beetles
Science and Teaching for Field Instructors

Ecosystems (and Matter) Theme Field Experience: Instructor Support

Note: For more information, see the Instructor Support sections included in each individual activity write-up referenced.

Note: For Ecosystems (and Matter): Introduction, Ecosystems (and Matter): Instructor Support, full write-up of *Ecosystems Theme Field Experience Script (2–3 Hours)*, and full write-up of *Ecosystems and Matter Theme Field Experience Script (3–6 Hours)*, see: http://beetlesproject.org/resources/for-field-instructors/ecosystems-matter-theme-field-experience

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Ecosystems (and Matter) Theme Field Experience: Instructor Support

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Teaching Knowledge

Multiple exposures make for stickier learning. It's difficult to hold on to information you only engage with once. That's one reason why an experience like these theme field experiences, which give students opportunities to go deeply into content and apply concepts in new contexts, can be so valuable. Early on, students are introduced to the idea of an ecosystem as a system of interacting living and nonliving parts. Then, students get the chance to think about a variety of organisms through the lens of that system and its interactions, and students make models of the ecosystem. Students add a layer to that understanding as they investigate the cycling of matter through different interactions, and finally, as they reflect on the ideas they've learned. It can be difficult to build that kind of deep experience in classroom science, which is often only taught in chunks of approximately 45 minutes. This kind of sustained experience with the concepts of ecosystems and matter is uniquely possible through extended time in the outdoors. How cool that you get to support such rich learning!

Vocabulary. Themed field experiences give students multiple opportunities to use a related set of words. It takes about seven exposures to a difficult word for students to fully adopt it. Words are concepts (in general), and students can't learn a concept just by learning the definition of a word—a word without an understanding of what it means isn't very useful. Giving students opportunities to develop a concept, introducing the word for it, and then giving students opportunities to keep using the word can help it stick. Ideally, students should be hearing, saying, reading, and writing the word in context. Introducing too many difficult words at the same time can be counterproductive. Too many such words, especially when only used once or twice, can be confusing for students. It's best to choose just a few difficult words on which to focus during a field experience, offering students opportunities to develop understanding of the concepts, using the words multiple times yourself, and encouraging students to use them. Vocabulary related to the content in the *Ecosystem Theme Field Experience Script (2–3 Hours)* includes: *ecosystems*, *connections*, *organism*, *interact*, *evidence*, *explanation*, *model*, and *observation*. The *Ecosystems and Matter Theme Field Experience Script (3–6 Hours)* includes all those words, plus: *matter*, *decomposer*, *decomposition*, and *cycle*. Useful vocabulary related to the Next Generation Science Standards (NGSS) Science and Engineering Practices in which students engage include: *evidence*, *explanation*, *model*, and *observation*.

Engaging students in discussion. Discussion is a key meaning-making aspect of many of the activities in these field experiences. For students to be able to engage in discussion, it's important to set up a culture of discourse in your group and to give students opportunities to discuss things in pairs and small groups before participating in a whole-group discussion like the one in *What Lives Here?* To establish a culture of discourse, create and nurture an atmosphere of respect and intellectual curiosity by responding equitably to students' ideas as a facilitator and by facilitating—not dominating—the discussion. When you respond to students, do so in a neutral, accepting manner and then probe their thinking with follow-up questions. Encourage respectful agreement and disagreement and establish that when there is disagreement about ideas, students will not be ridiculed for giving the wrong answer. Emphasize that sharing ideas as a group is an important part of the learning process and keep the discussions interesting! Be on the lookout constantly for ideas that may be of interest to your students, as well as perspectives that may help them shift their thinking. Shift between pair talk, small-group talk, and whole-group talk to encourage participation and interest.

Exploration leads to curiosity. These field experiences are structured so students engage in exploratory activities—the first parts of *What Lives Here?*, *Discovery Swap*, *Interview an Organism*, *Lichen Exploration*, and *Bark Beetle Exploration*—before doing activities that engage them more deeply in modeling and making explanations about the concepts and phenomena they explored—*Case of the Disappearing Log*, *Decomposition Mission*, and the second half of *What Lives Here?* Although we don't suggest that you try to pack all the exploratory activities into one field experience, giving students some of this initial time to check out parts of the ecosystem is essential for piquing their interest. If you plunge straight into content, you're skipping the phase where students touch, feel, smell, and wonder about the ecosystem they're exploring. Students need to become curious and develop a real desire to understand the organisms and ecosystem they're investigating. This exploration primes students for the deeper meaning-making they do later in the field experiences.

Conceptual Knowledge

The following information is meant as background to help you better understand ecosystems, matter, and other key concepts that relate to the field experience—they are *not* talking points for a lecture nor are they lists of concepts that students should understand.

What's the difference between the terms *environment*, *ecosystem*, *habitat*, and *microhabitat*? It's easy to confuse these terms because they overlap, but each term has a slightly different meaning.

- **environment:** all the living and nonliving things that surround an organism or an ecosystem. It can refer to nature as a whole or to a specific part of nature.
- **ecosystem:** all the living and nonliving things that interact with each other in a particular environment (e.g., desert ecosystem, tropical rain forest ecosystem, coral reef ecosystem).
- **habitat:** the home of a particular type of organism. A habitat is the area that includes all the living and nonliving things that a type of organism needs to survive (e.g., chickadee's habitat, the rock crab's habitat). The habitat of wolves can be very large. The habitat of a type of bird that migrates can be one place in the summer and a different place in the spring.
- **microhabitat:** a particularly small habitat (e.g., a clump of grass, the space under a rock).

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There's exploration in each individual activity, too! It's worth noting that *all* individual BEETLES activities give students a chance to explore before diving into content.

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Of these, the term *habitat* is probably most often misused when it's used to describe what should really be called an ecosystem. It's accurate to refer to the poison dart frog's habitat, but it's inaccurate to refer to the rain forest habitat; the rain forest ecosystem would be an accurate way to refer to a rain forest.

Studying ecosystems. Scientists use ecosystem models to try to understand specific ecosystems and make predictions about how they might change over time. Ecosystems can span from very small (e.g., a drop of water and the bacteria it contains) to very large (e.g., the ocean ecosystem). To understand any system, or an ecosystem, it's useful to study the parts and how they interact with one another. Scientists use ecosystem models like the one students create in *What Lives Here?* to think about how the parts of an ecosystem impact one another, as well as to make predictions about an ecosystem's stability and potential response to changes. Generally, the more different kinds of organisms there are in an ecosystem, the more resilient it is if something changes.

Since all parts of an ecosystem are connected, a change to one part will affect other parts. There are many ways that the living and nonliving things in an ecosystem interact and disrupting any of these interactions causes ripple effects on other parts of the ecosystem. Certain species may play a more critical role in the balance of the ecosystem than others. In some cases, these are species that are really abundant. For example, redwoods are an abundant, integral part of the redwood forest ecosystem. In other cases, these species may not be superabundant but still have a large impact on the system. For example, a beaver that builds dams in a river drastically affects the dynamics of the river and, in that way, influences many of the living and nonliving parts of its ecosystem. Small populations of predators may also play a disproportionately large role in their ecosystems by keeping prey populations in check. These types of organisms are often called keystone species, an analogy to the keystone (top stone) of an arch, which is critical to the arch's structure. If a keystone species disappears from an ecosystem, it can have big impacts on the rest of the parts of the ecosystem.

The loss of one type of organism doesn't doom the entire ecosystem. When first learning about the interconnectedness of ecosystems, sometimes students end up with an oversimplified idea of the concept and think that if one type of organism is gone, the ripple effects will crash the entire ecosystem. While it's true that indirect effects from the loss of a species can affect many parts of an ecosystem, those species closest and most connected are more greatly affected, and the effects lessen as you get more distant from a species. Some species, such as a predator that keeps an herbivore from overgrazing, are more important to an ecosystem than others, and their loss can deeply affect an ecosystem. The more diversity in an ecosystem, the more robust it is, and the better it can survive losses.

Food webs. Food webs are models that show which organisms eat or are eaten by others in an ecosystem. The arrows we draw in a food web represent the transfer of matter that happens when one organism eats another; typically, an arrow points in the direction that the matter is moving (toward the consumer).

***Producers*, *consumers*, and *decomposers* are three terms used to categorize organisms in an ecosystem.** Producers, such as plants, produce their own food from carbon dioxide and water. Consumers get their energy and matter by consuming other organisms. Decomposers are organisms that break down dead plants, algae, animals, and other organic matter into simpler forms of matter, such as nutrients that become part of soil, the air, or large bodies of water. Decomposers break down things into forms of matter that plants and algae can use to build and grow.

- **More about producers.** Producers are mainly photosynthetic organisms that transform light energy into the chemical energy in glucose through the process of photosynthesis. Using the light energy from the sun, plants and plant-like organisms such as algae make glucose (a simple sugar) by combining carbon dioxide from the air and water. No other type of matter is needed. There are also some producers living in environments without light (e.g., deep-sea hydrothermal vents) that use chemical energy to produce their food through a process called chemosynthesis. Chemosynthetic bacteria use different pathways to react inorganic compounds with carbon dioxide and oxygen to make the sugars they need to live. Organisms that produce their own food are also called autotrophs.
- **More about consumers.** Consumers can't make their own food, so they get it by eating other organisms. Humans and other animals can't make their own food and must get it by consuming plants or other animals that have consumed plants. Fungi and other decomposers are considered consumers because they can't produce their own food. Organisms that can't produce their own food and need to get it from the environment are also called heterotrophs.
- **More about decomposers.** As decomposers consume food to get the energy and matter they need to live and grow, they are also playing an important role in the ecosystem. Decomposers are heterotrophs that break down dead plants, algae, animals, and other organic matter into simpler forms of matter, such as nutrients that become part of soil, the air, or large bodies of water. Decomposers break down things into forms of matter that plants and algae can use to build and grow.

Interactions Between Living Things

Direct effects. An ecosystem is made up of all the living and nonliving things that interact in a particular environment. The many interactions that can happen between living organisms is complex and layered. The following are some types of (two-way) interactions:

- **Mutualism.** Mutualisms are interactions in which both organisms benefit. For example, a tree and a fungus may have a mutualistic interaction in which the fungus helps the tree get nutrients and water from the soil, while the tree gives sugars to the fungus.

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More information on decomposition. For more information on decomposition and the role it plays in the cycling of matter, see the Instructor Support sections of *Case of the Disappearing Log* and *Decomposition Mission.*

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- **Commensalism.** Commensalism takes place when one organism benefits, and the other organism is unaffected. For example, a squirrel living in a tree may get shelter from the tree without affecting the tree positively or negatively.
- **Competition.** In a competition between organisms, each organism is negatively affected by the other. For example, when two organisms compete for the same food source, each organism would have more food available if the other was absent. Therefore, each is negatively affected by the presence of the other.
- **Predation/Parasitism/Herbivory.** In these types of interactions, one organism benefits at the expense of the other. For example, when a tick sucks blood from another organism, the tick benefits at the expense of the other organism. When an animal eats plant leaves, the animal gets food at the expense of the plant. Eating a mouse may be great for a snake, but the interaction is not exactly beneficial for the mouse.

Each type of interaction above is an example of the direct effects of one organism on another. In each, the presence and abundance of one organism directly affects the other organism.

Indirect effects. An ecosystem model helps us see direct effects, but it also can model and help us understand indirect effects. Let's use an example in which coyotes eat rabbits, and rabbits eat wildflowers. The coyote may not have a direct effect on the wildflowers, but if there's a change in the coyote population (e.g., if the population drops due to hunting), the rabbit population could go up, resulting in rabbits' gobbling up more wildflowers, which would have a negative effect on the wildflower population. In this case, the coyote has an indirect effect on wildflowers because a change in one level (carnivore) affected lower levels (producer). The opposite can happen, too—a change in a lower level of the food chain can affect a higher level (e.g., if the population of wildflowers were to increase or decrease). Organisms in a food chain are highly interconnected with the ecosystem, so indirect effects may be made stronger or weaker by the interactions between organisms at any level of the food chain with other organisms in the ecosystem. Using the above example, that means that anything that affects the coyotes, rabbits, or wildflowers indirectly affects the other organisms in this food chain.

Keystone species. In some situations, one species may have big effects on many other species within an ecosystem. In an extreme case, changes to one species may cause dramatic changes in the entire ecosystem. Such a species is called a keystone species. Sea stars are one well-known example of a keystone species. Sea stars prey on mussels, so without sea stars, an intertidal ecosystem can be overrun by mussels, which outcompete other organisms. Another example of a keystone species is the honeybee. Honeybees are important pollinators, so without them, plants make fewer seeds, which could ultimately lead to catastrophic effects on plant populations and on the many species that rely on plants for food and shelter.

Relationships between living and nonliving things. In addition to living things interacting with one another in an ecosystem, ecosystem dynamics

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are made more complicated by interactions between living and nonliving parts of a given ecosystem. In many ways, the nonliving parts of an ecosystem determine the organisms that live there. The availability of water, nutrients in the soil, and quality of the air all affect which organisms can or can't survive somewhere. Changes to these and other nonliving parts of an ecosystem can affect living parts, which can cause more changes to nonliving parts, which can then change living parts, and on it goes!

Where do people fit in? Humans are major drivers of change in ecosystems. Some of the changes we humans have caused are direct and easily observable. For example, the destruction of forests to build cities and roads or to clear land for agriculture has clear, destructive effects on the ecosystems where they are happening. Extraction of resources—water, food, minerals, and so on—also has observable effects on ecosystems. Many other ways that humans affect ecosystems are harder to observe directly. The many effects of human-induced climate change on ecosystems is one glaring example. Research to better understand ecosystems and ecosystem dynamics can help us figure out how to better manage natural resources to prevent or reduce adverse impacts.

Interactions between living and nonliving things in an ecosystem make matter cycle and energy flow through the system. First, let's mention a few definitions:

- **Matter.** Matter is the stuff things are made of. Wood is matter, bones are matter, water is matter, and even air is matter. Matter takes up space, but it's difficult to feel that with air unless you capture some in a balloon or a bag. Matter also has mass (weight), but that's also difficult to feel with air because it has so little mass. We actually live in a "sea of air." It's difficult to feel the weight of air when we're surrounded by it on all sides.
- **Energy.** Energy is much harder to define than matter and has different definitions, depending on the branch of science thinking about it. In an ecosystem context, energy can be defined simply as what organisms get from food that allows them to do things. If you are introducing students to the term *matter*, *energy* can be partially defined as *not* matter. Unlike matter, energy doesn't take up space or have mass. Energy has no physical form; it's not a substance. When energy is transferred from one organism to another, no physical thing is passed from place to place. What's transferred is the capacity to do things—to live and to grow. Sounds weird, but it's accurate.

Now, back to how matter cycles and energy flows.

- **Energy from the sun sustains ecosystems.** Plants use energy from the sun to take matter from air (CO_2 and H_2O) and, through chemical reactions, plants "package" the matter as carbohydrates ($C_6H_{12}O_6$)—food! Plants use this food for themselves, building and repairing their body structures with the matter that makes up the food and doing things, such as growing, with the energy from the food. Through

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The concept of energy is complex. It's difficult for adults to understand, let alone students! That's why in the *Ecosystems and Matter Theme Field Experience Script (3–6 Hours)*, we've chosen to focus on matter and have included activities to get at the flow of energy only as an extension. Sometimes, matter and energy are treated as interchangeable. This isn't accurate, and a focus initially on matter cycling can help students get a grasp on matter before tackling the idea of energy, while seeing how they are different.

food webs—herbivores eat plants, other consumers eat herbivores, other consumers eat *those* consumers, decomposers break down dead organisms, etc.—matter cycles through the ecosystem. As organisms eat one another, there are many different directions in which matter may move through an ecosystem. When organisms eat food, they use the matter to build and repair their bodies, and much of the matter comes out as CO_2 in breath; H_2O in sweat, poop, or pee; and so forth, which may then get taken back up by plants.

- **Energy gets lost as it moves between parts of an ecosystem.** All this food (matter) that moves between organisms contains stored energy that can be released through chemical processes to do things—run, fly, grow, and so on. At every link in a food web, on average, ~90% of the energy is lost from the system, and only ~10% is passed on to the next organism. This is partly because many organisms can only digest certain parts of other organisms (e.g., few animals can digest bones). More importantly, a lot of this energy is lost as heat.
- **Matter just keeps cycling around and around.** The matter in Earth's system is pretty much fixed: it's the same matter that's been here for ages! We may lose a little bit of matter in the form of air molecules and spacecraft we send into outer space, and we gain some matter from meteorites and the like crashing down; otherwise, it's the same stuff that's been cycling around and around ever since Earth was formed. The matter in the air we breathe, in the food we eat, and in the water we drink has all been part of countless other living and nonliving things for millennia.

Common Related Misconceptions

Misconception. Predators are harmful to prey. For example, some students think that if wolves are reintroduced to an area, they will kill off all the deer.

More accurate information. While individual predators obviously kill, eat, and harm individual prey, the *populations* of predators and prey in an ecosystem are involved in a complex relationship. Predators tend to prey on the weakest prey they can find, which is often the young, old, and sick. This can actually help keep prey populations stronger, because the individuals that are healthy and well-adapted to escape from predators are more likely to breed and pass along their traits to their young. However, when humans hunt prey, such as deer, they typically avoid the young, old, or sick and try to kill bigger, healthier individuals, which can have the effect of making the prey population weaker. *"The caribou feeds the wolf, but it is the wolf who keeps the caribou strong."* —Keewation (Inuit) proverb

Misconception. Dead organisms spontaneously break down.

More accurate information. Organisms known as decomposers—such as bacteria, fungi, and invertebrates—consume the dead tissue, releasing some of the matter as carbon dioxide and water into the air and releasing undigested waste products into soil or water.

ⓘ **Misconception.** The matter that plants use to make sugar mostly comes from soil.

More accurate information. Plants make sugar/food from carbon dioxide and water in the presence of sunlight. Soil (on land) and water (in aquatic ecosystems) provide important nutrients (not food!) for plants. These nutrients are more like vitamins than food. Many students (and even adults) think that plants make food from soil, probably because soil seems to have more substance than carbon dioxide, and because the nutrient cycle tends to get a lot of focus in environmental education. Even people who have studied photosynthesis and are familiar with its equation (which doesn't include soil) often list soil as the thing that most of the mass of plants comes from. In the NGSS, an important concept is that plants get what they need to grow chiefly from air and water. Asking students to think about interactions between organisms and to make ecosystem models can help them actually apply knowledge of how plants grow and can help them be less likely to have this misconception.

ⓘ **Misconception.** Dead organisms are decomposed into nutrients that plants use.

More accurate information. Okay, we admit it. That's not really a misconception; it's just incomplete. Most of the matter that's decomposed is eventually converted into carbon dioxide and water that both become part of air. As stated in the previous misconception, plants do use carbon dioxide and water to photosynthesize. However, relatively small amounts of decomposed organisms become nutrients that plants use.

ⓘ **Misconception.** Energy cycles through ecosystems forever.

More accurate information. This is a very common misconception, even among adults. If energy cycled indefinitely through ecosystems, Earth would be super hot! During the day, there is a constant flow of energy from sunlight into an ecosystem and a constant flow of energy out of the ecosystem into space. At every link in a food chain or food web, ~90% of the energy is lost from the system and eventually drifts into outer space as heat, while ~10% is passed on to the next organism. The matter in an ecosystem (and everywhere on Earth) is rarely (as in the case of a meteorite) added to from space or lost to it. Earth's matter just keeps cycling around in different forms. That's why we say that matter *cycles* through ecosystems, and energy *flows* through ecosystems. Matter from air and water is used by producers to make food, using energy from sunlight (mostly). The food is essentially packets of matter and energy. When animals eat food, matter comes out as CO_2 in breath; H_2O in sweat, poop, and pee; and so on. When animals eat food, much of the energy is released as heat and eventually drifts out into space.

ⓘ **Misconception.** Organisms convert matter into energy.

More accurate information. This is a very common misconception, even among adults (and instructors!). Matter is *not* converted into

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energy in life systems on Earth. Even though chemical energy in matter can be transformed into usable energy by organisms, the matter in food does not turn into energy. Matter is a substance, but energy is not. The chemical substances in food are transformed into new substances (through chemical reactions), but there are no new atoms created or destroyed in the process. Under usual circumstances (as in all ecosystems and food webs on Earth), matter does *not* turn into energy. Through photosynthesis, plants "package" energy from the sun with matter from carbon dioxide and water to make food. When we digest food, we release this energy, but the matter in the food is not turning into energy.

Misconception. Changing the population of one species will have a domino effect on all species in an ecosystem and eventually will collapse that ecosystem.

More accurate information. Changes in populations of organisms in ecosystems do affect the whole ecosystem, but don't affect all species equally and likely won't cause a collapse of an entire ecosystem. A big change in the population of organisms that have a lot of strong connections will have an impact on the ecosystem as a whole. However, in most ecosystems, there are many connections among many organisms.

Misconception. Changing the population of one species will only affect species that eat or are eaten by this species of organism.

More accurate information. On average, species in a food web are just two links apart, and >95% of all species are within three links of one another. These other organisms are indirectly affected by changes to the other organism. In general, the farther away an organism is in a food web, the less the effect.

Misconception. Decomposers break down matter from dead things in order to provide soil for other organisms in the ecosystem.

More accurate information. Decomposers do consume dead organisms, but they do so to get the matter and energy they need to survive. Decomposers are not concerned with supporting the ecosystem by breaking down dead things and likely have no awareness of how what they're doing impacts the ecosystem as a whole. It's important to be careful that our language doesn't perpetuate this misconception because students can start to get the people-centric idea that nature and its systems exist primarily for our benefit and possibly for the benefit of the charismatic creatures we care about. The optional *Systems Game* can help you point out to students how some patterns can emerge from a system made up of individual parts that are simply trying to get their needs met. The misconception is also incomplete because most of our planet is covered with water, and decomposition in water doesn't result in soil. Decomposition in the ocean, lakes, and streams is often ignored, and that's a huge thing to overlook!

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Connections to the Next Generation Science Standards (NGSS)

There are a lot of Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas featured in these field experiences, some more fully than others. The sequence of activities and discussions included in these field experiences gives students deeper opportunities to engage particularly in the Science and Engineering Practices of *Developing and Using Models* and *Constructing Explanations* and to use the Crosscutting Concepts of *Systems and System Models* and *Energy and Matter*. These Science and Engineering Practices and Crosscutting Concepts are used to help students construct an understanding of the Disciplinary Core Ideas of *Interdependent Relationships in Ecosystems* and *Cycles of Matter and Energy Transfer in Ecosystems*. The strategically sequenced activities and opportunities for meaning-making included in these field experiences allow students to develop a deeper understanding of these practices and concepts than would happen in a single activity. However, none of these can be checked off as done after one experience, such as these field experiences. Students will eventually need far more experiences to gain expertise with these practices and a full understanding of these ideas.

Featured Science and Engineering Practices

Engaging students in *Developing and Using Models*. According to the National Research Council's *A Framework for K–12 Science Education*, scientists use models to represent and investigate parts of a system not visible to the naked eye in order to better understand how things work. These models include diagrams, physical replicas, mathematical representations, analogies, and computer simulations. Models help scientists focus on certain features of a complex system in order to test their ideas or revise explanations. The NGSS specify that students should be developing and revising models based on evidence to represent their current understanding of a system or a process under study. Students should use models to make explanations, communicate ideas to others, and make predictions about phenomena.

- In *Ecosystem Theme Field Experience (2–3 Hours)*, students are introduced to the idea of modeling during the field experience introduction. Although the term *model* is not used yet, the instructor asks students to think about systems they've heard about and to think about the parts that make up the system.
- In *What Lives Here?*, students create their own Ecosystem Models based on the organisms and evidence of organisms they've found, nonliving things, and interactions they see or think could happen.
- Throughout the field experience, students keep adding to and improving their models based on what they learn and see in other activities.
- Students also use their models to make explanations about the ecosystem and to predict how changes to certain parts of the ecosystem might affect other parts.

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- In *Ecosystems and Matter Theme Field Experience (3–6 Hours)*, students engage with modeling in all the ways described above and also add a new layer to their models—adding arrows to show how matter moves between parts of the ecosystem.
- Having opportunities to develop, revise, and use models throughout the field experience helps students develop their understanding of scientific models and appreciate the usefulness of models to better understand the world.
- It's also important to not skip over the questions during the "Reflecting On and Wrapping Up the Field Experience" section when students reflect on how their models helped them to think, discuss inaccuracies of their models, and consider how they might apply systems thinking in other contexts.
- Part of the goal of the NGSS is for students to be able to apply practices consciously in other settings, and the Reflection phase will help them recognize how models helped them to both think and learn.

Engaging students in *Constructing Explanations*. According to *A Framework for K–12 Science Education*, a major goal of science is to deepen human understanding of the world through making explanations about how things work. During these field experiences, students get to do this as they develop their understanding of science concepts by making their own explanations about natural phenomena.

- In *Ecosystem Theme Field Experience (2–3 Hours)*, students create Ecosystem Models built on evidence from their observations during *What Lives Here?* These models are essentially visual explanations about aspects of the ecosystem. As students do this, they get practice evaluating the strength of evidence, which is an important part of constructing explanations.
- Students then use their models to explain how a change to one part of the ecosystem could affect other parts.
- In *Ecosystems and Matter Theme Field Experience (3–6 Hours)*, students have these same opportunities, with the added lens of explaining how matter cycles in the ecosystem. They also have many more opportunities to construct explanations through additional optional activities.
- *Constructing Explanations* is the featured Science and Engineering Practice in *Bark Beetle Exploration*, *Lichen Exploration*, and *Case of the Disappearing Log.*
- Students also construct explanations in *Decomposition Mission* as they discuss questions such as *Why is decomposition important for ecosystems? Can humans be considered decomposers? Why or why not?*
- These opportunities help students develop skills in using evidence to support their ideas and in using the language of science.
- Instructors can support students in developing this practice by coaching them to be open to different explanations and helping them think about how the process of making explanations changed their understanding over time.

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- Instructors can further support students with this by encouraging students to use the language of uncertainty as they try to come up with evidence-based explanations for anything puzzling they encounter, which can be a mindset they take away with them after the field experience.

Featured Crosscutting Concepts

Note: Pick one to be your primary focus.

Learning science through the lens of *Systems and System Models.* The world is complicated! Isolating systems for study—when you focus on one body system or, in this case, focus just on the interactions between parts of an ecosystem—helps scientists and engineers understand parts of how the world works. Investigating the parts of a system can help students recognize that each organism and object does not exist in isolation but rather in relation to the other parts of the system of which it's a part.

- Early in *Ecosystems Theme Field Experience (2–3 Hours)*, students are introduced to the idea of a system and to the concept of an ecosystem.
- Throughout the field experience, students are encouraged to think about ways organisms interact with other parts of the ecosystem and to record those interactions in their journals.
- Students use systems thinking to construct explanations about how particular organisms play an important role in their ecosystems and to predict how changes to one part of an ecosystem could affect other parts.
- Make sure to include opportunities for students to think about how they're using a systems lens so they'll be aware of when they're using it. This will help them understand and appreciate the usefulness of this Crosscutting Concept to think about other systems in the world.

Learning science through the lens of *Energy and Matter* [in *Ecosystems and Matter Theme Field Experience (3–6 Hours)* only]. Tracking the transfer of energy and matter in and out of, as well as within, a system helps scientists learn about relationships between parts of systems.

- Students begin to apply this Crosscutting Concept at different points during the field experience (though not to the extent that they make use of *Systems and Systems Models*).
- Energy and matter are complex topics, and the *Case of the Disappearing Log* and *Decomposition Mission* are great opportunities for students to begin understanding how matter cycles in an ecosystem through the process of decomposition.
- When students return to their Ecosystem Models, they can apply this Crosscutting Concept at a broader level to show how matter moves through different interactions within the ecosystem.
- If you choose to include the *Bunny Question*; *Food, Build, Do, Waste*; or some of the Energy and Matter Theme cards for *Card Hike* (focused on energy transfer), students will also begin to think about energy's role in ecosystems.

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Featured Disciplinary Core Ideas

Building a foundation for understanding *Interdependent Relationships in Ecosystems*. One of the Disciplinary Core Ideas within the topic of *Interdependent Relationships in Ecosystems* has to do with how organisms interact with other living as well as nonliving parts of their ecosystems in order to survive. Students' understanding of this topic should progress over grade levels.

- At lower elementary levels, students are expected to understand how animals and plants depend on their surroundings to get what they need (animal needs: food, water, shelter, etc.; plant needs: water, minerals, sunlight).
- By upper elementary levels, this progresses into an understanding of food webs, decomposition, and the stability of a healthy ecosystem.
- Students should also understand how the patterns of interactions among organisms and nonliving things is similar across different ecosystems.

In *Ecosystems Theme Field Experience (2–3 Hours)*, students have a lot of opportunities to build understanding of different aspects of this rich Disciplinary Core Idea.

- In *What Lives Here?*, students look for specific organisms, evidence of organisms, and organisms' interactions with the environment.
- When students create Ecosystem Models during *What Lives Here?*, Part 2, they think more in depth about interactions between parts of the system and how organisms get what they need to survive through these interactions.
- Students use their models to think about how different parts of the ecosystem might be impacted by changes, which expands their understanding to the ecosystem as a whole and to the complex ways that organisms depend on and affect one another.
- The understanding of how organisms get what they need to survive can deepen if students do any of the optional focused explorations (*Discovery Swap*, *Interview an Organism*, *Lichen Exploration*, and *Bark Beetle Exploration*).
- *Case of the Disappearing Log* and *Decomposition Mission* reinforce these ideas and take students a step further into thinking about decomposition and its profound role in the stability of a forest ecosystem.
- The final questions in the "Wrapping Up and Reflection" section give important opportunities for students to apply and solidify what they have learned about interdependent relationships throughout the field experience.

Building a foundation for understanding *Cycles of Matter and Energy Transfer in Ecosystems*. According to the *Framework*, students' knowledge of how matter and energy move through an ecosystem should progress from understanding that organisms get what they need to grow and survive from both their environment and other organisms, to understanding that

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matter cycles through different parts of an ecosystem, and ultimately to understanding that food webs represent the cycling of matter and the transfer of energy within an ecosystem.

- The first of those ideas is the focus of the *Ecosystems Theme Field Experience (2–3 Hours)* as students model and discuss interactions within ecosystems.
- The second idea is the focus of *Ecosystems and Matter Theme Field Experience (3–6 Hours)* in which students try to explain where the matter of a log went in *Case of the Disappearing Log*. They may deepen their understanding of how matter cycles by creating Decomposition Models in *Decomposition Mission* and by labeling the arrows of their Ecosystem Models from *What Lives Here?* to show the movement of matter.
- You can tackle the third idea if you use the matter-related and energy-related activities in [Optional] Extending the *Ecosystem and Matter Field Experience (3–6 Hours)* to Include Energy. The optional activities *Food, Build, Do, Waste*; *Card Hike*; and the *Bunny Question* offer students the opportunity to deepen their understanding of how matter cycles and to build some initial understanding of how energy flows through an ecosystem as they discuss a model of where the food an organism eats comes from and where its waste goes.

Performance Expectations to Work Toward

The NGSS represent complex knowledge and multifaceted thinking abilities for students. The *Ecosystems Theme Field Experience (2–3 Hours)* gives students multiple experiences with certain Science and Engineering Practices and Crosscutting Concepts. This field experience is an opportunity for students to work toward these Performance Expectations, but it's not a complete preparation. As with all Performance Expectations, multiple learning experiences in different contexts are necessary to facilitate full preparation. However, this field experience definitely gets students closer than a single activity!

Keep in mind that Performance Expectations are examples of things students should be able to do after long-term instructional units to show their understanding of important Disciplinary Core Ideas and Science and Engineering Practices as well as their ability to apply Crosscutting Concepts. Performance Expectations are *not* a curriculum to be taught to students. This field experience can help students work toward one or all of the following Performance Expectations:

- **5-LS2-1.** Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.
- **MS-LS2-2.** Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
- **MS-LS2-3.** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

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Additional Resources on Ecosystems, Matter, and Energy

Daehler, K. R., Folsom, J., and Shinohara, M. 2011. *Making Sense of Science: Energy for Teachers of Grades 6–8*. San Francisco: WestEd.

Daehler, K. R., Folsom, J. and Shinohara, M. 2012. *Making Sense of Science: Matter for Teachers of Grades 5–12.* San Francisco: WestEd.

Hoagland, M., Dodson, B., and Hauck, J. 2001. *Exploring the Way Life Works: The Science of Biology*. MA: Jones & Bartlett Learning.

Sussman, Art. 2000. *Dr. Art's Guide to Planet Earth: For Earthlings Ages 12 to 120*. San Francisco: WestEd.

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California: YMCA Camp Campbell, Rancho El Chorro Outdoor School, Blue Sky Meadow of Los Angeles County Outdoor Science School, YMCA Point Bonita, Walker Creek Ranch, Santa Cruz County Outdoor Science School, Foothill Horizons Outdoor School, Exploring New Horizons Outdoor Schools, Sierra Nevada Journeys, San Joaquin Outdoor Education, YMCA Camp Arroyo, Shady Creek Outdoor School, San Mateo Outdoor Education, Walden West Outdoor School, Westminster Woods.

Other locations: Balarat Outdoor Education, CO; Barrier Island Environmental Education Center, SC; Chincoteague Bay Field Station, VA; Eagle Bluff Environmental Learning Center, MN; Great Smoky Mountains Institute at Tremont, TN; Wellfleet Bay Wildlife Sanctuary Mass Audubon, MA; Mountain Trail Outdoor School, NC; NatureBridge (CA, WA, VA); Nature's Classroom (CT, MA, ME, NH, NY, RI); North Cascades Institute Mountain School, WA; NorthBay, MD; Outdoor Education Center at Camp Olympia, TX; The Ecology School, ME; UWSP Treehaven, WI; Wolf Ridge Environmental Learning Center, MN; YMCA Camp Mason Outdoor Center, NJ; and YMCA Erdman, HI.

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