. When a candle burns, the methane gas from the melted candle wax is reacting with the oxygen in the air. This results in a flame, carbon dioxide, and water.
    - Begin the demonstration by showing them the candle on your desk. Light the candle and allow students to watch it burn for several seconds. Then cover the candle with a clear jar and watch as the candle extinguishes. Repeat demonstration a second time as this allows students to generate more detailed observations in their Student Guides.
    - We recommend this be done as a teacher demonstration since it involves an open flame. However, this may be done in small groups if you prefer.
    - We also recommend you facilitate a brief discussion about student observations and initial hypotheses for why the flame eventually goes out when covered with the jar.

3. After seeing the demonstration and recording their observations, students are faced with the phenomenon of the extinguished candle. In order to better understand what is happening, they need to look at the chemical equation.
    - In this activity, students are practicing **Developing and Using Models**, by using a model to describe an unobservable mechanism—the chemical reaction for a burning candle.

4. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
    - Ask the Facilitator to read the directions and to make sure everyone understands the task.
    - Ask the Materials Manager to handle any resources needed to complete the task (ie. if you decide to also use physical manipulatives for the atoms).
    - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
    - Ask the Recorder to make sure the group is recording their observations in their student guides.

5. Student groups use the chemical equation to count the number of each type of atom on each side of the equation. Recommended: project it on the board and write the common names for each molecule on the board underneath the equation. Methane from melted wax + oxygen > carbon dioxide and water (and flame).
    - You may want to model the process of counting atoms with carbon, which is already filled in on their student guide.
    - Students should come to consensus with the members of their group and record these numbers in the data table in their student guide.



- They should find that the number of each atom on the left side matches up with the number of each atom on the right side, as shown in the image of the scale above.

6. Once students have modeled the chemical reaction, return to the original demonstration to see if they can now explain the mystery of the extinguished candle. Have students discuss the question on their student guide in pairs.
    - As they modeled the chemical reaction and now attempt to explain the mystery of the extinguished candle, they are emphasizing the CCC of **Energy and Matter** by showing that because atoms are conserved in chemical reactions, matter is conserved. This is why the reaction cannot continue and the flame goes out when one of the reactants—oxygen—is removed by covering the candle with a jar.
    - If students are struggling to figure out this phenomenon, you may want to provide some of the following facilitating questions: What do you notice about the atoms in the left side and the right side of a chemical reaction? Where do the atoms come from that make the carbon dioxide and the water on the right side (products) of the equation? What molecule on the left did we take away by placing the jar on top?
    - After pairs discuss, use equity sticks to share out different explanations in a class-wide discussion, using the facilitating questions above as prompts to guide the discussion if necessary (See "How to Use This Curriculum" for more details on how and why to use equity sticks).

Explain

1. Now that students have seen and modeled how atoms are conserved and rearranged through chemical reactions, they are ready to apply this knowledge to a relevant chemical reaction in the river environment—cellular respiration.
    - Optional: As you transition from the *Explore* to this *Explain*, you may choose to tell students that this idea that atoms are merely rearranged in chemical reactions, rather than being created or destroyed, is known as "conservation of matter."

2. While observing the river environment images, students likely noticed that there is a fully-grown deer in the present-day river environment. First have pairs of students reflect on this organism and use their prior knowledge to discuss what all animals need in order to grow and do their daily activities.
    - Students will likely identify that animals need food, water, and air.

3. Building off this prior knowledge, have students read the information on the next page of their student guides individually, in groups, or as a class. This introduces them to cellular respiration, including why organisms do this process as well as the chemical reaction.
    - Optional: switch out the word "glucose" for "sugar".
    - Optional scaffold to aid student understanding: Make connections to what students experience in their everyday lives. For example, the sugar comes from the food they eat and the oxygen comes from the air they breathe. The carbon dioxide is breathed out and the water can be sweat out.
        - Discussions of ATP can remain broad: ATP is the energy that our bodies need to do work, like walk around and think, and to grow.
    - Again, if you feel like students need more direct instruction around these ideas, you may provide them with "The Science Behind It" Resource Card at the end of this teacher guide.

4. Once students have a basic understanding of cellular respiration, they are ready to create physical models of the reaction as a group. This activity asks students to continue practicing the SEP of **Developing and Using Models**, as they develop a physical model to again describe the unobservable mechanism of a chemical reaction. With this model, students are also demonstrating understanding of the CCC of **Energy and Matter** as they show that in a chemical reaction, the atoms are conserved and thus matter and mass are conserved.
   - Pass out the "Atom Pieces", at least one set per group. Also provide each group with a balancing scale or two normal scales.
   - Because this is a group activity, we recommend assigning roles to each group, mixing up the roles they were assigned in the *Explore*.
   - Have students analyze the cellular respiration chemical equation and assemble the number of atoms on each side, using one color for each atom.
     - Students should first record the color they choose for each atom in their student guides.
     - Then students weigh these piles on the scales to see whether there is an even amount of mass on each side of the chemical equation.

5. Since students have had an opportunity to discuss and co-construct a physical model, they should be ready to independently make a drawing of their model. Remind students to use the checklist in their student guides to draw their model and write their explanation. Again, students are practicing **Developing and Using Models** and emphasizing **Energy and Matter** in the ways described above.
   - Student models should show a scale with the accurate molecules on each side, including the number and types of atoms identified for the reactants and products. In the model and/or explanation, students should also describe how matter is rearranged during the chemical reaction; in other words, they should identify that the hydrogen in the water molecules comes from the glucose molecule, etc. Because they are using a scale in this model, they should also compare the mass of the reactants and the products to show conservation of matter.

Elaborate

1. Students will now participate in a language routine known as *Stronger Clearer*. This activity gives students the opportunity to share their ideas, gather feedback, and revise their models and explanations. This protocol is especially useful for this task since they are practicing both modeling and writing explanations.

2. Students will cover up their written explanations and share their models with three different partners from different groups; in this process, they also have opportunities to discuss feedback and record any notes. Once complete, have students return to their original model and explanation to revise based on their discussions. A protocol is provided in their student guide.

3. These revised models and explanations represent an opportunity for formative assessment. Collect student work to identify trends in students' ability to develop models of cellular respiration, including a demonstration of conservation of matter. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

4. Return to the whole-class concept map from the Lift-Off Task.
   - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
     - Some possible facilitating prompts to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
     - Draw circles around each question and boxes around each concept.
     - Write connector words to describe connections between the concept boxes.
     - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: the conservation of matter in chemical reactions, specifically cellular respiration.
   - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
     - **Energy and Matter**: These could be phrases such as, "is made by," "is put into," "is added to," "is cycled within," "is taken out by," "is extracted for," "is conserved," "is changed into," etc.
   - Once again, the purpose of this concept map is to facilitate the generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 2 section of the Unit 3 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with creating a sustainable aquaponics system that mimics the properties of the river environment, including any chemical reactions that may occur. Their prompt is as follows: Identify or add an organism to your aquaponics system that does cellular respiration.
   - Identify what molecules the organism requires for cellular respiration. How will your system provide these molecules?

- Identify what molecules the organism will create through this process. How will your system use up the products that it creates?
- Draw a picture of your organism and the molecules identified. Use arrows to show which molecules enter or leave the organism.

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
   - At the beginning of this task, you were asked to analyze a model of a chemical equation and compare the two sides of the equation. Look back at your comparisons: after exploring chemical reactions today, how would you change or add to your comparisons? Use evidence from the task to justify your changes or additions and record below.
   - In this task, we focused on the crosscutting concept of **Energy and Matter**: Matter is conserved because atoms are conserved. Where did you see us looking at **Energy and Matter** in this task?
   - Now that you have learned about another important chemical reaction in environments—cellular respiration—and how matter is conserved in these types of reactions, what questions do you still have?

2. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

Assessment

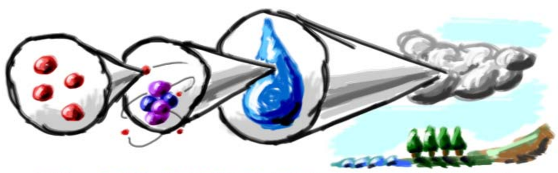
1. You may collect students' Project Organizer and assess using:
   - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
   - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
   - Students may make changes to their Project Organizer according to your comments OR
   - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

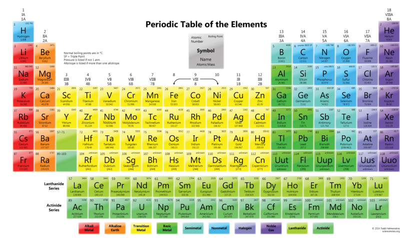
7th Grade Science Unit 3: Mimicking Nature's Design
Task 2: Matter Moves You

"The Science Behind It" Resource Card

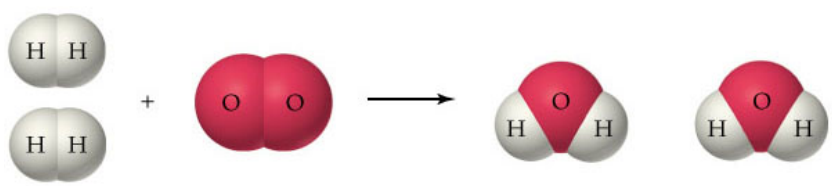
Atoms are the building blocks for all types of matter. They are like the letters that make up every language.



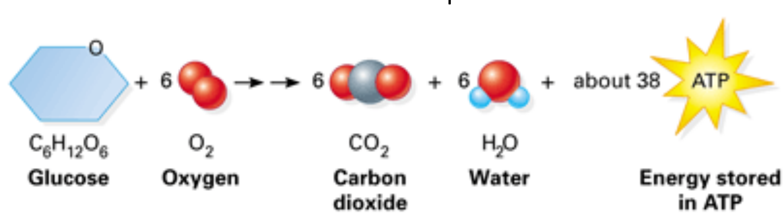
Each type of atom is known as an **element** and each element has its own different characteristics and properties.



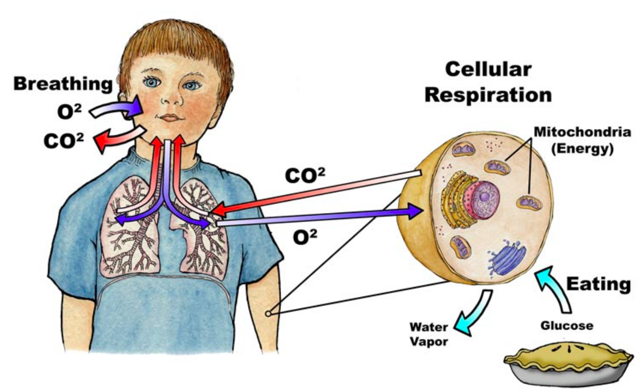
When one type of atom combines with another type of atom, it creates a **molecule**. For example, when you combine hydrogen atoms with oxygen atoms, it makes a whole new type of molecule that you may know: water!



When two or more molecules interact and the molecules change, it is called a **chemical reaction.** This means that the bonds between atoms are broken and new bonds are formed. Because breaking bonds makes energy and it takes energy to make new bonds, energy is either released or absorbed in a chemical reaction. A great example of this is cellular respiration:



All living things, including humans, do cellular respiration to make energy. The chemical reaction starts with glucose and oxygen. The glucose is a sugar that comes from the food we eat and the oxygen comes from the air we breathe. These molecules are broken down in order to create ATP, which is the type of energy our bodies need to do their jobs. As a result, this also creates carbon dioxide, which we breathe out, and water, which our bodies either uses or gets rid of in other ways.



7th Grade Science Unit 3: Mimicking Nature's Design
Task 3: Cycling Matter Through Living Things

Unit Essential Question: *How does energy and matter flow within natural and designed ecosystems?*

Introduction

In the last task, students modeled what happens at the molecular level in chemical reactions, including how atoms are rearranged and matter is conserved. They began to explore this within the context of a chemical reaction that happens in all environments—cellular respiration. By thinking about how matter enters organisms, is rearranged through chemical reactions, and released back into the environment, students began to form ideas about how matter cycles and energy flows through environments. This task builds on prior knowledge by introducing another critical chemical reaction that occurs in all environments—photosynthesis. Students conduct investigations that show how photosynthesis and cellular respiration interact to allow matter to cycle and energy to flow through living organisms. By the end of this task, students should have a clear model of this cycling, so they may apply this knowledge to the design of their aquaponics system.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]	**Constructing Explanations** • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • 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. **PS3.D: Energy in Chemical Processes and Everyday Life** • The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (ie. from sunlight) to occur. In this reaction, carbon dioxide and water combine to	**Energy and Matter** • Within a natural system, the transfer of energy drives the motion and/or cycling of matter.

7th Grade Science Unit 3: Mimicking Nature's Design

Task 3: Cycling Matter Through Living Things

		form carbon-based organic molecules and release oxygen (*secondary*).	
MS-LS1-7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.] **Note: This PE is primarily addressed in Task 2, but many ideas and practices are reinforced throughout this task.	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • 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, and to release energy. **PS3.D: Energy in Chemical Processes and Everyday Life** • 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 (*Secondary*).	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes.

Supplementary Science and Engineering Practices

- **Planning and Carrying Out Investigations**
  - Conduct an investigation [...] to produce data to serve as the basis for evidence that meets the goals of the investigation.

Crosscutting Concepts

- **Systems and System Models**
  - Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.

Equity and Groupwork

- Work within group roles to conduct investigations.

Language

- Read a short article, using annotation strategies to analyze text.
- Use evidence from an investigation and an article to support a written explanation.

7th Grade Science Unit 3: Mimicking Nature's Design

Task 3: Cycling Matter Through Living Things

- Represent a concept visually and in text.

Learning Goals

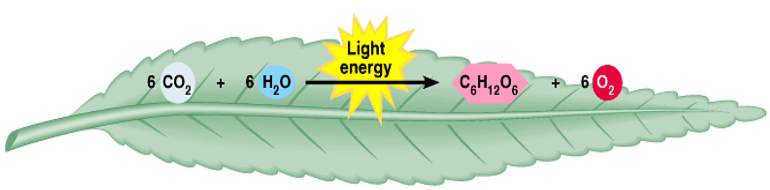
This learning task asks students to gather experimental evidence for the roles of cellular respiration and photosynthesis in the flow of energy and cycling of matter through living organisms. More specifically, the purpose is to:

- Engage prior knowledge of changes students noted in their river environment, specifically those pertaining to living organisms.
- Investigate the cycling of carbon dioxide through the processes of cellular respiration and photosynthesis, including the effects of light and dark conditions on those processes.
- Use information from an article about photosynthesis to explain what happened in the investigations.
- Model and explain how cellular respiration and photosynthesis interact to cycle energy and matter in ecosystems.
- Apply knowledge of photosynthesis to predict the role it will play in an aquaponics system design.

Content Background for Teachers

In this task, students look at two processes that are happening in parallel in living organisms in an environment—photosynthesis and cellular respiration. By exploring this activity through readings, investigations, and models, students will be able to conceive of these not as separate processes, but as processes that are constantly interacting and exchanging matter and energy. Not only do these processes both happen in some living organisms at the same time, but they can also exchange matter *between* organisms.

As described in the last task, cellular respiration happens in all living organisms—plants and animals alike. Cellular respiration takes glucose from the food organisms eat and together with oxygen creates the energy living organisms need to grow and function. As dictated by the conservation of matter, cellular respiration also creates byproducts in the form of carbon dioxide and water. Coincidentally, these molecular byproducts are exactly what plants need to do photosynthesis. Photosynthesis requires carbon dioxide and water, as well as energy from the sun, in order to make glucose. The byproduct of this process is oxygen. Ultimately, the equations for photosynthesis and cellular respiration are mirror images of each other. The only difference is the type of energy involved—sunlight vs. ATP.



Students may notice this relationship on their own just by looking at the chemical equations in the reading. However, this will soon be reinforced through the lab investigations. The lab investigation involves Elodea and BTB solution placed in different light conditions. This serves as evidence for the cycling of one essential molecule in both processes—carbon dioxide. Under light conditions, Elodea is able to do photosynthesis, thus using up carbon dioxide and turning the BTB solution from yellow to blue. In the dark, no photosynthesis takes place, so the BTB solution remains yellow.

7th Grade Science Unit 3: Mimicking Nature's Design
Task 3: Cycling Matter Through Living Things

By the end of this task, students will be able to form a holistic picture of the role of chemical reactions in the cycling of matter and flow of energy through living organisms. Rather than seeing photosynthesis and cellular respiration as two separate processes, students should in the end be able to model how matter like carbon dioxide, water, oxygen, and glucose is cycled through living organisms, using energy from the sun and producing energy in the form of ATP. This cycling will help them think about the needs of their Aquaponics System.

**For more background information, see the article in the Student Version as well as the TedEd video provided in the Explore.

Academic Vocabulary

- Indicator
- Bromothymol Blue (BTB)
- Photosynthesis
- Cellular Respiration
- Carbon Dioxide
- Oxygen
- Water
- Energy
- Matter
- Glucose
- ATP

Time Needed (Based on 45-Minute Periods)

4.5 Days

- Engage: 0.5 period
- Explore: 1 period (also requires 24 hours for experiment to run)
- Explain: 1 period
- Elaborate: 1 period
- Evaluate and Reflection: 1 period

Materials

- Unit 3, Task 3 Student Version

Explore

- Per Lab Group
  - Small Beaker 1/3 filled with Bromothyml Blue Solution
  - Straw
  - Investigation Card in sheet protectors for each table group
  - 2 Test Tubes or Baby Food Jars
    - If using test tubes, need test tube racks
  - Small Graduated Cylinder (to retrieve BTB solution from teacher)
  - 1-2 Sprigs Elodea Plant (available at most local aquariums)
  - Straw
  - Masking Tape

- Pen
- For Class
  - Empty Oatmeal Containers or Large Cardboard Box (For dark environment)
  - 2 Sun Lamps
  - Bromothyol blue solution
    - 1 g bromothymol blue
    - 1 L distilled water
    - 18 drops of 1M sodium hydroxide (Optional: makes it more blue)

Elaborate

- Optional: If students actually want to run the experiment described, follow the same instructions as the other jars, except add a sea snail or small fish. Be sure to use distilled water or the snail/fish will likely die before data can be collected.

Evaluate

- Project Organizer Handout

<u>**Instructions**</u>

Engage

1. Introduce Task 3: Through previous tasks, you have recorded all the different changes you observed in the river environment over time. In the last task, for example, you examined the role of cellular respiration in some of these changes. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
   - Before you pass out their Student Guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 3: You may remember that some off these changes in the river environment involved plants and animals that seem to have grown. Why do you think this is the case? In this task, you will explore different processes that lead to these kinds of changes in ecosystems.
   - Now pass out the Task 3 Student Guide.

3. To begin this task, students are asked to engage their prior knowledge to consider how animals and plants are able to grow and make energy. In pairs, ask students to discuss the questions on their Student Guides.
   - This begins to lay the foundation for the crosscutting concept emphasized in this task—**Energy and Matter**. As students engage their prior knowledge, they will likely begin to make connections between the matter needed to create energy, which will set the stage for them to later consider how energy transfer drives the cycling of matter.
   - Potential responses:
     - Question 1: Food and water are needed for animals to grow.
     - Question 2: Sunlight, water, and nutrients are necessary for plant growth. (Note: Students may say soil, instead of nutrients, but it is really the nutrients and water in the soil that plants need).

- After pairs discuss, use equity sticks to share out ideas in a class-wide discussion (See "How to Use This Curriculum" for more details on how and why to use equity sticks).

Explore

1. In this part of the task, students conduct investigations in order to figure out what animals and plants need to survive and grow, and how they must interact with their environments to get what they need.
    - This *Explore* gives students practice at the supplementary Science and Engineering Practice, **Planning and Carrying Out Investigations**, as students conduct an investigation to produce data that serves as evidence for the roles of cellular respiration and photosynthesis in the cycling of matter and flow of energy.

2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
    - Ask the Facilitator to read the directions and to make sure everyone understands the investigations.
    - Ask the Materials Manager to handle any resources needed to complete the investigations.
    - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
    - Ask the Recorder to make sure the group is recording their data in their Student Guides.

3. The first investigation serves two purposes: 1) to introduce students to the indicator they will be using in the more complex second investigation, and 2) to find evidence for the production of carbon dioxide by cellular respiration.
    - In both investigations, students use an indicator called bromothymol blue (BTB) to see the effects of photosynthesis or cellular respiration. BTB is an indicator that turns from blue to yellow when in the presence of CO_2.

4. Because humans do cellular respiration like all other organisms, students are going to use themselves to investigate cellular respiration using bromothymol blue (BTB).
    - We recommend first reviewing the cellular respiration equation on their Student Guide (Optional: project on the board and review).
    - Distribute materials to each group. Then have students follow the procedure on their student handout and record observations in their data table. *Safety: Make sure students do not suck in on the straw, but rather only blow out.
    - Once students have completed this short investigation, have them discuss and answer the analysis question in their Student Guide. Review the results and analysis in a brief class-wide discussion.
        - Students should find that the BTB solution turns yellow, which they will likely hypothesize means that BTB is an indicator for the carbon dioxide created during cellular respiration.

5. Transition students to Investigation 2 by reading the introduction on their Student Guide aloud. This confirms that BTB is indeed an indicator for carbon dioxide, which turns yellow when carbon dioxide is present and back to blue when it is absent. Students will use this same indicator for this investigation.

- This investigation is intended to provide evidence for how photosynthesis helps to cycle matter, such as carbon dioxide. By comparing light vs. dark conditions, it also provides evidence that the transfer of energy drives the cycling of this matter; this explicitly emphasizes the CCC for this task, **Energy and Matter**.

6. Distribute the investigation card and prepare all materials. You may choose to keep students in the same group roles or re-assign the roles for this investigation.
   - Student groups follow the procedure on the investigation card to set up their experiment. To ensure the experiments are successful, check that all student set-ups have yellow BTB solution to begin with; this provides the carbon dioxide plants will need to do photosynthesis.
   - After setting up their experiment, students should record initial observations, including labeled and colored sketches of both set-ups, so they can compare these to their observations after 24 hours. Space is also provided in their data tables to record predictions of what color they think the BTB solution will be after 24 hours in both light and dark settings.

7. The two lab set-ups will remain in light and in dark for 24 hours, so students will need to check them the same time the next day.
   - Again, students should make observations and draw colored and labeled sketches in their Student Guides.
   - An example is shown to the right: Students should find that the set-up left in the light turned blue (on left). This is because all of the carbon dioxide was used up for photosynthesis. The set-up left in the dark remained more yellow (on right). This is because photosynthesis does not happen in the dark (on right). Students will read a text in the next section of this task that describes this result.

Explain

1. While the first investigation dealt with a process they were familiar with—cellular respiration—students are likely not sure at this point what was happening in Investigation 2. To understand more, students read an article about cellular respiration and photosynthesis and use this new knowledge to explain and model Investigation 2.
   - This section of the task continues to emphasize the crosscutting concept of **Energy and Matter** as students explain and model how photosynthesis cycles matter through plants. This supports two elements of this CCC as students explore how energy transfer drives this cycling of matter and also how matter is conserved as the molecules are rearranged and released as different molecules.

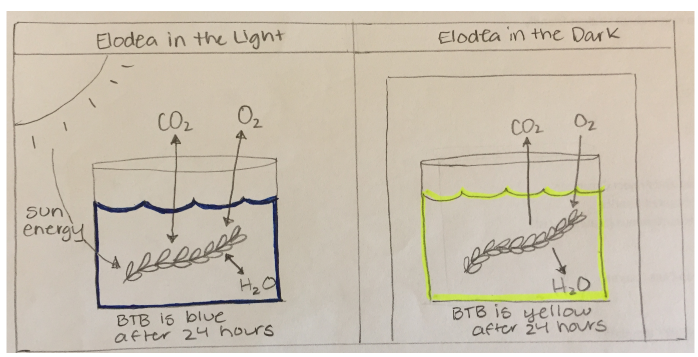
2. First have students read and annotate the article independently, using an annotation strategy of your choice.

- Optional resource to further tie photosynthesis and cellular respiration together: http://ed.ted.com/lessons/the-simple-but-fascinating-story-of-photosynthesis-and-food-amanda-ooten#review

3. Students then work in pairs to complete the explanation and model of Investigation 2. This allows students to practice two Science and Engineering Practices: **Constructing Explanations**, using evidence from both the article and experiment; and **Developing and Using Models** to describe the role of photosynthesis in the cycling of matter and flow of energy through the Elodea plant.
   - Sample sentence frames you may want to provide are:
     - "In Investigation 2, _____ happened."
     - " According to the article,…"
     - "Photosynthesis requires…"
     - "Without ____, _____ couldn't happen."
     - "This was shown in the experiment by…"
     - "In the dark setting…"
     - "In the light setting…"
     - "This means that…"
     - "…which means that…"

4. Sample Student Explanation: *In Investigation 2, photosynthesis happened in the Elodea plant in the light setting, but not in the dark setting. According to the article, the chemical reaction of photosynthesis needs energy from sunlight and matter from carbon dioxide and water in order to happen. We provided the water and carbon dioxide by blowing into the water, but in the dark setting, there was no sunlight, so the reaction couldn't happen. This was shown in the experiment by the BTB solution staying yellow in the dark setting. This means that the carbon dioxide was not used for photosynthesis. In the light setting, the BTB solution changed from yellow to blue, which means that carbon dioxide was used up for photosynthesis.*

5. Sample models:



   - Elodea in the Light: Notice that the sample shows both cellular respiration and photosynthesis are happening. However, at this point, students may just show the process of photosynthesis: sunlight, carbon dioxide, and water entering the plant (turning BTB blue) and oxygen leaving the plant.
   - Elodea in the Dark: Notice that the sample shows cellular respiration with oxygen entering the plant and carbon dioxide and water leaving the plant (keeping BTB yellow). However, at this point, students may just show the lack of photosynthesis by showing no inputs and outputs.

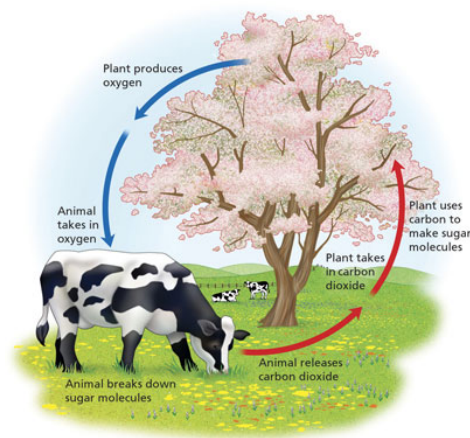
6. After pairs of students have drafted their explanations and models, we recommend facilitating a class discussion to co-construct these models and explain what happened in their experiment. Students can then go back and revise based on the classroom discussion.

7th Grade Science Unit 3: Mimicking Nature's Design
Task 3: Cycling Matter Through Living Things

Elaborate

1. In this activity, students take their understanding of photosynthesis and think about how that process interacts with cellular respiration to make ecosystems function properly. To do so, they imagine that a fish has been added to their original experimental set-up and placed in a light setting.
    - Students individually make a prediction about what would happen, drawing a new model, and explaining how cellular respiration and photosynthesis interact to cycle matter and energy through ecosystems.
    - This gives students more practice at **Developing and Using Models** and continues to emphasize the crosscutting concept of **Energy and Matter.** However, students are also beginning to look at these concepts through the lens of the supplementary crosscutting concept, **Systems and System Models,** as they show the interactions between two sub-systems (plant and animal, or cellular respiration and photosynthesis) as part of the functioning of the larger ecosystem.
    - Optional: Students can also set up an additional jar/test-tube to test their hypothesis. Have students follow the same instructions as the other jars, except add a sea snail or small fish.

2. Sample Student Responses
    - 1: If we left a fish and elodea in yellow BTB overnight, the BTB would likely stay the same color because both the fish and plant do cellular respiration, which produces carbon dioxide, but the plant also does photosynthesis, which uses up some of the carbon dioxide.
    - 2: Student should draw a light source and a jar with yellow BTB solution, a fish, and an elodea plant. Arrows and labels should show sunlight, water, and carbon dioxide entering the plant and oxygen leaving the plant. Arrows and labels should also show oxygen and the plant itself entering the fish, and carbon dioxide and water leaving the fish. This carbon dioxide and water can then be linked back to the plant as it is using these molecules for photosynthesis.



        i. 2a: During cellular respiration, animals use the molecules originally made by plants during photosynthesis. Plants can then recycle the carbon dioxide and water made during this process as they do photosynthesis. This is how the two processes interact to cycle matter in ecosystems. These processes also facilitate flow of energy by taking energy from the sun, which flows into plants for photosynthesis, and is then eaten by animals for cellular respiration, providing the energy they need.
    - 3: The sun drives this process.

3. This model and the corresponding explanations are a good opportunity for formative assessment. Collect student work to identify trends in students' ability to develop models of the two chemical processes responsible for cycling of matter and flow of energy in ecosystems. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

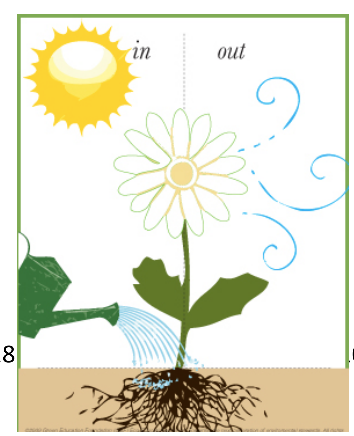
7th Grade Science Unit 3: Mimicking Nature's Design
Task 3: Cycling Matter Through Living Things

4. Return to the whole-class concept map from the Lift-Off Task.
   - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
     - Some possible facilitating prompts to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
     - Draw circles around each question and boxes around each concept.
     - Write connector words to describe connections between the concept boxes.
     - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: the cycling of matter and flow of energy in ecosystems, specifically relating to cellular respiration and photosynthesis.
   - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
     - **Energy and Matter**: These could be phrases such as, "is made by," "is put into," "is added to," "is cycled within," "is taken out by," "is extracted for," "is conserved," "is changed into," etc.
   - Once again, the purpose of this concept map is to facilitate the generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 3 section of the Unit 3 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with creating a sustainable aquaponics system that mimics the properties of the river environment, including any chemical reactions that may occur. Their prompt is as follows: Identify or add an organism to your aquaponics system that does photosynthesis.
   - Identify what molecules it will need to have in order to do photosynthesis. How will your system provide what the organism needs?
   - Identify what molecules it will create through this process. How will the system use up the products that it creates?
   - Draw a picture of your organism and the molecules identified,



using arrows to show whether the molecules enter or leave the organism.
  - Make connections to the organism you chose after Task 2: How do the plant and animal work together to cycle matter and keep energy flowing through the system?

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their Student Guide:
   - At the beginning of this task, you were asked to use your prior knowledge to explain why you think plants and animals grow over time. Look back at your explanations: after exploring photosynthesis and cellular respiration today, how would you change or add to your explanations? Use evidence from the task to justify your changes or additions and record below.
   - In this task, we focused on the crosscutting concept of **Energy and Matter**: The transfer of energy can be tracked as it flows through a system, is conserved, and drives the cycling of matter. Where did you see examples of **Energy and Matter** in this task?
   - Now that you have learned more about how cellular respiration and photosynthesis cycle matter and energy amongst living things in an ecosystem, what questions do you still have?

2. There are no right answers, but encourage students to look back at their Student Guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

Assessment

1. You may collect students' Project Organizer and assess using:
   - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
   - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
   - Students may make changes to their Project Organizer according to your comments OR
   - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

Investigation 2

Explore

Materials:

- Small Graduated Cylinder (to retrieve BTB solution from teacher)
- Bromothymol Blue Solution, using distilled water
- 2 Test Tubes or Baby Food Jars
    - If using Test tubes, need test tube rack
- 1-2 Sprigs Elodea Plant
- Straw
- Masking Tape
- Pen
- Sun Lamp
- Oatmeal Container or Cardboard Box (Dark Environment)

Procedure

1. Using your graduated cylinder, retrieve BTB solution from your teacher and return to your lab station. Blow into the BTB solution using a straw until the solution turns yellow (Check for Understanding: Once it turns yellow, what does this mean is in the water?)
2. Using your test tubes/baby jars, retrieve 2 sprigs of Elodea plant of approximately the same size and place one in each of your test tubes/baby jars. Return to your lab station.
3. Fill your test tubes/baby jars with BTB solution until the elodea sprigs are submerged.
4. Label one test tube/baby jar with your group's name, period, and "Dark".
5. Label one test tube/baby jar with your group's name, period, and "Light".
6. If using test tubes, place both test tubes into the test tube rack.
7. Record observations, including labeled and colored sketches, in your student guide.
8. Based on prior knowledge and what you learned in Investigation 1, make a prediction about what each lab set-up will look like in 24 hours. Record in your student guide.
9. Place the test tube/baby jar labeled "Dark" underneath the cardboard box/oatmeal container.
10. Place the test tube/baby jar labeled "Light" underneath the sun lamp.
11. Leave for 24 hours and then observe. Record results in student guide.

7th Grade Science Unit 3: Mimicking Nature's Design
Task 4: Cycling Matter Through Rocks

Unit Essential Question: *How does energy and matter flow within natural and designed ecosystems?*

Introduction

In the last task, students explored how photosynthesis and cellular respiration cycle matter and energy through living organisms in an ecosystem. However, this is not the only way matter is cycled in an ecosystem. Earth's materials can also be cycled through non-living components, like rocks, creating some of the changes students originally observed in the river environment in the Lift-Off Task. Students begin the task by thinking back to this river environment and some of the changes in rock formations they saw, using prior knowledge to consider why these changes occur. After simulating the rock cycle, students model the different processes that cycle Earth's materials, including how energy drives this process. By the end of this task, students are equipped to consider how the rock cycle may play a role in their aquaponics system.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [Assessment Boundary: Assessment does not include the identification and naming of minerals.]	**Developing and Using Models** • Develop and use a model to describe phenomena.	**ESS2.A: Earth's Materials and Systems** • 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.	**Stability and Change** • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.
Crosscutting Concepts • **Energy and Matter** ○ Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.			
Equity and Groupwork • Work within group roles to model the rock cycle. • Discuss errors in a model.			
Language • Learn new vocabulary by modeling the terms. • Represent new vocabulary in a visual model.			

7th Grade Science Unit 3: Mimicking Nature's Design
Task 4: Cycling Matter Through Rocks

Learning Goals

This learning task asks students to model how Earth's materials are cycled through rocks in ecosystems. More specifically, the purpose is to:

- Engage prior knowledge of what causes changes in rock formations, and how few rock-related changes are visible over short durations.
- Simulate the rock cycle, focusing on the processes that cycle Earth's materials.
- Create a visual model to describe how the flow of energy drives the cycling of Earth's materials in the rock cycle.
- Critique an incomplete or flawed rock-cycle model to inform revisions of their own model.
- Apply knowledge of the rock cycle processes to an aquaponics system design.

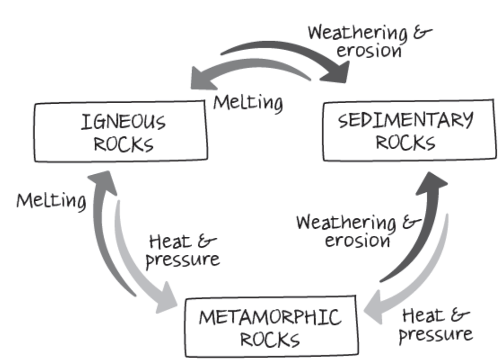
Content Background for Teachers

In this task, students continue to explore how matter is cycled and how energy flows within ecosystems. Having already looked at the role of living organisms in these processes, students are now examining the role of non-living components in cycling Earth's materials.

Rocks and minerals make up the majority of the planet's mass. They provide homes for organisms, make up much of Earth's landscape, and provide the basis for Earth's soil. Thus, rock and minerals are very important! The emphasis in this task is not on the type of rock or mineral, but rather the geoscience processes that form them and break them down. The processes students explore in this task are: the heating and compaction of rock deep underground, the cooling of very hot underground rock, and the physical and chemical breakdown of surface rock by wind and water.

These geoscience procesess are all driven by the flow of energy, which students will study through the crayon modeling activity. Thermal energy from Earth's interior provides energy in the form of intense heat, which leads to the deformation and crystallization processes of rock formation. Gravitational compaction provides energy in the form of pressure, which leads to the sedimentation process of rock formation. Earth's rock is also formed and broken down by interacting with other Earth systems, like the atmosphere and hydrosphere; these interactions are ultimately driven by energy from the sun. When rock is exposed to air, wind, or water, this can cause weathering of the rock. Weathering can be both physical and chemical.

When put together, these processes are known as the rock cycle. A classic representation from the NGSS framework is shown in the image to the right. As with most models, this rock cycle diagram can foster some misconceptions. For example, students may think that every rock experiences the same cycle or that the rock cycle occurs in this specific sequence. This model also doesn't explicitly show interactions with other Earth systems and the role of the Sun's energy. It is important to recognize and address these limitations as students explore Earth's cycling of materials. By the end of this task, students should have a more complete picture of how matter is cycled in an ecosystem, through both living and non-living components.



7th Grade Science Unit 3: Mimicking Nature's Design
Task 4: Cycling Matter Through Rocks

**For more background information, see the Crayon Modeling Resource Card.

Academic Vocabulary

- Rock formation
- Weathering
- Erosion
- Pressure
- Heat
- Sedimentation
- Deformation
- Crystallization
- Igneous Rock
- Sedimentary Rock
- Metamorphic Rock
- Rock Cycle
- Gravity

Time Needed (Based on 45-Minute Periods)

4.5 Days

- Engage: 0.5 period
- Explore: 1 period
- Explain: 1 period
- Elaborate: 1 period
- Evaluate and Reflection: 1 period

Materials

- Unit 3, Task 4 Student Version

Explore (Per Group)

- Modeling the Rock Cycle with Crayons Card (in a sheet protector)
- Crayons (at least two different colors)
- Source of very hot water in container
- Tweezers or small tongs
- Aluminum foil square
- Plastic knives
- Optional: Bring in real rocks as examples of the different types of rocks in the rock cycle

Elaborate (Per Pair)

- Critique, Correct, Clarify – Rock Cycle Model

Evaluate

- Project Organizer Handout

7th Grade Science Unit 3: Mimicking Nature's Design
Task 4: Cycling Matter Through Rocks

Instructions

Engage

1. Introduce Task 4: In the last task, we saw how some substances are cycled through living parts of the environment. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
   - Before you pass out their Student Guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 4: Today we will look at how other matter can cycle through the non-living parts of our environment, specifically through rocks!
   - Now pass out the Task 4 Student Guide.

3. In this activity, students think back to the changes they observed in their river environment, using the photos on their Student Guide to remind them. In pairs, ask students to find at least two changes in rock formations that occurred over 200 years. They should record each and explain why they think each happened.
   - You may want to encourage them to refer back to their Task 1 Student Guide for a list of all the changes they originally noticed.
   - Students' first instinct will be to look for obvious changes (ie. The big boulder in the front right of the photo). Encourage students to consider that the majority of the landscape is made of rock, and to use their own personal experience of the outdoors to help them.
   - Some sample responses may include:
     - The widening of the riverbed is due to continued pressure from the waterfall.
     - The erosion of the rock on the left is due to weathering from wind and rain over 200 years.
   - After pairs brainstorm and discuss, use equity sticks to share out ideas in a class-wide discussion (See "How to Use This Curriculum" for more details on how and why to use equity sticks).

4. The second question that follows asks students to begin thinking about the widening of the riverbed through the lens of **Stability and Change**, which is the CCC for this task. By drawing pictures of the riverbed now, 1 year ago, and 200 years ago, they begin to think about why many of these large-scale changes are only seen over long-term scales (ie. hundreds of years) instead of short-term scales.
   - Keep in mind that at this point some students may show noticeable changes even after one year, even though in reality these changes are likely not visible. They will revisit this concept after they have gathered more information in the *Explore.*

Explore

1. Rock is a crucial non-living part of our environments and when it appears to change or go away, as in the pictures above, it doesn't just disappear! This activity reminds students that the conservation of matter applies in how Earth's materials, like rock, are *cycled* through an environment.

- Here, students are engaging in the practice of **Developing and Using Models**, using guided instructions to develop a kinesthetic model of the rock cycle. This will set the stage for them to later develop a visual model of their own.

2. Pass out the Modeling Instructions Card and the relevant materials to each group. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
   - Ask the Facilitator to read the directions and to make sure everyone understands the investigations.
   - Ask the Materials Manager to handle any resources needed to complete the modeling activity.
   - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
   - Ask the Recorder to make sure the group is recording their observations in their Student Guides.

3. Students model the rock cycle with a focus on the processes rather than the type of rock. As they follow the directions on their resource card, they should answer the questions that are embedded within the procedure as well as their Student Guide.
   - These questions help students focus on the supplementary CCC of **Energy and Matter** as students consider the role of energy in driving each of these processes.
   - Optional: Provide an analogy map like the one shown below so students can clearly understand what the components of the model represent.

	Part of the Model	**What It Represents in Real Life**
Weathering	Crayon Shavings	
	Grating the Shavings with a Tool	
	Moving the Crayon Shavings	
Sedimentation	Layering of Crayon Shavings	
	Pressing Down with Fingers	
Deformation	Heat from Water	
	Partial Melting of Crayon	
Crystallization	Heat from Water	
	Full Melting and Cooling of Crayon	

4. Below is a summary of each process represented in the crayon model:
   - Weathering: Energy from the sun drives weather patterns, which create wind and water. Wind and water can cause both weathering (breaking down of rock into sediments) and erosion (movement of sediments). This is shown in the model as students physically shave the crayon and move the sediments around.
   - Sedimentation: This process includes the layering and compaction of sediments into sedimentary rock. In the model, the pressure of their fingers represents the gravitational compaction that occurs from layering of sediment.
   - Deformation: In deformation, heat and pressure from within the Earth change the chemical composition of rock. In this model, the heat and pressure is represented by the hot water transferred to the crayon "rock" through the aluminum foil.

- Crystallization: The main difference between this process and deformation is that crystallization entails full melting and cooling of rock, which is again represented by heating the crayon "rock" with the hot water.
- Optional: Bring in examples of the different types of rock to provide to each group for comparison.

5. The final question asks students to return to the timeline of the widening riverbed from the *Engage*. By examining rock cycle processes at this scale and comparing to the change in rocks they observe in reality, students should be better able to conclude that these processes are always happening but at a rate so slow, they cannot see them in short periods of time.

6. After students complete this modeling activity in small groups and complete the table with their observations, it is recommended that you do a class debrief of the discussion questions. In particular, emphasize how energy (from the Sun and Earth's interior) drives all of these processes.
    - Use equity sticks to create a more equitable discussion (See "How to Use This Curriculum" for more details).

Explain

1. Now that students have modeled each of the processes that cycle Earth's materials with a given procedure, they can turn this into a visual model of the entire cycle.
    - This gives students more practice at **Developing and Using Models**, building off the kinesthetic modeling done in the *Explore* to combine all the processes as part of one cycle. This also emphasizes the supplementary CCC of **Energy and Matter** as students again include the role of energy in driving this cycle.
    - Read the instructions aloud together as a class, emphasizing that students must use all the terms in the box on their Student Guide. Invite clarifying questions before students begin working on models individually.
    - Optional: You may want to model the process of using pictures, labels, and arrows by sketching one component of the model on the board. Pick one type of rock and draw an arrow connecting it to another type of rock. Label the arrow with the name of the process and a caption describing what is needed to cause the transformation.

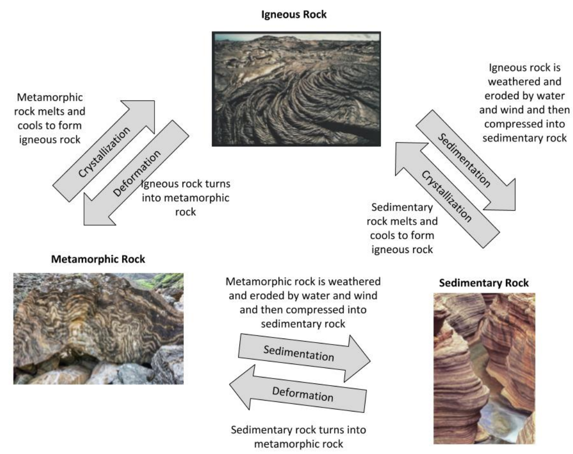
2. Students create a flowchart model showing how Earth's materials cycle throughout the environment.
    - For an extra challenge, you may remove, or limit, the list of terms provided.
    - In the final product, specifying the type of rock is less important than an understanding of each process in the rock cycle, including what causes each process to occur.
    - We recommend this model be drawn independently since students have already had a chance to co-construct a kinesthetic model in the *Explore* and this can then be used as a formative assessment of student understanding.

Elaborate

1. This activity gives students an opportunity to self-assess and revise their own model based on their critique of a model that has some errors. This activity is a language protocol known as Critique, Correct, Clarify.

- These can be completed in pairs, in groups, or individually. As with the previous section, if done individually, this can be used as a formative assessment.

2. Pass out a *Critique, Correct, Clarify – Rock Cycle Model* to each pair of students. Students will analyze the model to identify and discuss any errors they see, including ideas that are not clear or missing. They then write on the model to make it clearer and more accurate and describe how and why they corrected the model.



   - For students who are struggling, here are some facilitating questions you might ask: Look at your box of terms…what does the model do well? What is the model missing? Where and how would you be better able to incorporate these ideas? Will you change one part of the model or many parts of the model?
   - In their critique, students should notice that all types of rock and processes are identified and explained correctly. However, the role of energy in driving all of these processes is missing throughout the model. This would need to be added into each of the captions. This continues to emphasize the supplementary CCC of **Energy and Matter** as students identify the role of energy driving this cycle that is missing from the model.
   - We recommend sharing out critiques and revisions as a class before students go back to revise their own model in the *Explain* section of their Student Guides.

2. This revised model is a good opportunity for formative assessment. Collect student work to identify trends in students' ability to develop models of rock cycle processes, including the role of energy in cycling matter. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

3. Return to the whole-class concept map from the Lift-Off Task.
   - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
     - Some possible facilitating prompts to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
     - Draw circles around each question and boxes around each concept.
     - Write connector words to describe connections between the concept boxes.

   - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: how energy drives the cycling of matter through rocks.
- Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
   - **Stability and Change**: These could be phrases such as, "remains the same", "is changed by", "is disrupted by", "changes", "disrupts," etc.
- Once again, the purpose of this concept map is to facilitate the generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 4 section of the Unit 3 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with creating a sustainable aquaponics system that mimics the properties of the river environment, including any cycling of matter that occurs through the rock cycle. Their prompt is as follows: Look back at your design sketch for your aquaponics system.
   - How might cycling of matter come into play in your aquaponics system?
   - Describe which process(es) of the rock cycle might occur in your aquaponics system over time.
   - What will the effects be on your system?

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
   - At the beginning of this task, you were asked to identify changes in rock formations of the river environment and make hypotheses as to why they happened. Look back at your hypotheses: after exploring the rock cycle today, how would you change or add to your response? Use evidence from the task to justify your changes or additions and record below.
   - In this task, we focused on the crosscutting concept of **Stability and Change**: Stability and change can be explained by looking at changes over time and at different scales. Where did you see examples of **Stability and Change** in this task?
   - Now that you have learned more about how rocks also cycle matter in ecosystems, what questions do you still have?

2. There are no right answers, but encourage students to look back at their Student Guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their

own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

Assessment

1. You may collect students' Project Organizer and assess using:
    - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
    - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

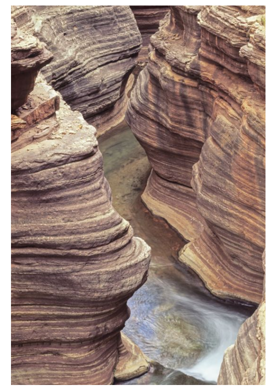
2. You may also give students time to make revisions with one of the two options:
    - Students may make changes to their Project Organizer according to your comments OR
    - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

Modeling the Rock Cycle with Crayons
Explore

Weathering:

1. Scrape crayons with your grating tools (plastic knives or popsicle sticks); this is analogous to a process called weathering in real life. Then move the crayon pieces around; this process is known as erosion in real life.
    - **In real life, wind and water cause weathering and erosion. Based on what you learned in 6th grade, what energy source is ultimately responsible for weather like wind and rain?**

Sedimentation



1. Gather a pile of sediments, or small pieces of rock, collected from various scraped crayons. Make layers of different color crayon sediments.
2. Press down on this pile to allow the particles to stick together.
    a. Encasing the sediments between sheets of paper, foil, etc will help keep the sediments together. Using a utensil or stepping on your pile will help this process along too.
        - **Here we are applying pressure with our fingers. Where do you think this pressure comes from with real rocks?**
3. Your pressed bunch of crayon sediments is now equivalent to a sedimentary "rock".

Deformation

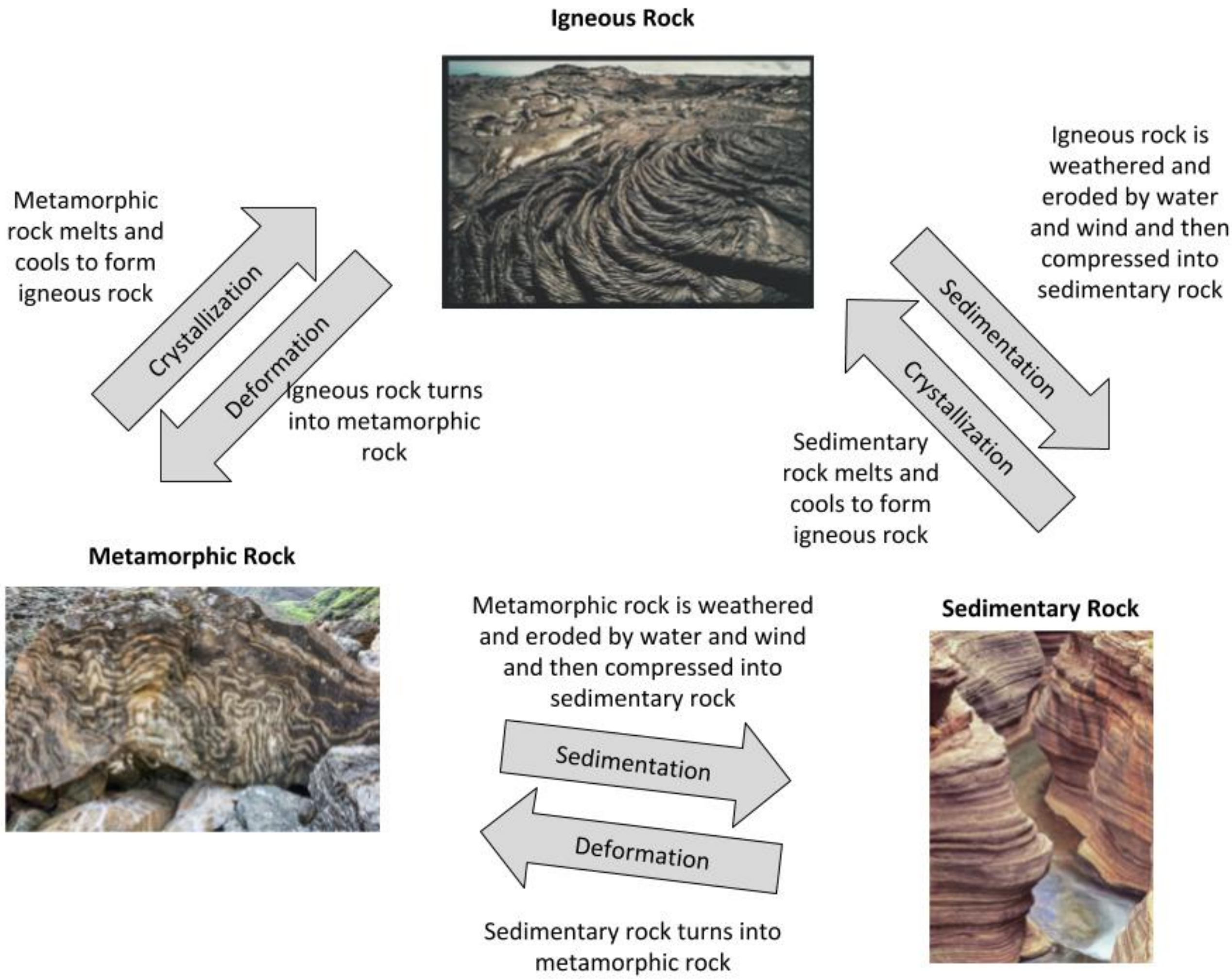
1. Place a small pile of sedimentary crayons into a piece of aluminum foil or foil cupcake cup.
2. Float this foil on hot water.
    - **Heat and pressure are very important in the rock cycle. Hypothesize: where do you think this heat comes from in real life?**
3. Remove the foil when the crayon wax is soft to the touch (don't use your finger, use a probe such as a popsicle stick).
4. Let your crayons cool.
5. Your partially melted and cooled crayons are now equivalent to metamorphic "rocks".

Crystallization

1. Place a small pile of sedimentary or metamorphic crayons into your piece of aluminum foil.
2. Float this crayon-containing foil on hot water.
3. When a smooth liquid forms, carefully remove the molten crayon wax and let cool. Your totally melted and cooled crayons are now equivalent to igneous "rocks".
    - **How is the process of deformation different from crystallization? Which one requires more heat?**

Critique, Correct, Clarify – Rock Cycle Model

Elaborate



7th Grade Science Unit 3: Mimicking Nature's Design
Task 5: Design a Thermal Device

Unit Essential Question: *How does energy and matter flow within natural and designed ecosystems?*

Introduction

Throughout this unit, students have seen heat being absorbed and released in the chemical reactions they observed. This was the case with chemical changes in Task 1, cellular respiration (ATP formation) in Task 2, photosynthesis (sunlight) in Task 3, and geoscience processes in the rock cycle in Task 4. In this task, students use their knowledge to approach a design problem: How can they heat a pool in the river environment so blue catfish are able to spawn? Students will use hot packs and cold packs in their initial investigations, testing which chemical reactions absorb or release heat. They will then use what they learned from these investigations to develop models of heat-regulation devices, which they will then build, test, and revise for their final product. Throughout this task, students are engaging in the complete engineering and design process, applying new knowledge and skills to the design of their aquaponics system. The device that students design in this task will be modified and used in their aquaponics system design.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.* [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.]	**Designing Solutions** • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific criteria and constraints.	**PS1.B: Chemical Reactions** • Some chemical reactions release energy, others store energy.	**Energy and Matter** • The transfer of energy can be tracked as energy flows through a designed or natural system.
MS-ETS1-3. Analyze data from tests to determine similarities and differences	**Analyzing and Interpreting Data** • Analyze and	**ETS1.B: Developing Possible Solutions** • There are systematic	**N/A**

among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	interpret data to determine similarities and differences in findings.	processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. **ETS1.C: Optimizing the Design Solution** • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process – that is, some of the characteristics may be incorporated into the new design.	
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	**Developing and Using Models** • Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	**ETS1.B: Developing Possible Solutions** • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. • Models of all kinds are important for testing solutions. **ETS1.C: Optimizing the Design Solution** • The iterative process of testing the most	**N/A**

<table>
<tr><td></td><td></td><td>promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.</td><td></td></tr>
<tr><td colspan="4">Supplementary Science and Engineering Practices
• Planning and Carrying Out Investigations
o Conduct an investigation […] to produce data to serve as the basis for evidence that meets the goals of the investigation.</td></tr>
<tr><td colspan="4">Equity and Groupwork
• Work within group roles to conduct investigations and build and test prototypes.
• Come to consensus on a design solution.</td></tr>
<tr><td colspan="4">Language
• Describe similarities and differences in data.
• Describe an experiment using procedural language.</td></tr>
</table>

Learning Goals

This learning task asks students to build, design, test, and refine a device that releases heat through a chemical reaction. More specifically, the purpose is to:

- Engage prior knowledge of how a change in one part of an environment can lead to further changes in the environment.
- Investigate how hot packs and cold packs work, specifically which mixture of substances leads to a chemical reaction that absorbs or releases heat.
- Use evidence from investigations to design two heat-regulation devices, and to develop models to explain their operation.
- Build and test two possible heat-regulation device prototypes, and use all groups' data to inform a final refined design that best meets the criteria and constraints of the problem.
- Draw, label, and explain a model of the final heat-regulation device to be used in their aquaponics system, including the data to support the design.

Content Background for Teachers

In this task, students use their prior knowledge of energy from earlier tasks to build, test, and modify a device that releases thermal energy. More specifically, students are designing heat-regulation devices that can keep river water warm enough for fish spawning, using hot and cold packs as inspiration.

Most commerical hot and cold packs contain dry chemicals and a sealed inner pouch of liquid (usually water). The hot or cold pack is activated by breaking the seal on the liquid pouch, and shaking the pack vigorously. The shaking mixes the liquid with the chemical substances, initating either an exothermic (heat-releasing) or endothermic (heat-absorbing) reaction.

Students investigate hot and cold packs during the *Explore* by testing five chemical reactions: sodium bicarbonate and water, potassium chloride and water, sodium bicarbonate and vinegar, sodium bicarbonate and calcium chloride and water, and calcium chloride and water. The first three reactions are endothermic, meaning they feel cold to the touch. This is because it takes more energy to break the bonds than will be given off when the new substances are formed. The fourth and fifth reactions are exothermic, meaning that they feel warm to the touch. This is because it takes less energy to break the bonds than is given off when the substances dissolve in liquid.

Once students have tested these five chemical reactions for heat absorption or heat release, they can select the best-suited chemical reactions for their heat-regulation device prototypes. By the end of this task, students will able to apply a version of this device to their aquaponics system.

Academic Vocabulary

- Spawn
- Heat
- Absorb
- Release
- Temperature
- Heat-Regulation
- Criteria
- Constraints
- Design Solution
- Prototype

Time Needed (Based on 45-Minute Periods)

5.5 – 6.5 Days

- Engage: 0.5 period
- Explore: 1 period
- Explain: 1 period
- Elaborate: 2-3 periods
- Evaluate and Reflection: 1 period

Materials

- Unit 3, Task 5 Student Version

Explore (Per Lab Group)

- Thermal Chemical Reactions Investigation Card (in sheet protector)
- Calcium chloride (used to melt ice on driveways in winter)
- Potassium chloride (e.g., Morton Lite™)
- Sodium bicarbonate (baking soda)
- Vinegar
- Five sandwich-size zip-lock bags
- Tablespoon measuring spoons

- 100 ml graduated cylinder
- Water
- Sharpie
- Materials List from Designing Heat-Regulation Devices Resource Card

Elaborate (Per Lab Group)

- Designing Heat-Regulation Devices Resource Card (in sheet protector)
- Students pick substances from the following list: calcium chloride, potassium chloride, sodium bicarbonate, vinegar
- Cold water
- Hot water (We recommend preparing a class-size vat of hot water so groups can start with hot water and add cold water to bring down the temperature to 68 degrees)
- Tablespoon measuring spoons
- 100 ml graduated cylinder
- 2 500 ml beakers
- Ice
- 2 Thermometers
- 2 - 4 sandwich-size zip-lock bags (thick and thin options)
- Additional material choices for building and modification of prototypes (ie. plastic wrap, foil, tape, cloth, felt, containers of different materials and sizes)

Evaluate

- Project Organizer Handout

<u>Instructions</u>

Engage

1. Introduce Task 5: Throughout previous tasks, you have thought about how energy, like heat or sunlight, drives the cycling of all matter on Earth. For example, we saw that great amounts of energy, or heat from the Earth's core, was required to change sedimentary rock into igneous rock. Before we move forward, think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their Student Guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 5: Throughout this unit, you have seen that heat is either absorbed or released in the chemical reactions you have observed. In this task, you will investigate these kinds of chemical reactions, and use what you learn to help address a problem the river environment is facing today.
    - Now pass out the Task 5 Student Guide.

3. Read the scenario on their Student Guides aloud: Blue catfish, as shown in the picture below, are very important to the river environment. However, in recent years the river environment has experienced climate changes, leaving the river water a few degrees colder than normal. It turns out that colder water interferes with fish spawning, which can only happen at a certain range in water temperature.

- This introduction links back to prior tasks, and sets the context for the design challenge in this task.
- Before moving on to the questions, take any questions that students have about the context of the design challenge.
  - We recommend explcitly defining the term spawn for students (ie. the process of laying eggs, reproduction, or making more fish).

4. In pairs or groups, have students think about the questions below the picture of the river environment. These questions are intended to motivate a need for their design solution as well as emphasize the core theme of interconnectedness in ecosystems. Below are some sample student responses.
   - Question 1: If fish are unable to reproduce, the population will die out over time.
   - Question 2: Anything that eats the fish will lose a food source and could also go extinct. This chain would continue. Also, whatever the fish eats will grow in population and could overtake other resources.

Explore

1. Now that students have an idea of why saving the Blue Catfish matters, they can begin to think about designing a device to keep the river water warm enough for fish spawning. Students will investigate hot packs and cold packs as inspiration to inform their design.
   - Read the introduction on their Student Guide aloud so students know that most commercial instant hot packs and cold packs use chemical reactions that either absorb or release heat, a concept they are familiar with from prior tasks. Each hot and cold pack uses different substances that when combined cause a chemical reaction to occur.

2. You may choose to pass out the Investigation Card and all materials to each group, or to set this investigation up as rotating stations (1 chemical reaction per station).

3. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
   - Ask the Facilitator to read the directions and to make sure everyone understands the investigations.
   - Ask the Materials Manager to handle any resources needed to complete the investigations.
   - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
   - Ask the Recorder to make sure the group is recording their observations in their Student Guides.

4. Students use the materials provided and the Investigation Card provided to test each combination of substances they are given. Based on their observations, they then decide which ones lead to chemical reactions that release heat and which ones lead to chemical reactions that absorb heat.
   - This emphasizes the crosscutting concept of **Energy and Matter** as students track how energy flows through these chemical reaction systems. This activity also gives students practice at the supplementary SEP of **Planning and Carrying Out Investigations** as students conduct investigations to gather evidence that chemical reactions can absorb or release heat.

- *__Safety note__: Remind students that gas may result from some of the chemical reactions, so they should be sure to let gas out of the bag as needed (or it will pop).

5. We recommend writing a data table on the board and conducting a class-wide debrief that elicits which combined substances released or absorbed heat. This will lay the foundation for their design later in the task. Again, the use of equity sticks is encouraged (See "How to Use This Curriculum" for more details).

6. Possible Investigation Extension – As students are generally excited by chemical reactions, and because this investigation does not have students investigate every possible combination of the reactants given, you might permit students to select one other combination they'd like to investigate based on the data collected thus far and using the materials provided. Ask students to briefly explain why they selected this extra investigation, and to predict what will happen based on data collected during the investigation. They should show you this before proceeding with their extra investigation.

Explain

1. In the *Explain*, students use what they have learned from the *Explore* to answer questions that will help them design a heat-regulation device.
   - Read the context aloud and take clarifying questions to ensure that all students understand the scenario: The Blue Catfish spawns in river water at 70-75 degrees Fahrenheit, but the pool where they spawn is currently at a temperature of 68 degrees Fahrenheit.
   - This *Explain* and subsequent *Elaborate* asks students to practice multiple elements of the engineering and design performance expectations. The *Explain* emphasizes the SEP of **Designing Solutions** as students undertake a design project, engaging in the design cycle, to construct a solution that addresses the fish-spawning problem.
   - We recommend assigning group roles for this section of the task, mixing up the assigned roles from the *Explore*.

2. First students engage in the practice of defining design criteria and constraints. This process is guided by facilitating questions. Sample student responses are below:
   - 1a: My device needs to warm up the water temperature of the river to at least 70 degrees, but no more than 75 degrees, so fish spawning can occur. I can measure the success of the device by testing the temperature of the water at the end.
   - 1b: The substances will need to be put in some sort of container and then put in the water, so chemicals don't pollute the water.

3. Students then use the data they collected in the *Explore* to decide which combination of substances to use in order to best meet the criteria of the problem.
   - This asks students to begin practicing the SEP of **Analyzing and Interpreting Data** as they interpret data for similarities and differences that they can use to categorize reactions as heat-releasing or heat-absorbing.
   - The following two chemical reactions from the *Explore* produce heat: sodium bicarbonate and calcium chloride and water, and calcium chloride and water. Students should be able to select one of these substance combinations as the best option for their heat-regulation device.

- This response to Question #2 is a good opportunity for formative assessment. Review student work to identify trends in students' ability to use understanding of criteria and data analysis to select the best chemical reactions. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

4. Lastly, students use one of the above chemical reactions to develop models of two different designs for their heat-regulation device, which they will build and test in the *Elaborate*. Both models should use the same chemical reaction, but will vary in the structure and materials of the device.
   - This asks students to engage in the SEP of **Developing and Using Models** to generate data to test ideas about designed systems. By identifying inputs and outputs in the models, they are also emphasizing the CCC of **Energy and Matter** as they track energy flow into and out of the designed system.
   - Before groups design and draw their models, review a list of materials you plan to offer them during the building process. You may use the material list in the *Designing Heat-Regulation Devices Resource Card* and add to it as desired. Adding additional materials will lead to more variety in design solutions (ie. double-bagging vs. single-bagging, foil on the outside of a Tupperware vs. plain Tupperware, double-bagging vs. double-bagging with a layer of cloth between bags, etc.)

5. Collect these models, which provide a summative assessment of the Engineering and Design Performance Expectation MS-ETS1-4. A rubric is provided at the end of this teacher version.
   - You may also wish to make this a checkpoint in which you give student groups feedback on their models, as necessary, before they can move forward to the testing process in the *Elaborate*. For groups who are struggling, encourage them to refer back to the criteria and constraints of the problem to make sure their design meets these.

Elaborate

1. Now that students have developed models of potential design solutions, they can test these devices to see which best satisfies the criteria for the catfish problem in the river environment.
   - Here, students continue to engage in the engineering and design cycle as they practice the SEP of **Designing Solutions.**

2. Pass out Design Card to groups and make materials available so groups can use what they need to build their devices. Assign student roles, mixing up their assigned roles from the *Explore*.

3. Keeping the criteria and constraints of the problem in mind and using the Design Card to guide them, students draw what their experimental set-up will look like and describe how they set up their experiment.
   - In their experimental set-up, students should show two beakers with approximately the same amount of water and a thermometer in each. Labels should note that each of the beakers starts at 68 degrees. Each of the chemical reactions should be conducted in some kind of container to be put into the water. This avoids contaminating the water, thus meeting an important constraint of the problem.

- We recommend checking students' experimental set-up and providing feedback before they move on to the actual test. If necessary, remind students to label each device to differentiate between the two.

4. Once their experimental set-up is approved, they may run the tests.
    - Remind students to record their data in the table provided on their Student Guides.
    - Note: In their data table, everyone should have 68 degrees as their starting temperature. If students get stuck on this, refer them back to the initial context at the beginning of the *Explain*.
    - Once the temperatures of both beakers seem to stabilize, they may record their ending temperature.

5. Once students have tested their two designs, they engage in the SEP of **Analyzing and Interpreting Data** as they interpret test data for similarities and differences that they can use to select best characteristics and improve their device.
    - Students first compare data about their own two designs to decide which worked better to meet the criteria of the problem.
    - Then, have groups share their best design with the class, including the data that supports it. We recommend using a document camera so each group can show their model and data. However, you may also have students draw on a whiteboard or share verbally. Make sure the rest of the class is recording features about designs they like, including the data to support them, in their student guides. They will use this information to revise their device and as evidence in the *Evaluate* section of this task.

6. Based on what they learn from other groups, students evaluate the data to identify best characteristics that they might combine with their design's best characterstics. Groups decide what adjustments they would like to make (ie. types of materials, amount of substances used, structure, etc.) and draw a labeled model of their revised device.
    - Encourage students to combine the best characteristics from their own design and others design. However, if students also feel they need to try testing a new combination of solutions, material, or structure, they may do so at this stage.
        - For example, using data from other designs, a group may choose to double-bag their prototype or reduce the amount of reactants if too much thermal energy is being transferred.
    - Students then run the test again using their revised device and collect data to finalize a design solution.
    - Student should also specify how they could continue to improve their design and justify the reason for those suggestions. Alternatively, if time and materials permit, they may continue to modify the device and re-test until it meets the criteria and constraints of the problem.

7. Return to the whole-class concept map from the Lift-Off Task.
    - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity

sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
    - Some possible facilitating prompts to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
    - Draw circles around each question and boxes around each concept.
    - Write connector words to describe connections between the concept boxes.
    - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: how chemical reactions can be used to design solutions for the regulation of temperature.
  - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
    - **Energy and Matter**: These could be phrases such as, "is made by," "is put into," "is added to," "is cycled within," "is taken out by," "is extracted for," "is conserved," "is changed into," etc.
  - Once again, the purpose of this concept map is to facilitate the generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 5 section of the Unit 3 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with creating a sustainable aquaponics system that mimics the properties of the river environment and regulates the temperature of the fish tank. Their prompt is as follows: Now that you have designed a heat-regulation device to help maintain river water temperature, you can use this knowledge to design your own heating devices that will work to maintain the temperature of your aquaponics fish tank.
    - Draw the final heat-regulation device.
        - Label the materials used and explain how it works.
    - Describe how you combined best characteristics of different designs to create a device that best meets the criteria and constraints.
        - Cite the data that supported your decisions.

3. This section of the Project Organizer provides a summative assessment of the Engineering and Design Performance Expectation MS-ETS1-3. A rubric is provided at the end of this teacher version.

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
   - At the beginning of this task, you were asked to consider the effects if fish can't spawn in the river environment. After designing a heat-regulation device today, how will these effects be reduced? Use evidence from the task to back up your explanation.
   - In this task, we focused on the crosscutting concept of **Energy and Matter**: The transfer of energy can be tracked as it flows through a system, is conserved, and drives the cycling of matter. Where did you see us looking at **Energy and Matter** in this task?
   - Now that you have learned more about how we can use chemical reactions to regulate temperature, what questions do you still have?

2. There are no right answers, but encourage students to look back at their Student Guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

Assessment

1. Collect students' Task 5 Student Versions and assess the *Explain* using Rubric 1 of the 3-Dimensional Task 5 Rubrics below.

2. Collect students' Project Organizer and assess using Rubric 2 of the 3-Dimensional Task 5 Rubrics below.

3. You may also give students time to make revisions with one of the two options:
   - Students may make changes to their Project Organizer according to your comments OR
   - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

7th Grade Science Unit 3: Mimicking Nature's Design
Task 5: Design a Thermal Device

Task 5 Rubric 1: Student develops models for iterative testing of a proposed heat-regulation device, describing how they acknowledge constraints and use an exothermic reaction to meet the criteria.

- Use to assess student responses for Prompt #3 of Explain
- Dimensions Assessed: SEP – Developing and Using Models; DCI – ETS1.B: Developing Possible Solutions
- Note: The relevant exothermic reactions are sodium bicarbonate and calcium chloride and water, and calcium chloride and water.

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student develops **irrelevant** models for iterative testing of a proposed heat-regulation device.	Student develops **partial** models for iterative testing of a proposed heat-regulation device, describing how they acknowledge constraints **OR** use an exothermic reaction to meet the criteria.	Student develops **complete** model for iterative testing of a proposed heat-regulation device, **partially** describing how they acknowledge constraints and use an exothermic reaction to meet the criteria.	Student develops **detailed** models for iterative testing of a proposed heat-regulation device, **completely** describing how they acknowledge constraints and use an exothermic reaction to meet the criteria.
Look Fors: ● Student's heat-regulation device models are irrelevant because they show no understanding of criteria or constraints. For example, they choose an endothermic reaction and dump chemicals straight in the river.	**Look Fors:** ● Student's heat-regulation device models show one, but not both of the following: 1) Meets the criteria of warming up the water by using a relevant exothermic chemical reaction from the *Explore*, and 2) Acknowledges constraint of minimizing pollution by containing the chemical reactions with some kind of material or structure (ie. plastic bag or container).	**Look Fors:** ● Student's heat-regulation device models show both of the following: 1) Meets the criteria of warming up the water by using a relevant exothermic chemical reaction from the *Explore*, and 2) Acknowledges constraint of minimizing pollution by containing the chemical reactions with some kind of material or structure (ie. plastic bag or container). ● The explanation of each model, in the form of labels and captions, is partial. For example, student labels the substances in the exothermic reaction and describes that it releases heat. However, while student shows the chemicals inside plastic bags, they don't explicitly explain why.	**Look Fors:** ● Student's heat-regulation device models show both of the following: 1) Meets the criteria of warming up the water by using a relevant exothermic chemical reaction from the *Explore*, and 2) Acknowledges constraint of minimizing pollution by containing the chemical reactions with some kind of material or structure (ie. plastic bag or container). ● The explanation of each model, in the form of labels and captions, is complete. For example, student labels the substances in the exothermic reaction and describes that it releases heat. Student also shows the chemicals inside plastic bags, and explains that this prevents water pollution.

7th Grade Science Unit 3: Mimicking Nature's Design

Task 5: Design a Thermal Device

Task 5 Rubric 2: Student redesigns a heat-regulation device to better meet the criteria for success, referencing the relevant test data of different devices to explain why they combine best characteristics.

- Use to assess Task 5 Section of Project Organizer
- Dimensions Assessed: SEP – Analyzing and Interpreting Data; DCI – ETS1.C: Optimizing the Design Solution

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student redesigns a heat-regulation device to better meet the criteria for success, **but does not** explain why they combine best characteristics. OR Student redesigns a heat-regulation device **that does not** meet the criteria for success.	Student redesigns a heat-regulation device to better meet the criteria for success, **but does not reference** the relevant test data of different devices to explain why they combine best characteristics.	Student redesigns a heat-regulation device to better meet the criteria for success, **referencing some** of the relevant test data of different devices to explain why they combine best characteristics.	Student redesigns a heat-regulation device to better meet the criteria for success, **referencing all** of the relevant test data of different devices to explain why they combine best characteristics.
Look Fors: ● Student's heat-regulation device shows clear improvement that combines best characteristics from different designs (from own and other groups). However, student provides no explanation of why it combined these design features. OR ● Student's heat-regulation device does not show any improvements or does not combine best characteristics from different designs.	**Look Fors:** ● Student's heat-regulation device shows clear improvement that combines best characteristics from different designs (from own and other groups). ● Student explains why they combined these design features, but does not reference any data. For example, "We used our original chemical reaction and wrapped it in foil, like another group did, because it warmed the water."	**Look Fors:** ● Student's heat-regulation device shows clear improvement that combines best characteristics from different designs (from own and other groups). ● Student explains why they combined these design features, using one piece of data. For example, "We used our original chemical reaction because it warmed the water. We also wrapped it in foil because another group's data showed that this led to a higher temperature. In the final test, data showed that this revised design works, resulting in a temperature of 73 degrees."	**Look Fors:** ● Student's heat-regulation device shows clear improvement that combines best characteristics from different designs (from own and other groups). ● Student explains why they combined these design features, using multiple pieces of data. For example, "We used our original chemical reaction because it warmed water to 70 degrees. We also wrapped it in foil because another group's data showed that this led to a higher temperature of 74 degrees. In the final test, data showed that this revised design works, resulting in a temperature of 73 degrees."

Thermal Chemical Reactions Investigation

Explore

Experimental Question: Which chemical reactions absorb heat and which chemical reactions release heat?

Materials

- Calcium chloride (used to melt ice on driveways in winter)
- Potassium chloride (e.g., Morton Lite™)
- Sodium bicarbonate (baking soda)
- Vinegar
- Five sandwich-size zip-lock bags
- Tablespoon measuring spoons
- 100 ml graduated cylinder
- Water
- Sharpie

Procedure

1. Put 1 tablespoon calcium chloride into a plastic bag, labeled "calcium chloride." Using your graduated cylinder, add 65 mL water and then close and shake the bag. Let out gas as needed. Observe what happens and record your observations in the data table on your student handout.

2. Put 1 tablespoon sodium bicarbonate into a plastic bag, labeled "sodium bicarbonate." Using your graduated cylinder, add 65 mL water and then close and shake the bag. Let out gas as needed. Observe what happens and record your observations in the data table on your student handout.

3. Put 1 tablespoon potassium chloride into a plastic bag, labeled "potassium chloride". Using your graduated cylinder, add 65 mL water and then close and shake the bag. Let out gas as needed. Observe what happens and record your observations in the data table on your student handout.

4. Put 1 tablespoon sodium bicarbonate and 1 tablespoon calcium chloride into a plastic bag, labeled "sodium bicarbonate and calcium chloride." Using your graduated cylinder, add 65 mL water and then close and shake the bag. Let out gas as needed. Observe what happens and record your observations in the data table on your student handout.

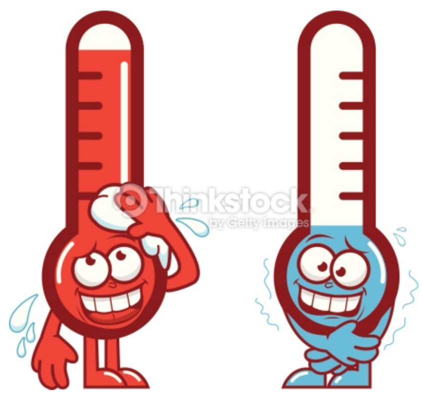
5. Put 1 tablespoon sodium bicarbonate into a plastic bag, labeled "sodium bicarbonate and vinegar." Using your graduated cylinder, add 65 mL vinegar to the bag. Do not close the bag and carefully shake the contents. Observe what happens and record your observations in the data table on your student handout.

Designing Heat-Regulation Devices

Elaborate

Possible Materials To Build Your Prototypes

- Pick your substances from the following list: calcium chloride, potassium chloride, sodium bicarbonate, vinegar, water
- Cold water
- Warm water
- Tablespoon measuring spoons
- 100-ml graduated cylinder
- Sandwich-size zip-lock bags
- 500-ml beakers
- Ice
- Thermometers
- Additional Materials Provided By Teacher



Procedure

1. Set up your experiment using the following questions and instructions to guide you:
    a. Based on what you know about your river environment, what temperature should the water in your beakers start at? Record this temperature in the data table on your student handout.
    b. Alternate pouring warm and cold water into a beaker until it has reached the desired temperature.
    c. Split this water into equal amounts in two beakers.

2. Based on the models you drew, gather the materials to build your two prototypes.

3. Assemble your two prototype devices, using the materials provided and procedural knowledge you gained in the *Explore* investigations.

4. Place a prototype device into each beaker of water and observe. Record data in the data table on your student handout.