GRADE FIVE VIGNETTE 4.3: PANCAKE ENGINEERING

Resources:

Lesson plans with further guidance are available at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link14

Sources:

Pictures and figures courtesy of Holliston Coleman and Matthew d'Alessio, California State University, Northridge.

IS2

Grade Five Instructional Segment 2: From Matter to Organisms

Prior to reaching grade five, students have developed understanding of the DCIs that all animals need food in order to live and grow; that they obtain their food from plants or from other animals; and that plants need air, water, and light to live and grow. Now, students tie all these ideas together with a **model [SEP 2]** that describes how **energy and matter flow [CCC-5]** within a **system [CCC-4]**. They trace matter from nonliving sources (water and air), to plants, animals, decomposers, and back again to plants. They also use their models and look for evidence to describe how **energy flows [CCC-5]** from the Sun to plants to animals.

GRADE FIVE INSTRUCTIONAL SEGMENT 2: FROM MATTER TO ORGANISMS

Guiding Questions

- What matter do plants need to grow?
- How does matter move within an ecosystem?
- How does energy move within an ecosystem?

Performance Expectations

Students who demonstrate understanding can do the following:

5-LS1-1. Support an argument that plants get the materials they need for growth chiefly from air and water. [Clarification Statement: Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil.]

5-LS2-1. Develop a model to describe the movement of matter among plants, animals decomposers, and the environment. [Clarification Statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth.] [*Assessment Boundary: Assessment does not include molecular explanations.*]

5-PS3-1. Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the Sun. [Clarification Statement: Examples of models could include diagrams, and flow charts.]

GRADE FIVE INSTRUCTIONAL SEGMENT 2: FROM MATTER TO ORGANISMS

5-ESS2-1. Develop a model using an example to describe ways in which the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: The geosphere, hydrosphere (including ice), atmosphere, and biosphere are each a system and each system is a part of the whole Earth System. Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*] (Introduced but not assessed until IS3)

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	LS1.C: Organization for Matter and Energy Flow in Organisms LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycles of Matter and Energy Transfer in Ecosystems PS3.D: Energy in Chemical Processes and Everyday Life ESS2.A: Earth Materials and Systems	[CCC-5] Energy and Matter: Flows, Cycles, and Conservation

Highlighted California Environmental Principles and Concepts:

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.

Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

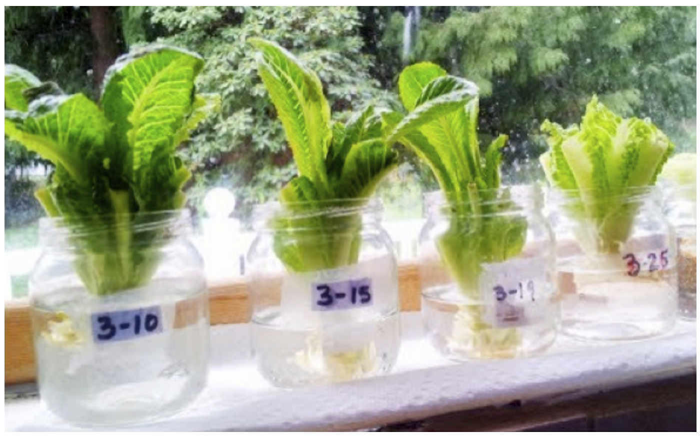
Principle V Decisions affecting resources and natural systems are complex and involve many factors.

CA CCSS for ELA/Literacy Connections: W.5.1, SL.5.4, 6; L.5.6

CA ELD Standards Connections: ELD.PI.5.1, 3, 9, 11, 12

Students have specifically investigated the needs of plants in kindergarten and grade two. Teachers can probe their students' existing ideas about plants by asking students to provide evidence that makes them **agree or disagree with the claim [SEP-7]**, "Plants can grow without soil." Students can directly investigate the question by trying to germinate and grow seeds in a medium of wet paper towels (inside a CD case so that they can watch the process). They can also try to regrow lettuce, celery, or other plants in water alone by placing the bottom section of a head of lettuce into a cup of water (figure 4.24). Students can track the mass of the plant and the mass of the water they add.

Figure 4.24. Lettuce Growing Without Soil



Source: Misilla 2014
Long description of Figure 4.24.

One of the first scientists to test out similar ideas was Jan Baptist van Helmont in the 1600s. He took about 5 kilograms (kg) of dry soil, put it in a pot, added water, and planted a tree in the soil. After a year the tree had gained about 1 kg of mass. Van Helmont carefully dried the soil and weighed it again. He was surprised to discover that the mass of the soil was still about 5 kg (figure 4.25). The result must have been very confusing. As the plant builds its body, the raw materials for making wood, leaves, bark must come from *somewhere* and the soil seems to be the most likely source. But his experiment showed otherwise. Where does the mass in plants come from? It must come from one or both of the plant's other needs for matter, air, and water. By tracking the amount of water in their own experiments, students may be able to figure out the answer. Unfortunately, the experiment is quite challenging to do precisely because water evaporates so easily. Could students design an experiment to figure out the contributions to the plant's mass that would be better than either van Helmont's or their own? Students will revisit this concept again in the middle grades when they develop a model of the chemical reactions by which atoms are rearranged from air and water molecules and transformed into plant molecules (MS-LS1-7).

Figure 4.25. Van Helmont's Experiment

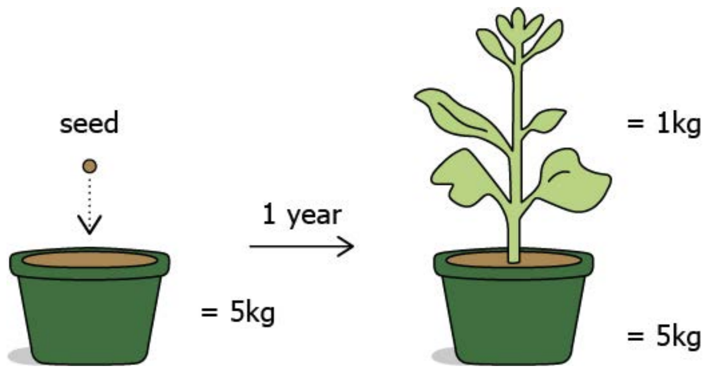


Diagram by Ed Himelblau.
Long description of Figure 4.25.

During the days that it takes the seeds and lettuce to germinate and grow, students can perform other simple **investigations [SEP-3]** to track the **flow of matter [CCC-5]** into plants. They can place celery or flowers in colored water to see transportation of water into the celery or flower, or try to grow a plant in a closed container with no airflow into the container. As they add their own measurements from seeds and plants grown in water alone, students should have enough evidence to construct an argument that plants get the materials they need to grow primarily from air and water (5-LS1-1). At grade five, students do not distinguish components of air such as oxygen and carbon dioxide but can describe the gases generally as air. Carbon dioxide in the air is a key ingredient in photosynthesis, a process used by plants to convert energy from the Sun into a form they can use to grow and reproduce. The DCI progressions from appendix 1 of this framework do not introduce the term *photosynthesis* until the middle grades. The rationale for this delay is to wait until the specific chemical process is introduced before giving it a label.

Since plants can survive with only air and water, can people? Students observed in kindergarten that all animals require food (K-LS1-1) because animals lack the ability to directly convert sunlight energy into usable energy. The next section explores the interdependence of animals and plants.

Plants within Ecosystems

Students constructed arguments that organisms interact with their environment in grade three (3-LS4-3). Now, students examine these dependencies in terms of the flow of energy and matter. There is no clearer illustration of the interdependence of organisms than a sealed glass sphere (figure 4.26) containing algae, brine shrimp, some air and water. If plants consume air and water resources from their environment, how can they continue to survive in the sealed sphere? Won't they run out of air? They would not survive alone, but the entire system can persist because the organisms exchange matter back and forth with one another. A system in which organisms interact and exchange matter and energy with each other and their environment is called an ecosystem.

Figure 4.26. A Sealed Glass Pod Contains an Entire Ecosystem

Source: Ecosphere Associates Inc. 2013
Long description of Figure 4.26.

As animals eat plants, they consume all the matter in the plants. They can use this matter as raw material for growing their own body, and they can metabolize it to convert it into usable energy. The same process occurs when animals eat other animals. Tracking which animals eat one another allows students to create a model of how energy and matter flow in an ecosystem. This **model [SEP-2]** is called a *food web*. Students can construct food webs by making direct observations about what animals consume. Observations can be in small classroom ecosystems such as a terrarium or fish tank or, whenever possible, students should take field trips to observe plants and animals in more natural conditions (including urban environments like parks as well as nature centers and outdoor schools).

Students can draw a food web for the visible organisms in the sealed spheroid ecosystem of figure 4.26—a very simple diagram showing brine shrimp eating algae. This relationship benefits the shrimp, but it does not explain how the algae (plants) continue to survive as they consume all the air in the sealed container. A food web is not a complete model of the flow of matter in an ecosystem. The algae transform energy from the light entering the ecosphere, and all of the organisms, including plants, give off waste.

To extend their models, students can investigate some of the waste products produced by plants. When students place a plastic bag over the leaves of a plant, the inside of the bag gets wet revealing that the plant gives off water. When they submerge Anacharis, Elodea, or rosemary plants in water, they observe tiny bubbles of gas released from the leaves. Students can measure the quantity of gas by counting bubbles or trapping the gas in an inverted test tube placed over the plant, recognizing that the rate of gas release depends on the amount of light shining on the plant. Is the gas that plants take in the same as the gas they release? Unfortunately, students do not have the tools to distinguish between these gases. They will have to wait to the middle grades to answer this question. Even without this information, students should be able to **explain [SEP-6]** that plants obtain matter as gases and water from the environment and release waste matter (gas, liquid, or solid) back into the environment (5-LS2-1). Similarly, they can integrate their own waste products into the model.

Because decomposers are often not visible, few people are aware that decomposers play a very important role in the flow of matter and energy through ecosystems. Students can view a sample of the water (or at least a photograph or video of it) from a local pond, stream, or even a drainage ditch, under a powerful microscope (with magnification of at least 400x) and see tiny bacteria floating around. What do they eat? How do they fit into the model of energy and matter flow? Students discuss the possibilities and come up with four options: (1) they get energy from the Sun like plants; (2) they eat the algae; (3) they eat the brine shrimp; and (4) they eat the waste given off by the other organisms. They rule out the possibility that the bacteria eat the brine shrimp because the shrimp are still alive. Students must **obtain information [SEP-8]** to learn more about bacteria in order to choose from among the remaining options. While some single-celled organisms get energy from the Sun, bacteria do not. Many bacteria eat the waste from other organisms. Many bacteria live inside the human intestine and eat parts of our food that we cannot digest by ourselves. When organisms die, the matter and nutrients that they have accumulated over their lifetime remain trapped in their body.

Decomposition is the process that releases the energy and nutrients from dead tissue for use by growing organisms. Decomposers can be both microscopic (bacteria) and easily visible (fungi and mold), but they all do the same thing: they consume plant and animal bodies, releasing energy and nutrients in a form that makes them more readily accessible to other organisms. Without decomposers, dead plants and animals and their waste products would accumulate in ecosystems and the energy and matter they contain would not be available to other organisms. Students add decomposers into their ecosystem models.

Grade Five Snapshot 4.6: Cycles of Decomposition

Anchoring phenomenon: At a nature center, a wide variety of plants and animals live together.

Ms. D has coordinated with the staff at a local nature center, and they have identified a specific area where the class can **investigate [SEP-3]** food webs and observe an area where decomposition is an active process. On the day of the field trip, the nature center staff helped students identify several different producers and consumers. As students discovered what lives in the area, they worked together to create and discuss a food web.

Everyday phenomenon: Plants and animals die.

Ms. D then asked, "What happens when one of the plants or animals in the food web dies?" The students looked around for evidence of decomposition nearby. They identified fallen leaves, a rotting tree trunk, and a dead insect on the ground.

Investigative phenomenon: The layer of leaves on the ground probably only took a few years to accumulate, but the tree has been growing for decades. (Where did all the other leaves go?)

Ms. D asked the students how long they think it took for all the dead leaves to fall on the ground, and the students estimated several years. Ms. D then pointed to the tree and said, "but this tree has been here for a hundred years. What happened to all the leaves that fell before?" While some students suggested that the wind blew them away, Ms. D asked them to look more closely at the leaves on the ground and the other dead objects. She then led them through a discussion about how the tree trunk, leaves, and animals are breaking down and reentering the soil.

When they returned to the classroom after the field trip, Ms. D had them read an informational text about some of the organisms involved in decomposition and how they relate to the rest of the ecosystem (see "Decomposition in the Forest" at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link15, p. 12).

Investigative phenomenon: Dead material seems to progressively break down.

She then projected different examples of decomposition in action (see "Evidence of Decomposition" at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link16, pp. 2–4) and asked the students to describe what they saw. In each case, Ms. D asked students where the matter

Grade Five Snapshot 4.6: Cycles of Decomposition

came from and what happened to it after it decomposed. She emphasized that when matter decomposes, it may seem to disappear, but it is actually moving into a different part of the ecosystem releasing nutrients back into the soil, air, or water. To help the students practice **constructing explanations [SEP-6]** of the decomposition process, she distributed a drawing with a sequence of events that relate to decomposition (leaves fall, worm eats leaves, worm feces fertilize soil, bird eats worm, etc.) (See *Breaking it Down—In the Forest* at https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link17, p. 13). Students wrote brief descriptions about each step and how it relates to the **flow of energy or matter [CCC-5]** in the ecosystem.

Ms. D led a class discussion about the picture and asked students if they noticed any patterns in the sequence of events. Several of the students commented that the drawing shows the matter flowing among plants, animals, and microbes as these organisms live and die. She asked, "Does this **flow of matter [CCC-5]** occur only once or is it an ongoing process?" and led the class in a discussion that helped students recognize that the **flow of matter [CCC-5]** in the diagram is an example of a **cycle [CCC-5]**. She then wrote a definition for the word *cycle* on the board, "a series of processes or events that typically repeats itself."

To help students recognize the importance of matter moving through ecosystems among plants, animals, and decomposers, Ms. D asked them, "What would happen if the cycle of matter flowing through ecosystems is interrupted by human activities?" This allowed the students to begin building an understanding that human activities can affect "the exchange of matter between natural systems and human societies affects the long-term functioning of both" (EP&C IV).

Ms. D asked students to reflect on how decomposition is important to them, strengthening their understanding that the ecosystem services provided by natural systems are essential to human life, including what we eat, the plants we can grow and the overall functioning of our economies and cultures (EP&C I).

Everyday phenomenon: Compost turns food waste into soil.

Several students mentioned that the decomposition process is related to the compost pile that the class has been managing near their school garden. Some of the others discussed that they were surprised that by composting at home, they were keeping most of the plant materials from their meals and yards from going into the landfill and they thought that their gardens benefited from the nutrients in the compost.

Resources

California Education and the Environment Initiative. 2013. *Breaking it Down—In the Forest*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link18.

———2013. *Decomposition in the Forest*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link19.

———2013. *Evidence of Decomposition*. Sacramento: Office of Education and the Environment. https://www.cde.ca.gov/ci/sc/cf/ch4.asp#link20.

While students collected evidence that plants can grow for at least some time without soil, plants acquire some essential materials from the soil. Nitrogen, iron, and many other nutrients must be obtained from the soil (usually by the roots) because plants cannot survive without these. These nutrients, however, make up only a small fraction of the total mass of a plant. If van Helmont had had a sensitive enough scale he might have detected a tiny decrease in the mass of his soil. Again, plants provide a means for animals to get many of the nutrients they need. For example, animals need very tiny amounts of metals like iron, zinc, and magnesium to survive, but they cannot get all the nutrients they need by just eating soil. To take these nutrients into their cells, the nutrients need to be incorporated into more complex molecules (sometimes called *vitamins*). These complex molecules are synthesized in plants. Plants, on the other hand, are able to absorb individual metal atoms from the soil surrounding their roots. Animals consume these nutrients when they eat plants, or eat other animals that have previously eaten plants. Students integrate this information into their model. How will they represent the fact that nutrients are only a tiny fraction of the plant's mass yet are important for plant growth and survival?

Students must now reflect on their models of ecosystems and develop ways to represent and **communicate [SEP-8]** them. They could play games (physical or kinesthetic models) where primary producers receive energy from the Sun, use some for growth and respiration and pass the rest to primary consumers and so on. The assessment chapter of this framework (chapter 9) includes a snapshot demonstrating how students can use a pictorial model generated on a computer to represent the energy flow in an ecosystem. They should be able to use their model to explain how the energy animals use to grow and survive originated as energy from the Sun (5-PS3-1).

This instructional segment reflects one of the key instructional shifts of the CA NGSS with a focus on the SEPs that require developing and refining models. Rather than having teachers present students with a model of ecosystems and defining the vocabulary terms of producers, consumers, and decomposers as components of the system, students began with an incomplete model. As they explored different phenomena, they progressively revised and extended their model to include additional exchanges of matter. The model students have at the end of grade five is by no means complete—they will revise it in the middle grades and again in high school. Despite the fact that this research began in the 1600s with van Helmont, professional scientists are continuing to refine the models of mechanisms and relationships within ecosystems. As teachers focus on **developing and using models [SEP-2]**, students will gain useful insight into the nature of science as well as construct their own understanding of DCIs about ecosystems.

Sample Integration of Science and ELD Standards in the Classroom

Students have observed, through pictures and simulations, some representations of the movement of matter within ecosystems. Working in small groups, the students build on those experiences by using their science texts and notes as they collaboratively construct their models of how matter moves within ecosystems. Each group constructs an argument about its model, focusing on the movement of matter among plants, animals, decomposers, and the environment. Each group shares its model with another group, while the other group provides feedback based on the following co-constructed criteria: 1) presentation effectiveness, 2) the types of materials and representations use, and 3) whether the cycling of matter is accurate (5-LS2-1). During their conversations, the students refer to a large chart on the classroom wall that contains options for different language purposes, such as entering a conversation (e.g., One/another piece of evidence that supports our argument is ___.); agreeing and disagreeing (e.g., I can see your design has ___; however, ___.); or elaborating on an idea (e.g., That's a good choice for ___, and I'd like to add that ___.). To support students at the Emerging level of English proficiency, the teacher asks each group to practice what each member of the group will share, and no member was permitted to opt out. The teacher had created heterogeneous groups, ensuring that each student at the Emerging level of English proficiency had a "language buddy" who was proficient in both English and the student's home language. The teacher had also created a supportive environment so that students worked together to make sure that each student understood and could communicate that understanding.

CA ELD Standards: ELD.PI.4.3
Source: Lagunoff et al. 2015, 248–249

Sample Integration of Science and ELD Standards in the Classroom

Students who are working in small groups to create models about the cycling of matter in ecosystems provide feedback to their peers, using appropriate verb tenses (e.g., "At first, the arrows you drew were pointing toward the soil. Now you have changed them, so I understand that materials from the water and air go into the plant.") (5-LS2-1). The teacher provides verbal support to students at the Emerging level of English proficiency by highlighting specific verb tenses for specific purposes in texts and speech.

CA ELD Standards: ELD.PI.4.3
Source: Lagunoff et al. 2015, 275–276