beetles
Science and Teaching for Field Instructors

Ecosystems and Matter Theme Field Experience Script (3–6 Hours)

Note: This field experience write-up includes parts that are the same as the *Ecosystems Theme Field Experience Script (2–3 Hours)*, but takes students deeper. Print this 3–6 hour script and carry it with you as you lead this field experience.

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

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Ecosystems and Matter Theme Field Experience Script (3–6 Hours)

Contents

All materials created by BEETLES™ at The Lawrence Hall of Science.
Find the latest activities and information at http://beetlesproject.org.

Ecosystems and Matter Theme Field Experience Script (3–6 Hours)

Contents (continued)

TEACHING NOTES

MATERIALS AND PREPARATION

MATERIALS

For the instructor

- 2 manila folders, large sheets of paper, or portable whiteboard
- marker, large

For each student

- journal
- pen or pencil

PREPARATION

1. **Print this script to carry with you as you lead the field experience.**
2. **Prepare definition of *ecosystem*.** On a manila folder, large sheet of paper, or the whiteboard, write "ecosystem = all the living and nonliving things that interact with each other in a particular environment."
3. **Print a copy of the *Systems and System Models* crosscutting concept poster.** (Print a free copy at: https://johnmuirlaws.com/product/crosscutting-concept-poster)
4. **Prepare for [Optional] Extending the *Ecosystems and Matter Theme Field Experience Script* to Include Energy.** If you have chosen to do [Optional] Extending the *Ecosystems and Matter Theme Field Experience Script* to Include Energy (pages 18–19), on a manila folder, large sheet of paper, or the whiteboard, write "In one year, a rabbit weighing 8 pounds eats and drinks 400 pounds of plant material and water. About 140 pounds of waste is produced by the rabbit as feces and urine. What happened to the other 260 pounds?"
5. **Read individual BEETLES activity write-ups, gather other materials you will need for these, and print the Field Cards.** Each BEETLES activity referenced in this theme field experience includes a list of materials and preparation steps, as well as an Instructor Support section that outlines key concepts and content knowledge. At the beginning of each section in this theme field experience, links to the activity write-ups are included. Read each individual activity write-up and print a copy of the Field Card from each activity to carry with you in the field.
6. **Optional: Print a copy of the Complex Ecosystem Model (on page 24).** You may choose to share this illustration with students to compare with the models they made as an example of how complex ecosystem models used by scientists can be.

Introduction (~25–40 minutes)

You are What You Eat Name Game (~5 minutes)

Note: See the BEETLES *You Are What You Eat* activity write-up to lead this activity (http://beetlesproject.org/resources/for-field-instructors/youarewhatyoueat/).

Thought Swap (formerly known as *Walk & Talk*) (~5 minutes)

Note: See the BEETLES *Thought Swap* (formerly known as *Walk & Talk*) activity write-up to lead this activity.(http://beetlesproject.org/resources/for-field-instructors/walk-and-talk/).

1. **Introduce the *Thought Swap* routine.** Introduce *Thought Swap* as described in the BEETLES student activity write-up.
2. **Lead *Thought Swap* as you move to your trailhead or first activity site.** Use some of the following questions as an Invitation to the field experience theme. This will help students access their prior knowledge about how organisms interact in an ecosystem.
   - *Find out as many ways as you can that you and your partner are connected. Are you connected through music, activities, interests, people you know?*
   - *Look around. What are the organisms (living things) you see? What about nonliving things?*
   - *How might those things be connected with one another?*
   - *Look at that [stump/tree/bush]. Discuss as many ways you can think of that other organisms might use that [stump/tree/bush] to survive.*
   - *What would different kinds of organisms need to survive in this ecosystem?*
   - *What organisms do you think live here that we can't see?*
   - *How do organisms interact with the human-made things that are here, such as the cars, buildings, viewing decks, garbage cans, etc.?*
   - *How do the human-built things here affect organisms—positively, negatively, or both? Do they affect all organisms the same way, or do they affect some organisms positively and some negatively? Explain why you think so.*

Introduction to Ecosystems and Matter Theme (~15 minutes)

1. **Explain that there are amazing, interesting things everywhere, if we pay attention.**
2. **Tell students to look around from where they're standing, notice the organisms (living things) that surround them everywhere, and describe one to a partner.**
   a. Look around! There are amazing, interesting things everywhere!
   b. Take a moment to notice some of those things with a partner and describe one thing to a partner.

TEACHING NOTES

Beginning your day. Begin the field experience with your preferred practices for tone-setting, checking in with students, and preparing logistically for the day.

Starting with *Thought Swap* (formerly known as *Walk & Talk*). Starting with this routine supports social engagement, teamwork, and inclusion and establishes a group learning culture of discussion. Once students know the structure, they can drop into the routine easily throughout the rest of the day (as is suggested in this write-up). If it's a very short walk between activity sites, though, just arrange students in pairs and tell them to discuss questions with that one partner. Younger students can struggle with the rotation procedure, so try just pairing them without the rotation.

Keep it moving. Keep this introduction to the theme fairly brief and fast-paced. The point is not to tell students everything about ecosystems, but to give them a frame for the activities to come.

TEACHING NOTES

3. **Tell students they will get to explore the surrounding area and ecosystem, much like scientists would.**

4. **Hold up the card with the definition of *ecosystem* and read it out loud to students.**

5. **Explain that the theme for the day is ecosystems and tell students that their goal is to learn as much as they can about how the ecosystem works:**
   - **a.** We're going to learn as much as we can about this ecosystem.
   - **b.** We'll do that by exploring and observing parts of the ecosystem and then thinking about how those parts interact with and impact one another.
   - **c.** You'll get close up and make observations of organisms so we can figure out what lives here.
   - **d.** It means that we're going to have to do some detective work, looking for evidence of organisms interacting with one another and with the environment.
   - **e.** It also means that we're going to have to work as a team, sharing observations and ideas so we can all learn together.

Getting kids pumped. The idea of exploring and making discoveries about how things work can be exciting for students. Use it to get them pumped up to start the theme field experience.

6. **Explain that scientists have studied many ecosystems to learn about how nature works. Then, pump up students about their unique opportunity to explore *this* place:**
   - **a.** You might be exploring an area scientists haven't studied yet!
   - **b.** Try to be thorough and careful in making observations and learning about the ecosystem.

7. **Share that they'll also be thinking about how matter moves through the ecosystem:**
   - **a.** Ask students if they know what matter is and, if necessary, share that it's the stuff that everything is made of (leaves, air, water, rocks, etc.).
   - **b.** We're also going to pay attention to how matter moves through an ecosystem.
   - **c.** For example, if an animal eats another animal, matter from one animal becomes part of the other animal.
   - **d.** For another example, as a leaf decomposes, matter from the leaf becomes part of soil and air.

Keeping the momentum. If you do choose to do one of these optional activities as part of your initial phase of the theme field experience, keep it quick and connected to the theme to keep the momentum going and to keep students excited about exploring the ecosystem. An introduction is important to frame the experience and set the tone, but it's also important that students get a chance to do something in nature fairly soon.

Using *Mind Pie* to assess student understanding. This activity helps students access their prior knowledge on the topic, gives them an idea of what to expect during the field experience, and gives the instructor some information about the group that they can use to make instructional decisions.

[Optional] *Mind Pie* (~7 minutes)

Note: See the BEETLES *Mind Pie* activity write-up to lead this activity (http://beetlesproject.org/resources/for-field-instructors/mind-pie-2/).

1. **Introduce and lead the *Mind Pie* activity.** Introduce the activity as described in the BEETLES activity write-up, including statements from the NGSS Ecosystems, Matter, and Energy category in the *Mind Pie* write-up, as well as a few from the NGSS Science and Engineering Practices category.
   - Suggested prompts related to the ecosystems and matter theme of the field experience:
     - I can explain how organisms in this environment interact with one another.
     - I can explain decomposition.

- I can explain one or more of these:
  - what an ecosystem is
  - ecosystem models
  - systems
- Suggested prompts related to Science and Engineering Practices:
  - I can participate in a scientific discussion.
  - I like exploring outside.
  - I can make an explanation based on evidence.

[Optional] *Systems Game* (~8 minutes)

1. **Introduce the game.**
   a. We're going to play a game to help us think about systems and ecosystems.

2. **Explain how to play the game:**
   a. Pick one person in the group who (just for the purposes of this game) is your "prey" and one person who is your "predator." Be sure to keep who you choose a secret from everyone.
   b. Prey is an animal that is hunted and eaten by another animal.
   c. Predator is an animal that hunts and eats another animal. (Give students time to silently choose their prey and predator.)
   d. When I say, "Go," your goal is to stay close to your prey and away from your predator without letting anyone know who your prey and predator are.

3. **Set boundaries, play the game, and notice any patterns that emerge.**
   a. Make sure students are aware of boundaries and are being careful not to crash into one another.
   b. The group might look a little chaotic initially, but patterns tend to emerge—a clump of students chasing one another, the group widening apart and then coming together, etc.

4. **After a few minutes, pause the game and ask students to *Turn & Share* and describe any patterns they noticed of how the group moved.**

5. **Share observations as a group.**
   a. Ask some students to share adjectives to describe what happened in the game.
   b. Ask other students to use whichever hand signal for agreeing that your group uses when they agree with an adjective that someone else mentions.

6. **Make generalized statements about the kinds of adjectives students used and the patterns they noticed.**
   a. For example: "It seemed like many of us described the group's movements as quick. It seemed like many of us turned a lot, and at times there was a pattern where there were some small circles of students moving around."

7. **Explain that as individuals, they were trying to achieve the goal of survival, not trying to play a role or help the system:**

TEACHING NOTES

Deciding whether to play the *Systems Game*. The *Systems Game* is a way to get students thinking about some ideas related to systems (and to get students moving, too!). This game is a fairly lightweight introduction to systems thinking, but it does help debunk the common misconception that members of an ecosystem are aware of how they impact the ecosystem and want to help the ecosystem by fulfilling a role (e.g., decomposers *want* to break down dead things to help the ecosystem, or plants *want* to help by making food).

About educational games. Games are fun and can be energizing, but the learning that takes place during a game is often overestimated. Games can be used well in outdoor education, but they are often relied on too much to teach concepts and make learning fun, to the exclusion of letting students actually engage with nature and engage in a productive struggle with ideas. While the instructor may be thinking that students are learning about predator–prey interactions during a game, students are often thinking, *I'm playing tag!* Still, a well-designed and well-led game can give students a different perspective on a process in nature that they can't directly observe and can deepen students' understanding of something they're exploring. However, for this to happen, it must have a thoughtful introduction and debrief before and after.

TEACHING NOTES

Using difficult words. It takes about seven exposures to a word for it to become part of a learner's vocabulary. Ideally, students should hear, speak, read, and write the word. Define the word *ecosystem* the first few times you use it and hold up the card showing the definition. This will help students have a better chance of remembering the word and developing understanding of the concept.

Foundational tools for exploring nature. It's important to lead an activity such as *I Notice, I Wonder, It Reminds Me Of* toward the beginning of a field experience because it gives students tools to engage with and explore nature through wonder, curiosity, and a scientific mindset. Those are important and foundational attitudes that will make all the other activities on your field experience more successful. *NSI: Nature Scene Investigators* is another BEETLES activity that provides these tools. Students can keep using these tools to explore nature after they leave your program!

a. A system of how the whole group moved began to form—but it wasn't intentional.
b. This is similar to how an ecosystem works.
c. Each part of an ecosystem is just doing what it can to survive, not trying to make patterns happen and not trying to play a role or help out the ecosystem.
d. We call some organisms **decomposers** and some organisms **producers**, but those are names assigned by humans. Sometimes, we forget that the organisms themselves have no idea that they are called that.
e. The organisms are just going about their lives, eating what they can digest in order to survive.
f. When we observe organisms interacting, or evidence of interacting, it may seem like the organism wants to help somehow, like a decomposer breaking down something dead, or plants making food. However, they are each just doing what they can to survive.
g. These organisms may play a role in the ecosystem, like what humans call a decomposer, but without intent.
h. Although some organisms depend on one another, they aren't actually trying to help or hurt one another or to form any of the patterns we observe.
i. To learn about this ecosystem, we're going to spend time looking at the parts of the ecosystem and how the parts interact.

[Optional] *I Notice, I Wonder, It Reminds Me Of* (~25 minutes)

Note: See the BEETLES *I Notice, I Wonder, It Reminds Me Of* activity write-up to lead this activity (http://beetlesproject.org/resources/for-field-instructors/notice-wonder-reminds/).

1. **If you haven't done so already, introduce *I Notice, I Wonder, It Reminds Me Of* and tell students they will learn observation skills that will help them learn about the ecosystem.**
2. **Lead the activity as described in the BEETLES activity write-up, without doing the Optional Extension: Focus on Asking Scientific Questions.**
3. **Afterward, explain to students that the observation tools they've learned will help them better understand parts of the ecosystem.**
4. **Remind students to use tools from the activity throughout the field experience.**
   a. For example, when you come across something interesting, remind students to use the prompts out loud in pairs: "Call out what you notice." or "Use your observation tools."
   b. Or, during an Exploration phase of one of the activities, remind students to use these tools during their explorations before you send them out to observe.

What Lives Here? (Parts 1 and 2) (~40 minutes)

Note: See the BEETLES *What Lives Here?* activity write-up to lead this activity (http://beetlesproject.org/resources/for-field-instructors/what-lives-here/).

1. **Explain to students that they will start to learn about the ecosystem they are in by working together as a team to figure out what lives there:**
   a. You get to do something exciting—exploring together as a team, trying to figure out what lives in this ecosystem.
   b. You'll be recording what you find, like scientists might do.

2. **Lead the first two parts of *What Lives Here?* as described in the BEETLES activity write-up.** For now, just lead the first two parts of *What Lives Here?*:
   a. Part 1: Searching for Organisms and Evidence of Organisms
   b. Part 2: Discussing Organisms and Evidence

3. **After the activity, continue with your field experience, telling students they can keep adding organisms to their lists as they hike and giving them opportunities to do so. Explain:**
   a. Keep observing organisms and evidence of organisms during the field experience.
   b. You'll use the lists for something else later.
   c. The more you have recorded, the better.

4. **[Optional] If students used field guides to identify organisms, occasionally ask students who you know have identified a plant to identify it for the group as you hike.**
   a. Consider occasionally pointing at a plant that you know someone in the group learned to identify and asking that person to identify it for the group.
   b. Ask that student to show the group the features that helped them identify it.

5. **When students see new organisms to add to their lists, briefly brainstorm ways those organisms might be connected with other living and nonliving things in the area.**

[Optional] Additional BEETLES Activities to Explore Parts of the Ecosystem (~40–120 minutes)

1. **Lead one or more additional BEETLES activities to focus on and further explore parts of the ecosystem.** If you have more time and want your students to explore the ecosystem by focusing in on one specific organism or group of organisms (or one or a few parts of the system), lead one of the following activities:
   - ***Discovery Swap*** (~60 minutes). To engage students in a continued search for organisms and then an in-depth study of one particular organism, lead *Discovery Swap* as written in the activity write-up. Integrate the crosscutting concept of *Systems and System Models* into the activity to better support the group's understanding of

TEACHING NOTES

Skipping some Invitation questions. Some of the Invitation questions in the *Thought Swap* (formerly known as *Walk & Talk*) at the beginning of *What Lives Here?* are the same as those listed at the beginning of this field experience. Skip any you've already asked, ask the other questions, and then jump straight into the rest of the activity.

Students making mental notes to record later. Instead of having students stop to record organisms throughout the field experience, you could have them put their journals away and make mental notes of evidence of other organisms and nonliving things in the ecosystem they find throughout the field experience. When the group continues with the second half of *What Lives Here?*, give the group some time to add what they've seen to their lists in their journals.

Students teaching students. Giving students a chance to identify organisms and teach others how to do it both solidifies their skills and empowers them to rely on themselves and on one another instead of always turning to you for information.

Choose one or two activities. All these activities help students focus on one part of the ecosystem, which helps them deepen their understanding of the ecosystem as a whole. Do one, or at most two, of these activities before continuing on to the rest of the field experience.

Don't do both *Discovery Swap* and *Interview an Organism*. Both *Discovery Swap* and *Interview an Organism* engage students in close observation of a single organism. If you choose to do one of these activities, then don't do the other activity during this field experience.

TEACHING NOTES

Don't overdo it with discussion. There's already a fair amount of discussion in this field experience, both in the "*What Lives Here?,* Part 2" and the "Reflecting On and Wrapping Up the Field Experience" sections. There are also optional rich and worthwhile ecosystem discussions in the *Bark Beetle Exploration* and *Fungi Exploration* activities, but it might be best to skip those dicussions if you choose to do them in this field experience. Pay attention to how your group is doing. Mixing activities that are exploration-based and movement-based between discussions can be helpful.

ecosystems. See the sidebars and Instructor Support section to help integrate this crosscutting concept (http://beetlesproject.org/resources/for-field-instructors/discovery-swap-2/).

- ***Lichen Exploration*** (~45 minutes)**.** To engage students in studying lichen and discussing the unique relationship between the two organisms that make up lichen (fungi and algae), lead *Lichen Exploration* as written in the activity write-up (http://beetlesproject.org/resources/for-field-instructors/lichen-exploration-2).
- ***Fungi Exploration*** (~60 minutes)**.** To engage students in investigating fungi and discussing the impact of fungi on ecosystems, lead *Fungi Exploration* as written in the activity write-up (http://beetlesproject.org/resources/for-field-instructors/fungi-exploration/).
- ***Bark Beetle Exploration*** (~50 minutes)**.** To engage students in examining and making explanations about the evidence that bark beetles leave behind as they interact with trees, lead *Bark Beetle Exploration* as written in the activity write-up (http://beetlesproject.org/resources/for-field-instructors/bark-beetles-2/).
- ***Interview an Organism*** (~40 minutes)**.** To focus students on deep observations of a single organism and how it interacts with living and nonliving things in its surroundings, lead *Interview an Organism* as written in the activity write-up (http://beetlesproject.org/resources/for-field-instructors/interview-an-organism/).

2. **When introducing any of these activities, make connections to the theme and point out that studying one part of the ecosystem in depth will help students better understand the ecosystem as a whole.**

3. **Hold up the *Systems and System Models* poster and explain:**
   - **a.** When looking at a system, it can be helpful to study one part of it in depth.
   - **b.** Looking at systems is a way of thinking that scientists often use to understand things.
   - **c.** Knowing how [bark beetles, spiders, macroinvertebrates, etc.] interact with other parts of the ecosystem to get what they need to survive can give us a deeper understanding of this whole ecosystem and how the parts of the ecosystem affect one another.

4. **As you wrap up any of these activities, help students connect what they learned to the theme by asking them to reflect on their understanding and have them add any organisms or interactions they've seen to the lists in their journals. Explain:**
   - **a.** Take some time to add the names of any new organisms you've seen to your journals.
   - **b.** By focusing on _____, we went in depth and learned about one of many parts of the system.
   - **c.** *Turn & Share* (or *Thought Swap*) with a partner about some of the following questions after doing the optional activities:
     - *What are parts of the ecosystem we observed during that activity?*
     - *How do those parts connect to/interact with other parts of the ecosystem?*
     - *What do you wonder about the ecosystem?*

[Optional] *Thought Swap* (~5–10 minutes)

1. **If you need to move locations between *What Lives Here?* and other activities, use some of the following questions to help students keep thinking about the theme:**
   a. Explain: I once saw an interesting interaction between two animals. [Describe an interesting interaction you've seen, ideally at your site.]
      - *Tell your partner about a time you've seen animals interact (do something with each other) in nature. It could be from a video.*
   b. Explain: I once saw an interesting interaction between an animal and a plant. [Describe an interesting interaction you've seen, ideally at your site.]
      - *What are some ways that animals and plants might interact?*
   c. Explain: I once saw an interesting interaction between a living thing and a nonliving thing. [Describe an interesting interaction you've seen, ideally at your site.]
      - *What are some ways organisms interact with nonliving things in their ecosystem?*

Case of the Disappearing Log and/or *Decomposition Mission* (~60–170 minutes)

1. **To support the ecosystems and matter theme, do at least one of these activities (or both, depending on how much time you have and the energy of your students).**
   a. Both activities (in separate blue boxes on pages 12 and 13) give students experience with how matter moves between parts of an ecosystem, but *Decomposition Mission* is a deeper dive into matter cycling.
   b. In *Decomposition Mission*, students collect objects to make a spectrum from fresh wood or leaves to soil, search for decomposers, investigate and make models of the process of decomposition, and discuss the role of decomposers in cycling matter through an ecosystem.
   c. *Case of the Disappearing Log* is more mystery-focused. Students explore a decomposing log, learn to identify different kinds of evidence that decomposers leave behind, and make explanations about what happened to the log. Students also discuss how the decomposing log is evidence of matter cycling within an ecosystem.
   d. For younger students or groups currently struggling to focus, *Case of the Disappearing Log* might be the better choice for helping them stay engaged.

TEACHING NOTES

Abbreviated and less structured *Thought Swap*. If it's just a short distance, tell students to quickly find a partner and discuss the questions with that partner as they walk toward where you will do the activity.

Lunchtime question. A lunchtime question that can help students think at the level of environmental planning and management is: *Should we preserve ecosystems? If so, should humans be allowed into them?* If you discuss this question, point out the disproportionate impact people have had on ecosystems for students to use as evidence in their discussions. Also mention that people often think nature in America was pristine when colonists arrived, but it wasn't. Indigenous people managed nature for centuries throughout the continent, using such strategies as controlled burns. Hold back from telling students *how* to think. Encourage a diversity of ideas from different perspectives.

TEACHING NOTES

***Case of the Disappearing Log*: Crosscutting concept.** The crosscutting concept of *Cause and Effect* is used throughout *Case of the Disappearing Log*. It's a useful thinking tool for students as they try to explain what's happening to the log, so be sure to include those steps and language in the activity. When you introduce the activity and debrief it afterward, discuss how what students are doing relates to systems thinking (as described in the additional steps in the blue box on this page).

***Case of the Disappearing Log*: Brainstorming systems within systems.** For fun, you might want to start off with the system of a galaxy and then challenge students to think of a system within that system and then systems within *that* system, and see how far students can go down that path—to the tiny system in a cell.

Case of the Disappearing Log (~60 minutes)

Note: See the BEETLES *Case of the Disappearing Log* activity write-up to lead this activity (http://beetlesproject.org/resources/for-field-instructors/case-disappearing-log/).

Incorporate this introduction:

1. **Frame the activity as an investigation of a smaller system within the ecosystem. Explain:**
   a. When we started making ecosystem models based on what lives here, we talked about how scientists choose what to include in their models, depending on what they want to learn from a model.
   b. Scientists do the same thing when they think about systems—they decide how big of a system they want to study, depending on what they want to figure out.
   c. Sometimes scientists study really big systems, and sometimes they study smaller systems that are part of larger systems.
2. **Show the *Systems and System Models* crosscutting concept poster and describe the study of a smaller system within an ecosystem.**
   a. There are systems within systems within systems.
   b. For example, some scientists may study the digestive system of a bunny, others may study the whole system of a bunny's body, others may study the system of a food web, and still others may study the whole ecosystem.
   c. We're going to investigate a smaller system within the ecosystem we've been exploring—a log.
3. **Lead the activity as written in the activity write-up.**
4. **When finished, if you're going to do *Decomposition Mission*, see the box on the next page. If not, go to *What Lives Here?* Parts 3–5, beginning on page 14.**

TEACHING NOTES

Decomposition Mission (~110 minutes, includes the aditional steps here)

Note: See the BEETLES *Decomposition Mission* activity write-up to lead this activity (http://beetlesproject.org/resources/for-field-instructors/decomposition-mission/).

Incorporate this introduction and these adjustments to the activity:

1. **Explain that you'll be investigating one part of the ecosystem.**
   - **a.** We'll look at one part of the ecosystem—decomposers—and the important role they play in an ecosystem.
   - **b.** Scientists often look at one part of a system.
   - **c.** Studying one part of a system can help us understand the whole system.

2. **Lead *Decomposition Mission* as written in the activity write-up, making the following adjustments:**
   - **a.** In the "Making Decomposition Diagram Models" section, students need an opportunity to incorporate the lists they've made from *What Lives Here?* into the models they make in *Decomposition Mission*. This opportunity is not in the activity write-up, so you'll need to add it.
     - Call the models Ecosystem Models (instead of Decomposition Diagram Models) and tell students they are making models of the ecosystem, including any kind of interactions between living and nonliving things.
     - In addition to all the parts about decomposition included in the write-up (example of decomposition, explanation about how decomposition happens, decomposers, and results of decomposition), tell students to include all the living and nonliving things they've written on their lists so far in their Ecosystem Models, even if those things don't seem to relate to decomposition.
   - **b.** In the "Decomposition Discussion" section:
     - For Step 1, be sure to use the question, "Where is the stuff that used to be part of the wood now?"
     - For Step 2, use cards #1, #2, and #4 to help students think about cycling of matter in ecosystems.
     - For Step 5, tell students to change or add to their models what they've learned about decomposition. Also tell them that they can add arrows showing any other kinds of matter cycling that they can think of (e.g., To show matter cycling during a bird eating a bug, the arrow would go from the bug to the bird in the direction of the movement of matter. To show a frog breathing in oxygen, the arrow would go from air to frog. To show a plant breathing out CO_2 the arrow would go from plant to air.).
   - **c.** In the "Wrapping Up: Reflecting on Decomposition" section:
     - For Step 1, be sure to use Question #3.
     - For Step 4, be sure to use some of these questions with students.

TEACHING NOTES

NGSS crosscutting concept: *Systems and System Models*. To help your students understand and use this thinking tool, explain that scientists use models to isolate one system, or parts of it, to learn about the larger systems that make up our world. Scientists decide what parts of the system to focus on and which to leave out in order to better understand something. They pay attention to interactions between parts of a system. They also notice things outside the system that affect it. It's important that students interpret their models and use them to answer questions in order to use their models in a scientific manner.

Noticing systems within systems. Throughout your students' field experience, keep asking them to point out interactions between the parts of the different ecosystems they see. A further step could be to ask them to begin to notice smaller systems within the ecosystem, such as recognizing a tree as a system with its own internal parts or an organism as a system of interacting body parts. The more systems students identify, the more they will come to recognize how useful a systems lens can be to understand the natural world.

What Lives Here? (Parts 3–5) (~40–45 minutes)

The "Making Ecosystem Models," "Discussing Ecosystem Models," and "Wrapping Up" sections of *What Lives Here?* have been adapted to serve as a conclusion to *Ecosystems and Matter Theme Field Experience Script (3–6 Hours)*. Use the adapted sections as written here (Part 3: pages 14–17, Part 4: page 20, Part 5: pages 21–23) rather than using the *What Lives Here?* activity write-up. If you've done the *Decomposition Mission* activity, skip *What Lives Here?* Parts 3–4 and end with whatever aspects of Part 5 feel appropriate.

Part 3: Making Ecosystem Models (adapted from *What Lives Here?*) (~10 minutes)

1. **Seat the group and have students add the names of any organisms they've seen to their journals.**
2. **Tell students to look outward and take a moment to imagine the complexity of all the plants, big animals, tiny animals, fungi, and bacteria in this ecosystem.**
   - **a.** Look out at nature.
   - **b.** Quietly imagine how many different kinds of plants there are in the area and how many of each type of plant there might be.
   - **c.** Repeat Step b, listing big animals (e.g., mammals, snakes, lizards, fish), tiny animals (e.g., insects, spiders, worms), fungi, etc.
   - **d.** Pick up a pinch of soil. There may be millions of bacteria in there—it's unimaginable how many there are in the whole ecosystem!
   - **e.** The organisms you've found and recorded today are a very tiny fraction of what's actually living there.
3. **Explain that students will be using a science "thinking tool" of systems and system models to try to understand parts of the ecosystem.**
4. **Describe how scientists often make a model of a system and its parts to try to better understand the natural world.**
   - **a.** Since there is so much out there in the world, we can't understand or investigate all of it at once.
   - **b.** Scientists often isolate one system (e.g., an ecosystem, as opposed to everything living on Earth), or parts of it, to learn more about the larger systems that make up the world.
   - **c.** In this activity, we identified parts of the ecosystem we explored and focused on the many interactions between those parts.
5. **Explain to students that they will make models of parts of the ecosystem to help them understand it, kind of like scientists do:**
   - **a.** You'll each use the information you've already recorded and add more to make a model of the ecosystem to try to understand it better.
6. **Explain that students will include living and nonliving things to make their models.**
   - **a.** So far, you have only included living things.
   - **b.** But there are lots of nonliving things in every ecosystem, too.
7. **Have students do a quick brainstorm of nonliving things in the ecosystem.**

8. **Explain that students won't be able to include everything in their models and that including what they think is important affects what they'll learn from their models.**
   a. When you're making a model, you get to choose what's included and what isn't included.
   b. These are important decisions because they affect the kind of understanding you'll be able to get from the model.
   c. We probably can't include every nonliving thing here in our models.

9. **Brainstorm nonliving things in the area that might be connected to organisms and that are important to include in students' models. Have students record some of these.**
   a. Ask students to brainstorm nonliving things that might be connected to the organisms they saw and that might be important both to them and to understand the ecosystem.
   b. For example:
      - *If you've noticed strong winds and have seen ravens riding the winds and plant growth being short and rounded from wind, then wind could be an important nonliving thing to include in your models.*
   c. Tell students to add significant nonliving things (e.g., sand, rocks, dirt, logs, creeks, litter) to their models.

10. **Encourage students to add more living and nonliving things to their models.**
    a. When students come up with new living and nonliving things, brainstorm ways they might be connected with other living and nonliving things in the area.
    b. If you're doing this while continuing to move through your field experience, it can be helpful to pause the whole group after an experience or observation, or when they've arrived at a new location, to take a minute to add new evidence to their models.

11. **Get students pumped up about how they are gaining a deeper understanding of how connected things in the ecosystem are. Explain:**
    a. We've discussed how parts of this ecosystem are connected throughout this whole field experience, but now we're REALLY seeing how connected things are.
    b. For example, we figured out that matter in logs becomes part of the air we breathe in!
    c. When we breathe out, some carbon dioxide from our bodies could, in turn, become a part of these trees!
    d. Matter keeps cycling in Earth's systems, which means that the water here could have been a part of dinosaur bones at some point, or a part of a sneeze from Cleopatra!

12. **Tell students that they'll spend time thinking about how parts of the ecosystem are connected through the cycling of matter.**

13. **Show an example of adding a couple of "matter" arrows (labeled "M") on your whiteboard. Explain:**

TEACHING NOTES

Are dirt and logs nonliving things?
Dirt is full of living things, and so are logs. This write-up refers to logs as nonliving things, but it could be argued that they are living things because they house so many living things within them, much like soil does. Decide whether you want to keep things simple and let students call them nonliving things, or if you want to get students thinking more deeply about the topic. Or, perhaps you can challenge students to decide as a group, through an evidence-based discussion, whether they think a log can be considered living.

TEACHING NOTES

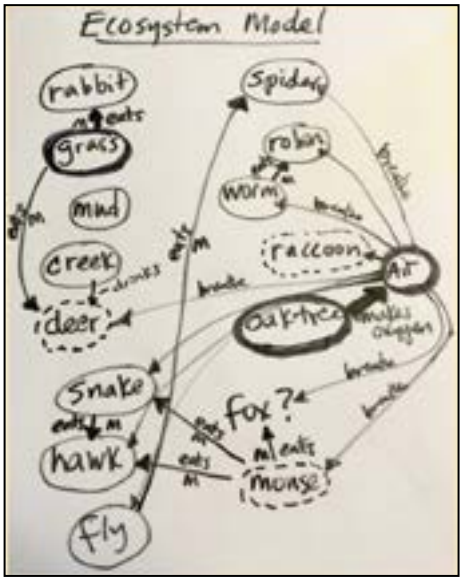
a. Now you're going to add an arrow labeled with an "M" (for "matter") to show the flow of matter from one organism to another and both to and from nonliving parts of the ecosystem.
b. Add organisms and nonliving things (such as a log) from the *Case of the Disappearing Log* and/or *Decomposition Mission* to your Ecosystem Models.
c. For example, to show the flow of matter from the log, draw an arrow from the word *log* to the word *termite* with an "M" next to the line.
d. Then, draw another arrow to the term CO_2 because the termite then breathes out carbon dioxide.
e. Draw arrows in the direction that matter moves, such as from prey toward predator.

14. **Ask: "How does matter cycle through other parts of this ecosystem?"**
a. Remind students that they discussed how the matter that used to be in the log (or in their decomposition displays) cycled and became a part of organisms that ate it, as well as the soil and the air.
b. Then ask:

▶ *What are other parts of the ecosystem that matter moves through?*

c. Listen to students' responses and assess their understanding of matter cycling.
d. If students don't have ideas right away, ask them to look at their Ecosystem Models and discuss how matter moves between parts that are interacting.

15. **Tell students to show the cycling of matter in their Ecosystem Models.**
a. Explain that just as you added small arrows and a letter "M" on the whiteboard to show how matter cycles between parts of the ecosystem, students should add labeled arrows to their Ecosystem Models to show how matter moves through the ecosystem.
b. If necessary, give another example: For example: "If you have a line between a deer and grass, you can make the line into an arrow pointing from the grass to the deer to show that as the deer eats the grass, matter from the grass is moving into the deer."



16. **Explain that the model will be more useful if it shows which parts might have more influence over other parts of the ecosystem. Students can circle these parts with thick lines.**
    a. In any ecosystem, there are living and nonliving things that are more influential to what is going on in the ecosystem.
    b. Maybe it's a top carnivore. Maybe it's strong winds. Maybe it's water in a desert or snow on the mountains. Maybe it's a plant that many organisms depend on.
    c. Use thicker lines to circle these parts of the ecosystem.

17. **Explain that students can show more influential connections with bigger/thicker lines or arrows:**
    a. Some interactions might be more influential, too, such as fungus decaying wood or elk eating young trees.
    b. You can show these by making lines or arrows that are bigger or thicker, while making other lines or arrows smaller or thinner.

18. **Tell students that they can also add labels to the lines, such as "eat" or "makes home in" to explain the type of connection/interaction.**

19. **Give pairs (or groups of four) about 10 minutes to discuss and record as many connections/interactions as they can while you circulate and ask questions.**
    a. Encourage students to talk to one another as they work.
    b. Circulate and check in with pairs or groups.
    c. When students add a connection, ask questions such as, "What's your evidence for that connection?" or "Does that seem like a more influential part of the ecosystem? What makes you think that?"

20. **Optional: If you printed a copy of the Complex Ecosystem Model (on page 24) to share with your students, hold it up now.** Explain that it is an example of how complex ecosystems models used by scientists can be.

21. **If your students seem antsy, move them to another location before the "Discussing Ecosystem Models" section.**
    a. Some groups will be focused enough to continue directly to the next stage of the activity, but others will need to move around and maybe do something different for a while.
    b. This may also give students more things to add to their Ecosystem Models before the discussion.

TEACHING NOTES

Check for understanding. Circulate as students add arrows to their models and ask questions to assess and support their understanding. For example: "What was the interaction you observed between ____ and ____?" "Does that involve matter cycling? If so, how?" "Why did you decide to point that arrow in that direction?"

Complex ecosystem models. At this point, it's likely that students' Ecosystem Models might look fairly chaotic. There may be arrows every which way, showing small and large connections between different organisms and parts of the ecosystem. Often, what looks chaotic to the instructor makes sense to the student, and that is fine. Explain that although students' models may seem complex, those made and used by scientists are often far more complex. Consider showing students the Complex Ecosystem Model (from page 24) as an example of how complex ecosystem models that scientists use can be. Then, remind students that although this model looks super complex, it can only show a fraction of the complexity of an actual ecosystem.

TEACHING NOTES

The *Bunny Question*. The *Bunny Question* takes thinking and conversation to a conceptually higher level. It's listed as optional because it's best used with groups you think are sophisticated enough in their thinking so far to tackle it. (It's even challenging for adults!) If you do decide to use it, build it up for students. For example: "I've got another question for you that's more challenging. Do you think you're ready for a more challenging question? Are you sure? Okay. Here it comes . . . ."

Assessing student understanding. One goal of the bunny discussion is assessment of student learning. After the previous activities, students should have some understanding of how matter cycles and should show that understanding by saying that some of the plant mass comes out as carbon dioxide. Listen to what students say to gauge how deep their understanding is of matter cycling. Use this as information to make decisions about where to put your focus for the rest of the field experience, and where students may need some additional support to build their understanding.

[Optional] Extending the *Ecosystems and Matter Theme Field Experience Script* to Include Energy (~120 minutes)

If you have time and if students are engaged and focused (or if you wish to extend the field experience to another day), consider using the following activities to dive more deeply into the cycling of matter in an ecosystem and to introduce the idea of energy flowing through an ecosystem. If you do include energy, tell students to add energy arrows to their models, using either a different color or a different kind of line, such as a squiggly line. They could do this immediately after drawing matter arrows, or they could add them after doing the *Food, Build, Do, Waste* activity.

The *Bunny Question* (~10 minutes)

1. **Ask and discuss the bunny question.** Hold up the question you wrote on a manila folder, a big sheet of paper, or the whiteboard and pose it to students. Give them a chance to *Turn & Share* about their ideas and then to share in the group.
   a. Ask: "In one year, an 8 pound rabbit may eat and drink ~400 pounds of plants and water. About 140 pounds come out as poop and pee. What happens to the other 260 pounds?"
   b. Listen to students' ideas. There are a variety of possible correct answers, as well as one very common incorrect answer—*The matter in the rabbit was burned off into energy*. Don't correct students if they give that answer (yet!). Accept all ideas. Probe to find out more about students' thinking. Ask students to share the reasoning behind their ideas and to agree and disagree respectfully. Ask: "What's your evidence for that?" or "What makes you think that?"
   c. After some students share their ideas (and before the momentum slows down), bring the discussion to a close. It's more than okay if students are still scratching their heads. Tell them that they'll learn a bit more about what happens when something eats and that this will help them answer the bunny question.

Food, Build, Do, Waste (~10 minutes)

Note: Refer to the BEETLES *Food, Build, Do, Waste* activity write-up to lead this activity (http://beetlesproject.org/resources/for-field-instructors/food-build-waste/).

1. **Lead the *Food, Build, Do Waste* activity.**
2. **Revisit the *Bunny Question*.** After leading the *Food, Build, Do, Waste* activity, revisit the bunny question to see if students have any new ideas about where all that food and water has gone. Listen to their ideas and

ask for their evidence behind their explanations. Students might say: *Some of the food is actually a part of the rabbit's body, and my reasoning is that if the salamander I just observed used food to build part of its body, so would the rabbit.* Or: *Some of the food was used as energy the rabbit needed to move around and stay warm.* Again, use this as an opportunity to get a sense of students' level of understanding of the material.

Matter and Energy Theme *Card Hike* (~60 minutes)

Note: Refer to the BEETLES *Card Hike* activity write-up to lead this activity (http://beetlesproject.org/resources/for-field-instructors/cardhike/).

1. **Lead the *Card Hike*, using the matter and energy–themed cards, as written in the activity write-up.** If you don't have time for the *Card Hike*, consider sharing any of the following additional pieces of evidence. All but the last of these are included in the *Card Hike* activity.
   a. During the hike, share additional pieces of evidence—either intermittently through sharing or through showing *Card Hike* cards—such as the following:
      - **water vapor:**
        - If you breathe on a mirror or a window, the droplets that appear are evidence that you lose water vapor with every breath.
        - Humans release about 1½ pounds of water per day through breathing and sweating. That's a little under the weight of a 1 liter bottle of water.
        - Just by breathing, humans release about 2 pounds of weight every day from the carbon dioxide that is breathed out.
      - **air:**
        - It's difficult to feel it, but the air around us does have mass (weight).
      - **matter and energy:**
        - Under the usual circumstances found here on Earth, matter does *not* turn into energy.
        - $E = mc^2$ is an important idea in physics and the theory of relativity, but it's *not* useful for explaining matter and energy in ecosystems. (This is not included in the *Card Hike* cards, so only share this if a learner brings it up.)

TEACHING NOTES

Confused about energy? Energy is a complex, difficult-to-grasp concept. For more on what energy is and how it's different from matter, see the Instructor Support section of the BEETLES activities *Matter and Energy Diagram* or *Card Hike*.

TEACHING NOTES

Part 4: Discussing Ecosystem Models (adapted from *What Lives Here?*) (~10–15 minutes)

1. **After students finish adding connections/interactions to their models, lead a discussion in which they use their Ecosystem Models as evidence for their explanations about the ecosystem.** Ask students some of the suggested discussion questions (Step 2, below) to lead a discussion. During the discussion:
   a. **Help students evaluate the strength of evidence used.** If students cite something on their models as evidence, ask if they have strong, less strong, or weak evidence for it and, perhaps, also ask what their evidence was. (Tracks? Hair? The actual organism? etc.)
   b. **Follow students' interests, use *Turn & Shares*, and ask follow-up questions.** Follow students' interests in the discussion and move the discussion along before the group becomes uninterested. Use *Turn & Shares* after some questions and also use hand motions showing agreement to keep the whole group involved in the discussion. After students share their ideas, ask follow-up questions such as: "What makes you think that?" "What's your evidence for that?" or "Does anyone agree, disagree, or have a different idea?"

2. **Suggested discussion questions:**
   - *Based on our models, which organisms might compete for the same food?*
   - *How might other organisms in the model be affected if _____ decreased?*
   - *If _____ increased or decreased, how might it affect the organisms we saw? Trace out the connections. How does it affect all the connections?*
   - *How might it affect the ecosystem if this* [choose something with a thick line around it] *were to disappear?*
   - *How might it affect other organisms in the model if this producer* [choose one] *were to die off?*
   - *How might it affect other things in this model if _____* [name an organism something many organisms interacted with] *disappeared?*
   - *How might it affect the organisms in this model if there were less of _____* [name a nonliving thing that many things interacted with]*?*
   - *How might all these interactions be affected if a road were put in the middle of this environment we just explored? If we turned this piece of land into a farm?*

3. **Suggested matter-related questions:**
   - *Explain how the matter that makes up a plant could have been part of a deer at some point in the past.* (If students don't mention carbon dioxide in their explanations, ask how it might play a part.)
   - *Based on what you learned about this ecosystem, make some predictions about how matter might cycle through another ecosystem, such as _____.* [Name an ecosystem different from the one you're in, such as the desert, the ocean, the tropical rain forest, etc.]

Don't leave out carbon dioxide! Many students think that when organisms decompose, the matter from their bodies mostly becomes part of soil. A relatively small amount does, but the bacteria and other decomposers convert most of the matter from the organism into carbon dioxide and water in the air.

Part 5: Reflecting On and Wrapping Up the Field Experience (adapted from *What Lives Here?*) (~20 minutes)

1. **Review the activities you did.**
   a. Review the activities you did throughout the day and the different ways students looked at the ecosystem. For example:
      - *Today we investigated the _____ ecosystem in different ways.*
      - *We looked for evidence of different living and nonliving things.*
      - *We looked at the connections/interactions between many living/nonliving things in the ecosystem.*
      - *We looked at how matter cycles within an ecosystem.*
      - *We looked at _____.* [Include review of any other activities you did.]

2. **Review some of the main concepts with which students engaged and ask them to share examples of things they observed that relate to the concept. Explain:**
   a. Let's think about some of the main ideas we looked at during this field experience.
   b. One of them is that everything is connected in an ecosystem.
   c. When one thing in an ecosystem changes, not everything dies, but everything is impacted.
   d. What are some examples of this that we observed or discussed?
   e. Matter cycles between organisms, air, soil, water, us, and dead things. What are examples of how we saw that in this ecosystem?
   f. What are some examples of how that might happen in another ecosystem or another system (such as where you live)?

3. **Point out how scientists use ecosystem models to decide how to lessen human impacts because we humans have had such a large impact on ecosystems.**
   a. Scientists often use ecosystem models to understand how parts of an ecosystem are affected by humans and to make decisions about how to lessen our impacts.
   b. Ecosystem models are helpful for this because mapping out the different connections and impacts helps us predict how the introduction of something, or the lessening of something else, might affect an ecosystem.

4. **Discuss the usefulness and limitations of an ecosystem model.**
   a. Highlight how students' Ecosystem Models helped them visualize and think about the questions they discussed.
   b. Also remind students that, like all models, their Ecosystem Models are not exact representations of the real ecosystem.
   c. Ask a few students to share things that are inaccurate about their models (e.g., Real organisms are living and breathing—not just our words on a page.).

TEACHING NOTES

It's engaging and important to critique models. Students often enjoy coming up with the inaccuracies in a model. It's also an important step to include and important for students to understand the practice of using models in science. Without taking the time to identify and name the inaccuracies, students may walk away with new misconceptions they got from their models.

TEACHING NOTES

5. **Ask students to *Turn & Share* about some things they can't learn through using their models. Then explain:**
   a. It's impossible to know all the ways an ecosystem might be affected by a change—which is why scientists sometimes try management strategies that end up not working the way they expected them to.

6. **Explain that systems thinking is useful for understanding *many* parts of the world, not just ecosystems, and especially important when considering making a change to a system:**
   a. Systems thinking is a useful way of looking at how different parts of any system affect one another.
   b. It's especially important when you want to make a change to a system.
   c. As we saw when we discussed _____ [use an example from your discussions], shifting one part of a system can change what happens in the other parts of that system.

Connection to built systems. Natural systems are different from human-built systems. Unlike natural systems, a human-designed and human-built system (e.g., a bicycle) *is* planned and designed with a certain goal or function in mind. If your students (or your program) are interested in design and engineering, it can be useful to point out this difference.

7. **Ask students to discuss where else they might be able to use systems thinking.**
   a. It's important to think about how different parts of a system affect one another.
   b. For example, even your school is a system.
      - If you wanted to change something in your school, it might help to think about it as a system.
      - You'd consider how the change would affect all the parts of the system and how the system functions as a whole.
      - That would give you a better idea of all the effects of the change.
   c. *Turn & Share* with a partner about a system you could apply this thinking to. It could be a human-built system (such as a bicycle you want to fix), a body system that you are curious about (such as your respiratory system), or a system in nature, etc.

8. **[Optional] Return to *Mind Pie*.** If desired, show students *Mind Pie* again and ask them to consider whether they feel more solid about certain parts of the pie than they did at the beginning of the day.

9. ***Thought Swap* about reflection questions.** Give students the chance to *Thought Swap*, using only a few of these questions:
   - *Dr. Martin Luther King said, "We are all of us interconnected." What are some ways you learned that you are connected to this place? How does it feel to think about those connections?*
   - *Explain how the air you are breathing in could have come from a leaf.*
   - *What were some interesting things we experienced today?*
   - *What are some questions you have about organisms or anything else we saw today?*
   - *What were some ideas that made you think in different ways?*
   - *Talk about things you enjoyed.*
   - *Describe some of the funniest moments of the day.*

- *What did you do today that makes you feel proud? What are some things you could do better?*
- *Did you notice anyone else doing something today that impressed you?*
- *What are some examples of how people treated one another well today?*
- *What helped you to learn today?*
- *Describe some things you learned today.*
- *Describe some things you learned today that are not facts—such as different ways to look at things or to think about things.*
- *Did you learn anything that surprised you today? If so, what?*
- *If you were to take a family member to this site or one like it, what are some organisms you would show them? What could you show them and teach them about how to observe, think, and learn in nature?*
- *Pretend you are talking to a younger brother or sister or a younger friend. Describe to them how to make observations in nature.*
- *Think of some places near your home where you could do these sorts of explorations.*

TEACHING NOTES

Writing about a question. After discussing some of the reflection questions, you might want to choose one or more of the questions and give students time to write about them. Depending on the question(s) you choose, this can give students a chance to apply what they've learned throughout the day about interdependent relationships in ecosystems and/or the cycling of matter in an ecosystem. This could be an important opportunity for students to solidify their understanding, as well as a chance for you to informally assess their understanding so you can plan how to address any lingering confusion in your remaining time with them. Note that some of these prompts overlap with questions you may have discussed during various activities. If you've already discussed some of these reflection questions, you may want to choose a new prompt for this discussion or writing. On the other hand, choosing a similar prompt could be a useful scaffold for students who benefit from talking about their ideas before writing and may also give students a chance to revise their explanations in case they understand more now than they did earlier.

COMPLEX ECOSYSTEM MODEL

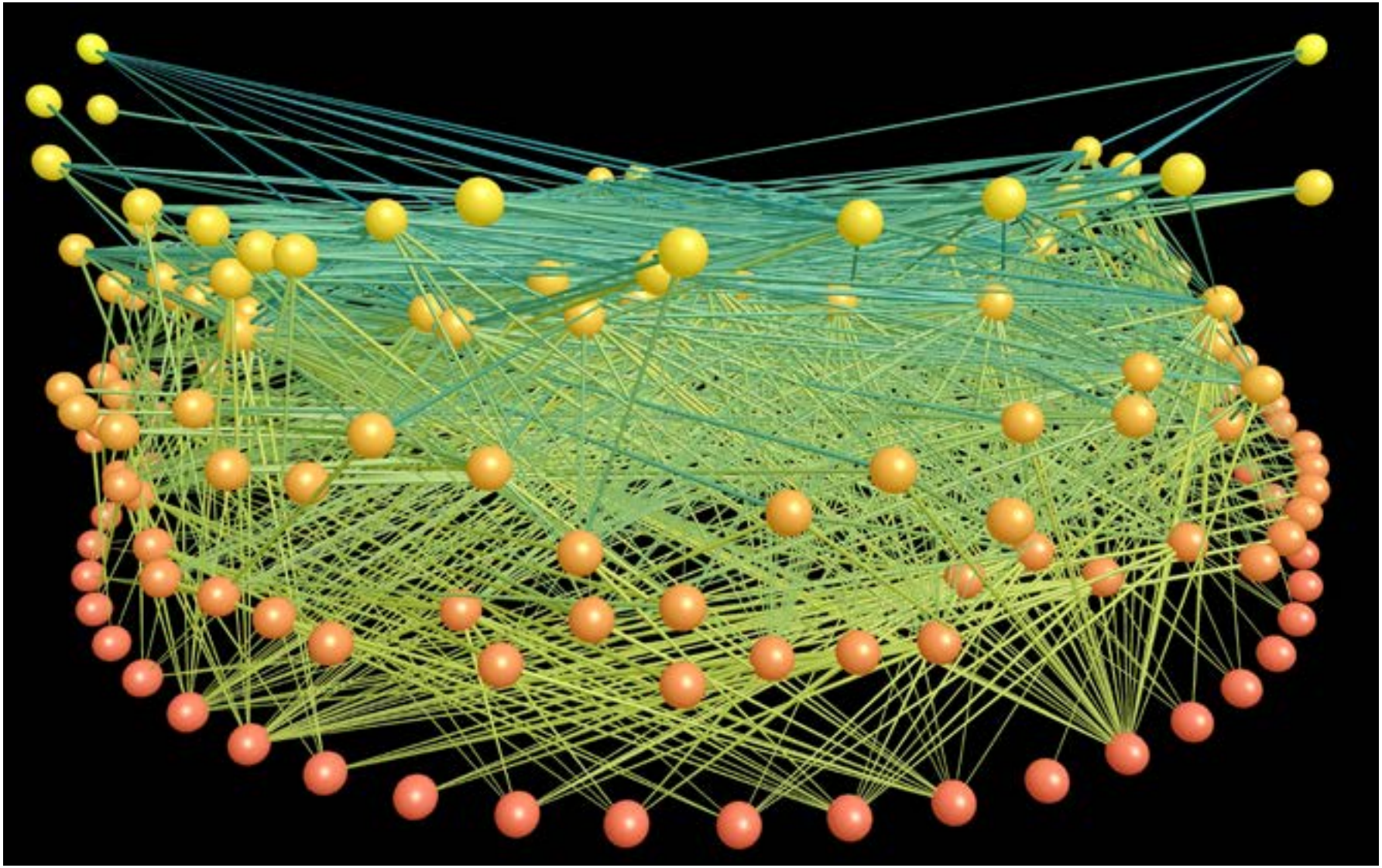


Image produced by Neo Martinez with Network3D software (Yoon et al 2004) available by request from jdunne@santafe.edu. Yoon, I., R.J. Williams, E. Levine, S. Yoon, J.A. Dunne, and N.D. Martinez. 2004. Webs on the Web (WOW): 3D visualization of ecological networks on the WWW for collaborative research and education. Proceedings of the IS&T/SPIE Symposium on Electronic Imaging, Visualization and Data Analysis 5295:124–132.

ABOUT BEETLES™

BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) provides environmental education programs nationally with research-based approaches and tools to continually improve their programs.

www.beetlesproject.org

Lawrence Hall of Science is the public science center of the University of California, Berkeley. *www.lawrencehallofscience.org*

BEETLES Team: **Craig Strang**, **Kevin Beals**, **Jedda Foreman**, and **Emilie Lygren**
Additional Contributors: **Emily Arnold**, **Lynn Barakos**, **José González**, **Catherine Halversen**, **Valeria Romero**, and **Emily Weiss**
Research Team: **Mathew Cannady**, **Melissa Collins**, **Rena Dorph**, **Aparajita Pande**, **Valeria Romero**, and **Aujanee Young**. Emeritus: **Bernadette Chi**, **Juna Snow**
Project Consultants: **John (Jack) Muir Laws**, **Penny Sirota**, and **Mark Thomas**
Advisory Board: **Nicole Ardoin**, **Kevin Crowley**, **José González**, **Maggie Johnston**, **Celeste Royer**, **Bora Simmons**, and **Art Sussman**. Emeritus: **Kathy DiRanna**, **Kathryn Hayes**, **April Landale**, **John (Jack) Muir Laws**, **Jack Shea**, **Penny Sirota**, **Drew Talley**, and **Mark Thomas**
Editor: **Trudihope Schlomowitz**
Designer: **Barbara Clinton**

The following programs contributed to the development of these materials by field testing and providing invaluable feedback. For a complete list of contributors and additional partners, please see beetlesproject.org/about/partners/

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.

Photos: Pages 1 and 2 by Kevin Beals. *Icons*: Backpack by Rémy Médard; Growth by Arthur Shlain; Cut by Nathan Thomson; Outside by Petr Holusa; Park by Antar Walker; Time by Wayne Middleton; & Diversity by Cara Foster all from The Noun Project.

Funding from 2012-2020 for BEETLES publications such as this one has been generously provided by the S.D. Bechtel, Jr. Foundation, The Dean Witter Foundation, Pisces Foundation, the Mary A. Crocker Trust.

To contact BEETLES™, email beetles@berkeley.edu