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Science and Teaching for Field Instructors

Student Activity Guide

Decomposition Mission

Decomposition is a fascinating and complex process. This activity gives learners an opportunity to build an understanding of decomposition that is grounded in real-world examples and lays the foundation for concepts related to matter and energy transfer in ecosystems. First, learners study the process of decomposition through observation and discussion as they create a sequence of decomposing wood and leaves. Then, learners consider the difference between physical decomposition and chemical decomposition and discuss forces that contribute to decomposition. Learners search for and discuss evidence of decomposers, make model diagrams to develop their ideas about the process of decomposition, and discuss the role of decomposition in the cycling of matter. Finally, learners are invited to recognize the evidence and impact of decomposition in the ecosystems they will explore in the future.

Learners will:

- **Explore, observe, and compare samples of decomposing materials and use reasoning to determine the level of decomposition among them.**
- **Work collaboratively in pairs to develop and discuss models of decomposition.**
- **Search for decomposers and evidence of decomposers.**
- **Discuss the definition of *decomposition* as the process of breaking down dead organisms and their waste materials into smaller and simpler forms of matter.**
- **Create a model diagram for the process of decomposition.**
- **Discuss the role decomposers play in making matter available to living plants.**

Grade Level:
Grades 5–8. Adaptable for younger or older learners.

Related Activities:
You Are What You Eat Name Game; *Matter and Energy Diagram Card Hike; Food, Build, Do, Waste; Case of the Disappearing Log; What Lives Here?; Ecosystems (and Matter) Theme Field Experience*

Tips:
To ensure a successful experience, review the teaching tips found on page 2 and throughout this guide.

Timing:
~95 minutes

Materials:
See the Materials and Preparation section on pages 3–4 for details.

Setting:
An outdoor area (such as a leafy forest floor or garden) with many examples of ~4 species of decaying leaves and logs/wood; an area with decomposers or evidence of decomposers. (See the Materials and Preparation section for more details.)

Equity, Inclusion, and Cultural Relevance (informed by Youth Outside)**:**
This activity has been designed to demonstrate how to create an equitable, inclusive, and culturally relevant teaching and learning experience. Read more, beginning on page 22.

NEXT GENERATION SCIENCE STANDARDS

For additional information about NGSS, go to page 24 of this guide.

FEATURED SCIENCE AND ENGINEERING PRACTICE	FEATURED CROSSCUTTING CONCEPT	DISCIPLINARY CORE IDEAS
Developing and Using Models	Energy and Matter	Cycles of Matter and Energy Transfer in Ecosystems

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Decomposition Mission

ACTIVITY OVERVIEW

Decomposition Mission	Learning Cycle Stage	Estimated Time
Introducing the Activity	Invitation	5 minutes
Decomposition Displays	Exploration, Concept Invention	25 minutes
Searching for Decomposers	Exploration, Concept Invention	25 minutes
Making Decomposition Diagram Models	Concept Invention, Application	15 minutes
Decomposition Discussion	Concept Invention, Application	15 minutes
Wrapping Up and Reflecting	Reflection	10 minutes
TOTAL:		~95 minutes

TEACHING TIPS

Read the Instructor Support section. Beginning on page 15, you'll find more information about pedagogy, science background, equity and inclusion, and standards.

Discussion is an important part of learning. Learners can build on their existing understanding of decomposition and decomposers through discussion. Offering opportunities for learners to engage in peer discussion, examine evidence, raise questions and ideas, apply concepts, and make connections can build deeper understanding and make the learning stick. These conversations also make learners' thinking visible to the instructor and support student-centered learning.

Pay attention to group needs. Consider moving to a new location between sections of this activity to support learner engagement. Alternatively, split the activity into three main chunks and teach them at different times throughout the day or week.

More information on decomposition and common misconceptions. See the Instructor Support section (beginning on page 15) for more information about decomposition and common misconceptions.

Field Card. At the end of this activity write-up, you'll find a condensed, pocket-sized version to use in the field.

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Find the latest activities and information at http://beetlesproject.org.

MATERIALS AND PREPARATION

MATERIALS

For the instructor

- portable whiteboard
- whiteboard marker
- 1–2 sets of Decomposer Cards, 3 cards/set (pages 28–30)
- 1–2 sets of Decomposition Statements Cards, 4 cards/set (page 31)

For each learner

- journal
- pencil
- optional: 1 hand lens

PREPARATION

1. **Gather materials.**
2. **Find the area(s) where you will do each part of the activity.**
    - **For the first part of the activity:** Find an outdoor area (such as a leafy forest floor or garden) with many examples of approximately four species of decaying leaves and logs/wood or a beach with rotting algae.
    - **For the second part of the activity:** Find an area with decomposers or evidence of decomposers present (such as fungi, rotting logs, or rocks in a damp area to turn over, etc.).
3. **Make copies of the Decomposer Cards and the Decomposition Statements Cards (pages 28–31).** Make 1–2 sets of each card set.
    - **Decomposor Cards.** There are three cards/set. Cut out each card. In the "Searching for Decomposers" activity, you will introduce three categories of decomposers: bacteria, invertebrates, and fungi (BIF) by showing learners the Decomposer Cards and inviting them to describe their observations of the photographs of each organism on the cards.
    - **Decomposition Statements Cards.** There are four cards/set. Cut apart each card. In the "Decomposition Discussion" activity, if you feel the information on a card will further the discussion, you will pass that card to a learner to read aloud. You will help learners integrate this new information into their discussion by asking questions or bringing learners back to the main topic. Don't introduce the cards randomly.
4. **Consider how you will tend to learners' physical comfort throughout the activity.** Being physically uncomfortable makes it more challenging to focus, make observations, and engage in

TEACHING NOTES

Ideas about decomposition develop over time. Multiple learning experiences help build understanding of a complex process such as decomposition. Ideally, lead this activity within a longer sequence of activities focused on concepts related to ecosystems and matter cycling. Situate this learning experience within the larger context of your group's learning by making room for them to build on the knowledge and experiences they already have and by using broad questions to invite learners to share ideas and make connections to their lived experiences.

TEACHING NOTES

MATERIALS AND PREPARATION (continued)

a learning experience. Some suggestions for tending to learners' physical comfort include the following:

- Give learners a clear picture of how long they will be outside, what kinds of activities they will be doing, and what kind of gear they might choose to bring to be comfortable in that setting.
- Offer extra jackets or warm clothes that learners could choose to bring and wear during the field experience.
- Offer frequent breaks for learners to move their bodies or eat a snack.
- Check in regularly with individuals and with the group.
- Be responsive to the group's needs, making adjustments as needed to support learners' comfort and engagement.

Introducing the Activity

1. **Ask learners what they think happens to the matter from dead organisms.**

   ▶ *If living things have been living and dying here on Earth for millions of years, why aren't we hiking through all their dead matter right now? Where has all that stuff gone?*

   - Allow a few learners to share their ideas. If they say "decomposition" or "they decomposed," ask them to describe what they mean.

2. **Use a fresh leaf and soil to introduce early and late stages of decomposition.** Show learners a "fresh" green leaf and some soil.

   ▶ *How could a leaf become part of the soil like this?*

   - Invite a few learners to share their ideas and then offer this definition:

   ▶ *Decomposition is the process of rotting or decaying. Decomposition breaks down dead organisms and their wastes into smaller and simpler forms of matter—such as nutrients, carbon dioxide, water, and organic matter that all become part of soil, air, and water.*

3. **Offer the idea that by looking closely at different stages of decomposition, learners can find evidence of how it happens.**

   ▶ *Today, we're going to explore and study decomposition in action to try to figure out how it happens.*

Decomposition Displays

1. **Groups of approximately four learners find and lay out stages of leaf or wood decomposition.** Divide learners into groups of approximately four. Offer each group a different type of abundant leaf or wood to work with that has already fallen (e.g., oak leaves, birch bark, pine wood). Invite learners to begin making displays by organizing samples starting with "fresh" (i.e., the least decomposed) to part of the soil (i.e., the most decomposed). If you're at the seashore, students can use samples of algae or kelp.

   ▶ *Your mission is to make a display that shows the stages of decomposition of the leaves or wood that your group is working with, starting with "fresh" or not decomposed, to very decomposed and part of the soil. Try to include as many stages as you can.*

   ▶ *As you make your displays, work together with your team and discuss the differences and similarities you observe between the different stages.*

2. **Circulate, ask questions, and offer support.** Circulate as learners work. Ask questions and encourage them to explain their reasoning behind putting pieces in a particular order. Encourage learners to make comparisons between stages of decomposition. Support groups in working

TEACHING NOTES

What is matter? If your learners aren't familiar with the Western science definition of the term *matter*, offer an accessible definition such as: stuff, a physical substance, something that has mass and takes up space. You can provide some examples of matter: "This tree is made of matter, the water is, you are, and air is. All the stuff in the universe is matter. But energy, like heat or light, is not matter."

Defining *decomposition* with younger learners. With learners who are less familiar with concepts related to matter and energy in ecosystems, consider stating the definition in simpler terms, such as: "Decomposition is when dead things and their wastes rot. They are broken down into smaller pieces, or changed into different types of materials such as poop, rotten fruit, water, and air."

Decomposition is not just stuff breaking down into soil. It's a common misconception that decomposition is a process in which organisms turn things into soil, which is inaccurate. Decomposition also happens in the ocean, lakes, ponds, and rivers. Even when decomposition produces soil on land, the process also produces water and releases carbon dioxide into the air. Make sure to mention air and water whenever you talk about decomposition.

Hand lens introduction. If you haven't done the activity *Hand Lens Introduction*, take the time to introduce the hand lenses as described in that activity (http://beetlesproject.org/resources/for-field-instructors/hand-lens-intro/).

TEACHING NOTES

Offer structure and support. Pay attention to how groups are doing with this task. Where needed, offer structure and guidance for learners as they build their decomposition displays. For example, you could invite learners to take on specific roles—one group member can be in charge of looking for more samples, another can be in charge of putting the samples in order, another can be in charge of asking group members to share why they think samples should go in that order, etc.

Supporting Social and Emotional Learning (SEL). Small-group work is an opportunity for learners to build SEL competencies within the context of an outdoor science experience. See the *Social Emotional Learning Routine* activity and the *Supporting Social Emotional Learning in Outdoor Science* guide for ideas on how to invite learners to intentionally incorporate SEL skills and competencies into this activity and other outdoor science experiences.

together; encourage learner participation; and encourage learners to share their evidence, ideas, and thinking with one another. Ask questions such as:

- *What characteristics are you using to decide which things are more decomposed than others (e.g., dry, brittle, soft, with holes, more grayish)?*
- *Could you share your reasoning for putting those pieces in the order you did?*

3. **Groups present displays to one another and describe characteristics they used to generate the order of decomposing materials.** Invite each group to present their work to the whole group, or give groups time to check out and observe one another's displays. Ask learners to share their reasoning and explain what characteristics led them to classify objects as more decomposed or less decomposed.

4. **Ask learners to briefly *Turn & Share* with a member of another group about the patterns or similarities they notice in the stages of decomposition shown in different displays.**

5. **Invite the group to share about patterns and commonalities from different displays that the decomposing leaves and sticks have in common. Add your thinking as appropriate.** Ask learners to look for characteristics of decomposition from the different group displays that the decomposing leaves and wood share in common. For example, "The decomposing leaves and sticks tend to be more dull in color." Or, "Many of the decomposing leaves and sticks had holes in them." Or "The algae that was more decomposed was drier and easier to break into pieces."

6. **Offer the idea that many of the commonalities and patterns learners noticed—such as changing color, drying out, or having tiny holes—are evidence of decomposition.**

7. **Invite learners to notice evidence of decomposition in their displays—such as holes, sponginess of wood, or something missing—and ask them to think about where those things may be now.** For example:

   - *Check out the holes in this wood. There used to be wood there, but now it's not there anymore. Where could it have gone?*
   - *Feel how spongy this wood feels. That's evidence that stuff that used to make it feel hard is missing. Where could that stuff be now?*

8. **Share that learners are using the displays as models and offer the idea that models are tools that scientists use to figure out and learn about complex processes, such as decomposition.** Share that when scientists try to understand a process such as decomposition, they often create models similar to the displays that learners made. Scientists use the models to make predictions about what they might see in nature over a long period of time. Then, they might check to see if their models are accurate by leaving the material outdoors to decompose more while carefully recording what happens.

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Searching for Decomposers

1. **Ask learners to make explanations for what might be causing the process of decomposition, using evidence of what they observed in their displays or elsewhere.** Ask learners to think back on the leaves and wood in their displays and make explanations of what could be causing the process of decomposition. Invite learners to include evidence in their explanations (e.g., *We saw tiny holes that could be evidence of an insect eating it.* Or: *I think that the spongy wood could be evidence of rot.*) Invite learners to point out evidence they've seen during other parts of the field experience or any other time from their lives. Offer the opportunity for learners to return to their displays for a moment, if they wish to.

2. **Gather the group around a display that has clear evidence of decomposition (things breaking down into both smaller and simpler parts).** Examples of things breaking down into smaller parts could include leaves or wood broken into smaller pieces. Examples of material breaking down into simpler parts could include insect poop (which can look like sawdust) or soil with a lot of organic matter in it (leaves/wood that have been changed into a different substance).

3. **Share that one part of the process of decomposition is breaking down things into smaller pieces.** Offer the idea that there are two parts to decomposition. One part of the process is breaking down things into *smaller* pieces, such as breaking a leaf or a piece of wood into smaller bits.

4. **Demonstrate breaking something nearby (e.g., a dead leaf or a piece of wood) into smaller pieces and say:**

   - *Each smaller piece of wood (or leaf) I'm breaking off is smaller, but it's still made of the same stuff. It's just smaller pieces of wood (or leaf).*

5. **Invite learners to share examples of other processes, organisms, or forces that might break down leaves or wood into smaller pieces [Chewing, stomping, grinding, etc.], including examples they have seen before. Listen to their ideas.**

6. **Share that another part of decomposition involves breaking down things into simpler materials—different stuff—such as rotting plants, carbon dioxide (CO_2), and water (H_2O) and point out examples in the displays.** Explain that decomposition isn't complete until dead things are broken down into *simpler* parts that are made of a different substance than what they were before. Offer an example.

   - *As we just saw, when we break up a leaf, it becomes smaller pieces of leaf. Another part of decomposition is breaking down things into simpler pieces, which involves actually changing the form of the leaf, wood, or other object into something else. This usually happens through digestion.*

   - *For example, when bacteria living in the gut of a deer digest grass, the grass is changed into deer poop, carbon dioxide, and water, which are all different substances than grass.*

TEACHING NOTES

Continue connecting discussions to the definition of *decomposition*. There is a lot to absorb in the definition of *decomposition* used in this activity, and it takes multiple exposures to build understanding of a complex concept and learn the term associated with it. Throughout the activity, connect what learners are doing to the definition of *decomposition* and offer questions that invite learners to use the concept in their thinking and meaning-making. For example, "So you think that's a decomposer? How do you think it breaks down dead stuff into simpler forms of matter such as soil, water, and CO_2 in the air?"

Chemical vs physical decomposition. Learn more about chemical vs. physical decomposition in the Instructor Support section (beginning on page 15).

TEACHING NOTES

***Decomposer* describes the role within an ecosystem.** Organisms don't know what category humans put them in; they are focused on their own survival and not acting to fulfill a role in an ecosystem. Offer the idea that the term *decomposer* describes a role within an ecosystem and doesn't always mean that decomposers only eat dead things. Support learners to move toward a more accurate understanding of this idea by sharing that invertebrate decomposers don't always eat dead things; they can and often do eat things that are still alive. When learners discuss what they find during the BIF hunt, encourage them to use language of uncertainty. For example: *I found an insect that looks like a beetle. It might be a decomposer.* Read more about defining decomposers in the Instructor Support section (beginning on page 15).

Why not "FBI"? Referring to decomposers with the acronym FBI (fungi, bacteria, invertebrates) has been a common practice in some environmental education contexts. We've intentionally chosen to shift away from this to avoid references to policing that could have a harmful or negative impact on learners. If you'd like to offer an acronym for learners to use to refer to decomposers, we invite you to use BIF (bacteria, invertebrates, fungi) instead.

Fungus or bacteria? Spots on leaves are evidence of bacteria and fungi. Round spots are more likely from fungi because fungi tend to grow outward in circular patterns.

- *Or, when a fungus breaks down a leaf, we observe round circles and dark patches on the leaf. The fungus is changing the leaf into a different form and releasing some carbon dioxide gas and nutrients that become a part of the soil.*

7. **Invite learners to share more decomposition examples in which things are broken down into simpler parts.**

8. **Share that scientists put organisms in categories that describe the role the organisms play within an ecosystem and how the organisms get their food.**

9. **Share that decomposers are organisms that break down things that used to be alive, and the wastes of organisms, into simpler parts that can be used by plants and algae.**

   - *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, a part of the air, or parts of large bodies of water. Decomposers break down things into forms of matter that plants and algae can use to build and grow.*

10. **Introduce three categories of decomposers: bacteria, invertebrates, and fungi (BIF) by showing learners the Decomposer Cards and inviting learners to describe their observations of the photographs of each organism on the cards.**

    - **Show images of bacterial decomposition.** Share that bacteria itself is too small to see, but it can leave behind evidence, such as spots on leaves, that we can observe. Then, ask learners to make observations of the photographs and describe what they notice to a partner.
    - **Show images of invertebrates.** Ask learners to describe what they notice to a partner.
    - **Show images of fungi.** Ask learners to make observations of the photographs and describe what they notice to a partner. [Round spots on leaves, white thread-like stuff in dirt, decomposing logs may be fungi or evidence of fungi.]

11. **Let learners know that they will have an opportunity to search for decomposers and evidence of decomposers in the area.**

12. **Share that decomposers leave evidence behind such as spots on leaves, holes, tunnels, poop, etc.** Share that although many decomposers—such as microscopic bacteria and fungi—can be difficult to find, see, or observe directly, there are ways to see decomposers at work.

13. **Offer some ideas about where learners can find decomposers or evidence of decomposers in the area.** Describe fallen logs where learners might be able to find small invertebrates, tunnels or droppings that are evidence of invertebrates, or more specific examples of where learners might be

able to find decomposers or evidence of decomposers in the surrounding area. Offer the idea that holes or bites in leaves are sometimes evidence of invertebrates.

14. **Offer boundaries and safety expectations for searching for decomposers.**
    - Roll logs toward your body. (Demonstrate this.)
    - Ask learners not to touch any organisms without an instructor (except plants, if you know they're safe to touch).
    - Avoid putting your fingers, hands, or limbs where you can't see in order to avoid accidentally touching harmful organisms, such as scorpions or spiders.
    - Gently return logs or rocks to their original position to preserve moist habitats.
    - Provide warnings about any harmful organisms you are aware of in the area.
    - Identify any physical boundaries where learners will conduct their explorations.
15. **Learners search for decomposers while the instructor circulates.** Share that learners will have approximately 10 minutes to search for decomposers and evidence of decomposers. As you're searching with learners, ask broad questions to encourage exploration and thinking:
    - What evidence have you found? What might have caused it?
    - What organism could have made this happen to the wood or leaf?
    - What about this place might make it possible for the organism to live here?
    - What do you think it eats? Where might it get the matter it consumes?
    - Where did you find the most evidence of decomposers? Where did you find the least amount of evidence?
16. **Gather the whole group and invite a few learners to share what they found.** Listen as learners share their observations and take the group to directly observe any evidence that seems particularly interesting.
17. **Ask learners to describe the areas where they found more decomposers or fewer decomposers and invite them to make some possible explanations for those patterns.** Ask where learners found the most decomposers/evidence of decomposers and what they think made it possible for the decomposers to live there. Ask where learners found the fewest decomposers/evidence of decomposers and what they think might make it less hospitable for the decomposers there.

TEACHING NOTES

Model how to look for decomposers. Model digging in the duff and decaying wood or peeling bark away from logs to get learners to explore actively. The BEETLES resource *Ecosystem Literacy and Exploration Guides* offers more framing you could use to guide learners' search for decomposers and evidence of decomposers.

Engaging directly with nature. Centering learning on students' in-the-moment observations of worms helps create an inclusive learning experience by focusing it on a shared experience to which every learner has access. This sets up a collaborative learning context in which learners' ideas and observations drive the learning experience, and learners recognize themselves and one another as sources of expertise. This is in contrast to some science learning in which participation requires prior knowledge about science ideas, and learners who have had more exposure to science tend to have an advantage.

Not all invertebrates are decomposers. Remind learners that finding an invertebrate under a log does not necessarily mean it's a decomposer. As learners find invertebrates, ask, "What is some evidence that might lead you to think this organism is or isn't a decomposer?"

Making Decomposition Diagram Models

1. **Share that the decomposition displays learners made were one type of model for decomposition; now, learners will have the opportunity to make a different type of model.**

2. **Share that learners will have the opportunity to make a diagram model by using drawings, lines, arrows, and words to share their ideas about how decomposition works.**

   ▶ *Your goal will be to use words, pictures, and numbers to make a diagram and describe what decomposition is and how it happens.*

3. **Offer the idea that scientists use diagrams with drawings, lines, arrows, words, and numbers to explain a complex process, such as decomposition.**

4. **Write the following on a sheet of paper or on a whiteboard and invite learners to include all these things in their diagram models:**

   - Use words and/or drawings to show an example of decomposition.
   - Explain how decomposition happens.
   - Include words or pictures that describe or show the role of decomposers.
   - Show results of decomposition.

5. **Post this list where learners can see it as they work on their diagram models.**

6. **Briefly demonstrate making an example diagram model, using learners' suggestions.** On a portable whiteboard, make a simple example diagram model, using drawing, writing, lines, and arrows to show the process of decomposition. Ask what learners might write or draw to show an example of decomposition and quickly sketch and write what they suggest. Do the same for the other parts of the diagram (how it happens, examples of decomposers, and the results). Use arrows to show when something changes into something else and lines to show connections. Narrate your thinking as you go, explaining your thinking process as you model making the diagram. For example:

   ▶ *Let's work through an example of what a diagram model could look like. What could you write or draw to show an example of decomposition?* [Soft or falling apart wood, holes in leaves, soil, etc.]

   - Model making a quick, labeled drawing of one of the examples of decomposition that learners suggested, narrating your thinking as you go. For example:

   ▶ *If spongy, rotten wood is an example of decomposition, I could make a quick drawing to show what that looks like and then use words to make a label and describe that it is spongy, soft, and falling apart.*

TEACHING NOTES

Using diagrams as scientific models. Models are used by scientists to represent a system that's being studied; to help develop questions, predictions, and explanations; and to communicate ideas to others. A diagram model makes the underlying processes more visible and accessible when they are difficult to observe directly. By developing a diagram model that represents their understanding of decomposition, learners are actively building on their own explanations and communicating ideas with others. For more on models, see *Featured Science and Engineering Practices* in the Instructor Support section (beginning on page 15).

Connections to the *Matter and Energy Diagram* activity. If you have used the BEETLES *Matter and Energy Diagram* activity with your learners, take out the diagram and point out any evidence of matter cycles they just observed. If learners' ideas have grown, add to the diagram.

- Model adding words or pictures to show the role of decomposers, narrating your thinking as you go. For example:

▶ *Then, I'm going to show the role that decomposers play by making a list of some of the decomposers we saw today, such as worms, fungi, and bacteria, and I'm going to add an arrow going away from the wood, with some words that describe what the decomposers do: eat, digest, change. I could also use pictures to show what the decomposers do.*

- Model adding the results of decomposition to your diagram, using drawings or words, and arrows to connect to other parts of the diagram. For example:

▶ *I also want to show the results of decomposition, so I'll add an arrow and draw a pile of soil. I'll also add some arrows that point to the air, since part of the stuff in the log is a part of the air now, too.*

▶ *I can also use words to explain how decomposition happens, based on what we've observed and talked about today.*

7. **As you make your example diagram model, offer examples of how learners might integrate drawings, labels, writing, arrows, and lines in their models.** Share that diagrams can be a useful way to show things that are difficult to describe or see. Invite learners to use:

   - **lines** to show specific connections between different parts of the diagram.
   - **labels** to describe something that's difficult to draw (such as air) or to say what something is.
   - **arrows** to show when something changes into something else.
   - **writing** to explain ideas or observations.

8. **Invite learners to include examples or evidence of decomposition they've observed today and from other parts of their lives.** Share:

   ▶ *We have seen and observed examples of decomposition and of decomposers today. You've also likely had experiences where you've seen and observed examples of decomposition before today's activity. Include examples from what we've observed—today and/or in the past.*

9. **Learners create diagram models, engaging in discussion with a partner for approximately 5–10 minutes.** Ask learners to find a partner to engage in discussion as they complete their diagram models. As learners work, circulate and ask questions to help you understand their thinking. Offer guidance and ask questions to support learners to improve their diagram models or deepen their thinking, such as, "How do growing plants fit into all of this?" Or, "How might you add arrows to show how these parts of the diagram are connected?"

10. **After learners have had time to make their diagram models, but before they become disengaged, ask each pair to join another pair to share**

TEACHING NOTES

Including non-terrestrial examples in models. If you are near a stream, lake, or the ocean, consider asking learners to include these bodies of water in their models and to try to explain how decomposition happens in water.

Assessment opportunity. As you circulate, pay attention to what learners have included or not included in their diagrams. Ask questions and use this opportunity to find out as much as you can about learners' level of understanding. Use this information to build upon later, to inform any clarifications to bring up, or which follow-up activities to do. If possible, collect learners' journals at the end of the experience, so you can more carefully read what they've written and drawn to understand their thinking.

TEACHING NOTES

Consider using these additional discussion questions for groups of learners who have a more complex understanding of decomposition. *How long might it take different materials such as wood, glass, or plastic to decompose? How could you find out? Do you think scavengers, such as vultures, should be grouped as decomposers? Why or why not? How do you think decomposition might happen in the ocean?*

Discussing humans as decomposers. Read more about discussing humans as decomposers in the Instructor Support section (beginning on page 15).

Opportunity to contrast producers. If learners bring up plants during this discussion, share that plants are actually producers, not decomposers, because they take in carbon dioxide and water and make more complex matter out of it. They do the opposite of what decomposers do with matter. It could be helpful to frame producers as composers in the context of this activity.

and compare. Invite learners to discuss the similarities and differences between their diagram models. Let learners know that they can change or add to their diagrams after the discussion, if they would like to.

Decomposition Discussion

1. **Engage the group in a discussion about decomposition, using the questions below.** After pairs have completed their diagram models, ask learners to share questions or ideas about decomposition for the group to discuss. Use some or all of the following questions below to lead a discussion. Follow learners' interest and invite them to build on one another's thinking.

   - *What are some questions or ideas you have about how decomposition works?*
   - *Where is the stuff that used to be a part of the wood now?*
   - *Why is decomposition important for ecosystems?*
   - *What other things can you think of that might help make decomposition happen?*
   - *How might the process of decomposition change during different seasons or in different ecosystems?*
   - *Can humans be considered decomposers? Why or why not?*

2. **Optional: Incorporate information from the Decomposition Statements Cards when appropriate.** As needed, select a card that might add to learners' thinking and/or build on their ideas. Pass that card to a learner and invite them to read the decomposition statement aloud to spark more discussion or to offer new information. Don't introduce the cards randomly.

3. **Reference a learner's diagram model or a nearby example and share that decomposers play an important role in ecosystems: breaking down dead things into CO_2, H_2O, and minerals that plants and algae can use to grow.** Choose one or more learner diagram models that include a plant and offer the idea that it takes decomposers to break down dead things into carbon dioxide gas (as well as water and nutrients) that can be used by plants. If you are near the ocean, a lake, or a stream, share that there are photosynthesizing organisms that are not plants (such as microbes, phytoplankton, and algae) that also depend on these nutrients and CO_2.

   - *Decomposers are important for ecosystems because they make matter available for plants and other photosynthesizing organisms such as algae.*

4. **Share that once matter becomes carbon dioxide gas, it takes many steps for it to change into matter that living things can consume again—it takes photosynthesizers.** Through photosynthesis, plants, algae, phytoplankton, microbes, etc. make carbohydrates from carbon dioxide and water gas by using energy from the sun. If no learner diagram model

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includes a plant (which offers you information about a learner's current understanding of decomposition), reference living plants around you as you share these ideas.

- *Plants and algae are important to ecosystems because they make matter available as food for living things.*

5. **Invite learners to reflect on how their ideas have changed during the decomposition discussion and offer a few minutes for them to add to or change their diagram models to show this.**

Wrapping Up and Reflecting

1. **Lead learners in a *Turn & Share* or *Thought Swap* pair discussion.** Ask the following questions to encourage learners to reflect on their learning process:

   - *Describe something new that you learned about decomposition and how you learned about it.*
   - *How would you describe decomposition to a younger sibling or relative?*
   - *How does a leaf become part of the soil? Part of the air? Part of water?*
   - *How might this area look different without decomposition?*
   - *What helped you to learn today?*

2. **Invite learners to share their reflections on the learning process.** Invite a few learners to share ideas from their discussions.

3. **Review the definition for *decomposition*:**

   - *Decomposition is when dead organisms and their wastes are broken down into smaller and simpler forms of matter—such as nutrients, carbon dioxide, water, and organic matter—that all become part of soil, air, or bodies of water.*

4. **Invite learners to find more decomposers and evidence of decomposition as they continue on the field experience.**

5. **Encourage learners to keep looking at the outdoors through the lens of matter cycling.** Invite learners to look at all the plants, dead plants, soil, water, and air around them and to think about how matter is cycling through them. Throughout the rest of the field experience, bring this perspective back now and then as appropriate. For example:

   - *The stuff around us in nature is changing. Some of the stuff seems to be disappearing. What is changing it and what is it changing into?*
   - *Where do you think that lizard gets the matter it's made of? Where do you think the matter in the lizard will go after the lizard dies?*
   - *Breathe in some air that used to be part of plants, animals, and soil. What you breathe out will eventually cycle back into those.*

TEACHING NOTES

Concluding the discussion. As part of concluding the decomposition discussion, consider sharing that some scientists consider only bacteria and fungi to be true decomposers. From this point of view, invertebrates such as worms would not be considered decomposers, but the bacteria in their guts that help them to break down matter would be the decomposers.

Logistics of the *Thought Swap* (formerly known as *Walk & Talk*) routine. See the BEETLES activity *Thought Swap* (formerly known as *Walk & Talk*) for the logistics of this discussion routine. Wondering why we changed the name from *Walk & Talk*? As a part of an effort to use more inclusive language in our resources, we changed the name so we were not normalizing walking as the only way of moving and talking as the only way of communicating.

Be sure to take time for reflection! Don't skip this part of the activity. Providing opportunities for learners to reflect on their own learning is important for cementing their understanding. As they talk to each other during the *Thought Swap*, you can listen in on their conversations to hear their ideas about decomposition.

TEACHING NOTES

Telling the "story" of matter cycling through an ecosystem. If you think your group may be into it, in order to build on the learning in this activity you might narrate a "story" describing how matter might move through an ecosystem. While you invite learners to move around, point out examples of each part of the narrative. Consider inviting learners to act out the decomposition process with their bodies as you describe each step as matter is being transferred. For example: "There's air around us that is matter. Some of that matter—carbon dioxide—is being sucked into leaves of trees and other plants and, combined with water, using energy from the sun to make sugars for the plant. Some animals eat parts of the plants, and the matter goes into their bodies. Some matter gets used to build and repair their bodies, and some goes out as poop and carbon dioxide. When the plants die, other critters eat them up, taking the matter into their bodies. Some of the matter gets used to build, some ends up as poop, and some ends up being breathed out into the air as carbon dioxide. Then, that carbon dioxide gets sucked into other plants. The matter keeps cycling around..."

- *Look at all the trees, other plants, wood, soil, and air around you. Imagine all the matter that is moving through them as they change. Think about how long this has been happening with the same matter changing from one thing to another, cycling round and round on Earth.*
- *How might the water in that stream become part of living or nonliving things? What other living or nonliving things do you think the matter in the water has cycled through?*

6. **Optional journal activity.** If learners seem particularly curious about any topic that came up during the activity, invite them to write about this in their journals, using evidence to explain their thinking. If you want to ask learners an assessment question, consider asking, "Are humans decomposers?" This journal prompt can be used as an assessment to learn what students took away from their decomposition explorations and discussions.

Instructor Support

Teaching Knowledge

Engaging learners in discussion. In order for learners to be able to engage in discussion, it's important to set up a culture of discourse in your group and give learners opportunities to discuss in pairs and in small groups before participating in a whole-group discussion. To establish a culture of discourse, create and nurture an atmosphere of respect and intellectual curiosity by responding equitably to learners' ideas as a facilitator and facilitating—not dominating—the discussion. When you respond to learners, do so in a neutral, accepting manner and then probe their thinking with follow-up questions. Encourage agreement and disagreement that builds toward a deeper understanding and establish that when there is disagreement about ideas, learners will not be ridiculed for having the "wrong" answer. Emphasize that sharing ideas as a group is an important part of the learning process.

Sharing ideas in pairs first. Offering time for learners to share ideas in pairs before sharing them with the whole group is an important way to support participation in this activity. Pair-Shares interspersed with whole-group talk tends to lead to more participation in the whole-group discussion and also to more thoughtful responses.

Introducing concepts. Avoid sharing vocabulary and content at the beginning of the activity as this can squelch learner curiosity and thinking. After learners have explored the area and created their stages of decomposition displays, offer more specific details about decomposers and the decomposition process. Support emerging multilingual learners by creating posters with key vocabulary and concepts written out.

Spirit of inquiry and investigation. Looking in and under rotting wood can be a rich place to find a variety of organisms. The "Searching for Decomposers" phase of this activity is an opportunity to encourage learners to pursue their curiosity.

Science language. One goal of science is to come up with the best explanation possible based on all available evidence. Invite learners to be open-minded to hearing one another's explanations and to work toward a deeper understanding together. As learners craft their explanations, offer framing around the language of uncertainty—the idea that nothing is ever "proven" in science. Scientists tend to use language of appropriate levels of uncertainty when discussing ideas and explanations. Invite learners to use sentence starters such as *Maybe…*, *I wonder if…*, *That evidence makes me think…*, and *The evidence seems to show…* and encourage learners to carefully phrase their statements and explanations.

TEACHING NOTES

Broad questions and science learning. Science is often viewed or taught as a collection of facts; this is reinforced by science learning experiences that focus on memorization or recall of facts and narrow questions posed to learners that invite only one correct answer. However, science is a way of knowing and a process for thinking and learning, not just a body of knowledge. Including broad questions in science learning (questions that have multiple possible responses such as, *Why might decomposition be important for ecosystems?*) engages learners in scientific sense-making, encourages critical thinking, and makes space for divergent perspectives and differing ideas to be shared. Weaving broad questions throughout science lessons also sends the message that learners' ideas and creative thinking are an essential part of science learning, contradicting the exclusionary idea that memorizing facts is what it means to be good at science.

Listening and responding to learners. How you respond to learners' observations and comments matters. Create a culture in which learners feel safe sharing ideas by frequently asking broad questions that have multiple acceptable responses and by giving all learners neutral, accepting responses to your questions. When we ask learners broad questions and then react to their responses by showing a preference for some responses over others (e.g., *Yes, that's right.* Or *No, but keep thinking.*), we're sending the message that only some learner thinking is acceptable. When we give neutral, accepting responses (e.g., *Hmm . . . interesting. Can you say more?* Or *Thank you for sharing. What do others have to say about that idea?*), we encourage a group culture of participation and sharing.

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Conceptual Knowledge

The following information is meant as background information for the instructors, not as talking points for a lecture or as a list of concepts that learners should understand.

Decomposition is a complex process that takes time to fully understand. The main ideas regarding decomposition that 4th–8th grade learners can begin to develop through this activity are:

- Decomposition is the process of dead organisms breaking down into smaller and simpler parts.
- When dead organisms decompose, they eventually become part of the soil, water, and air. Decomposition also takes place in the ocean where there is no "soil."
- Decomposers break down (or decay) dead organisms.
- Plants use the nutrients from soil, and algae use nutrients from the ocean water, not as food but as vitamins that help keep their body systems healthy.
- Decomposers are important to ecosystems because they make matter available to photosynthesizing organisms such as plants, algae, phytoplankton, and microbes. Decomposition is an important part of matter cycling through ecosystems.

***Producers, consumers,* and *decomposers* are three terms used to categorize organisms in an ecosystem.** Producers, such as plants, microbes, and algae, are able to produce their own food from inorganic substances such as carbon dioxide and water. Consumers get their energy and matter by consuming other organisms. Decomposers are organisms that break down dead organisms and their wastes into simpler forms of matter—chemically different substances—such as nutrients that become part of soil or ocean water, and carbon dioxide that becomes a part of air.

What exactly are decomposers? To try to understand matter cycling and energy flowing through ecosystems, ecologists have given names to categories of organisms to describe their roles in ecosystems. Of course, whenever you try to categorize something as wonderfully complex as an ecosystem, there are always gray areas, and organisms can fit into multiple categories and aren't bound to behaviors within their human-described roles.

Offer the idea that categorizations are useful, but that there are gray areas to discuss. The term *decomposer* can itself be confusing because there are many things (including animals and plants) that *contribute* to decomposition but are not considered decomposers. For example, fire contributes greatly to decomposition, but it's not an organism, so it's not called a decomposer. Anything that eats contributes to decomposition, but most organisms are placed in other categories.

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TEACHING NOTES

Fungi and bacteria are considered by some to be the only decomposers. This is because these organisms can break down cells of dead organic matter without internal digestion. Earthworms, sow bugs, and other invertebrates are often accepted as decomposers; in this session, we've chosen to highlight bacteria, invertebrates, and fungi (partly because invertebrates are often easier to observe). However, fungi and bacteria are the true stars of decomposition. Bacteria live all over the place, including in the digestive systems of other organisms, such as worms, and decompose organic matter inside of them. Fungi is generally considered to be the most important decomposer in forest ecosystems. Fungi are the only decomposers able to break down the lignin in wood, and there's a lot of wood to break down in many ecosystems. You can adjust which decomposers to emphasize based on your learners' grade level and prior knowledge. With older students (8th grade and up), you might want to highlight fungi and bacteria more.

Decomposition involves chemical and physical changes. When we discuss breaking down things into *smaller* parts, we're referring to the physical changes in decomposition. Breaking down things into *simpler* parts is an introductory way of describing how chemical bonds are being broken and new ones formed. By middle school, learners can begin to build an understanding of the idea that organic matter is changed into different, simpler substances through the process of decomposition.

Carbon cycle. Sharing parts of the carbon cycle with learners offers concrete ways in which we are connected to living and nonliving things in our environment and how they are connected with one another. Plants and other photosynthesizing (mostly) or chemosynthesizing (rarely) organisms take in carbon dioxide, water, and energy and convert them into food. Through food webs, all organisms feed off this food. As each organism eats and uses some of the food, it gives off carbon dioxide and water into the air and loses energy that flows from Earth to outer space. When dead organisms decompose, they are mostly converted into carbon dioxide and water in the air and lose energy that flows from Earth to outer space. When you breathe out carbon dioxide, you are concretely connected to that ecosystem—you're part of the carbon cycle!

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 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 more difficult to define than matter and has different definitions depending on the branch of science. In this context, *energy* can be defined simply as what organisms get from food that allows them to do things. If you are introducing learners to the term *matter*, the term *energy* can be partially defined as simply not matter. Unlike matter, energy doesn't take up space or have mass. Energy has no physical form; it isn't a substance.

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When energy is transferred from one organism to another, no physical thing is passed from thing to thing. What's transferred is the capacity to do things—to live and to grow. A little confusing, huh? That's why when working with learners, we recommend starting with matter and working up to energy.

Matter cycles, energy flows. If you tackle these topics with learners, it's important to offer the idea that matter cycles, and energy flows. In ecological science, that's an important distinction. 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 out into outer space, and we gain some matter from meteorites, etc., but otherwise, it's pretty much the same stuff that has been cycling around and around since Earth was formed. The matter around us and that we are made up of has been cycling through countless different forms throughout Earth's history. Energy, on the other hand, flows through Earth's systems. Everyday energy from the sun enters Earth's atmosphere, while an (almost) equal amount is released from the atmosphere and travels into outer space. If that wasn't the case, Earth would become an extremely hot planet. Sometimes in environmental education, matter and energy are treated as interchangeable, which is inaccurate and can be confusing to learners. The concept of energy is complex and can be harder to understand; matter is a much more concrete concept and is often easier to grasp. That's why in this activity we've chosen to focus on the cycling of matter through the process of decomposition. If you're working with older learners (7th grade and up), you may choose to invite them to think about how decomposition is also involved in the flow of energy through ecosystems, or engage them in BEETLES activities such as *Food, Build, Do, Waste*; *Matter and Energy Diagram*; or *Card Hike*, all of which include opportunities for learners to build understanding of concepts related to energy.

Importance of photosynthesis. Photosynthesizing organisms, such as plants, phytoplankton, algae, and microbes, take matter from air (CO_2 and H_2O) and use energy from the sun to "package" it as carbohydrates ($C_6H_{12}O_6$), giving off the waste product of O_2. This is an amazing thing, and it converts stuff that life-forms couldn't otherwise use into carbohydrates that they can use. This stuff is food to organisms when it's in a form they can consume and take matter from the food and use it to build and repair body parts, fluids, and energy and use that to do things such as run, fly, grow, etc.

Understanding the nutrient cycle. Plants need nutrients from soil to grow, and algae need nutrients from ocean water to grow, just like people need vitamins and other substances from their food. Soil nutrients come from gases in the air; from the breakdown of mineral-bearing rocks; and from organic matter, which comes from the decomposition of organisms. The nutrients that plants get from soil are stored in all plant tissues, such as leaves, stems, and flowers. When these tissues fall to the ground, they start to break down, and, together with decomposing dead insects, dead animals, and animal poop, they are eventually reincorporated into the soil by rainfall and soil organisms. In the soil, the organic matter is further broken down and

slowly transformed to become nutrients that are available to growing plants, and the cycle continues. The nutrient cycle also takes place in bodies of water, such as the ocean, but with nutrients suspended in the water, rather than in soil.

Living things interact with soil by creating tunnels for water and air, recycling nutrients, and mixing mineral particles throughout the soil. Organisms such as earthworms, isopods, bacteria, and fungi help decompose dead plants and animals. Nutrients from the decomposing materials are left in the soil where they can be used by plants. The plants, in turn, provide food for the animals, and the cycle continues.

Two carbon reservoirs—the soil and the ocean. Plants, microbes, and algae remove CO_2 from the air, and the carbon becomes part of their bodies. Decomposers break down organic material, such as dead plants and algae, and release the carbon back into the atmosphere as CO_2. Most of the organic matter moves through the cycle pretty quickly, and the carbon cycles back into the atmosphere. However, some organic material breaks down much more slowly, thus "storing" some carbon in the soil or the ocean. Earth's soils contain about three times more carbon than vegetation does and twice as much as is in the atmosphere. The largest carbon reservoir on Earth is the ocean. Many dry land soils have become depleted and are very low in organic materials and carbon storage. Currently, the idea of restoring these soils is seen as a hopeful way to lower CO_2 levels in the atmosphere to reduce the impacts of climate change, until carbon released through fossil fuels can be reduced. Manure from grazing animals is considered the most efficient way to get carbon into soils. Studies have shown that dense herds of grazing animals moving through an area dramatically increases the soil's health and carbon storage.

Humans as decomposers. If you discuss this optional question with learners, offer the idea that humans do contribute to decomposition, but scientists do not usually consider humans to be decomposers. The "decomposer" label is used for organisms that primarily break down matter into substances that can be used by plants and other photosynthesizers to grow.

Common Relevant Misconceptions

Misconception. Dead organisms spontaneously break down.

More accurate information. Organisms known as decomposers—such as bacteria, invertebrates, and fungi—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. When things decompose, they are "used up," and there is nothing useful left.

More accurate information. All the matter in dead organisms eventually cycles through the soil, water (the ocean), the atmosphere, and the bodies of other organisms.

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Misconception. Energy from the sun is captured by Earth and keeps cycling round and round in ecosystems.

More accurate information. Eek! If that were true, Earth would be a very warm planet! Matter cycles through ecosystems here on Earth and does not usually leave the planet. A large amount of energy flows to Earth from the sun in the form of light energy, and it is captured by plants and "packaged" with matter in the form of food. However, at every link in a food chain or web, ~90% of the energy is released from the organism and eventually drifts into outer space as heat. Only ~10% of the energy is passed on to the next organism. There is a constant flow of energy from sunlight into an ecosystem (during the day) and a constant flow out of the ecosystem into space.

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

More accurate information. This is not totally a misconception—it's just incomplete. Most of the matter that's decomposed eventually is converted into CO_2 and water, which becomes part of air. A tiny bit becomes nutrients that plants can use.

Misconception. The matter that plants use to build their structures mostly comes from soil.

More accurate information. Plants make sugar/food from carbon dioxide and water in the presence of sunlight. The soil provides tiny amounts of important nutrients (not food!) for plants that are kind of like what vitamins are for people. Many people think that most of the mass of plants comes from soil, maybe because carbon dioxide seems so insubstantial. Another confusing thing is that nutrient products that are added to garden plants are often labeled as "plant food," while "plant nutrients" or "plant vitamins" might be a more accurate label.

Misconception. Plants grow by taking in soil in order to get bigger.

More accurate information. This is a very common misconception, even among adults. The matter that plants use to grow chiefly comes from carbon dioxide and water. Plants acquire nutrients from the soil, which help them to grow larger than they would without it, but mostly they are built from water and carbon dioxide. The Next Generation Science Standards (NGSS) emphasize this distinction and make sure learners understand that most plant matter comes from carbon dioxide and water.

Misconception. Organisms convert matter into energy.

More accurate information. This is a very common misconception, even among adults. Matter is not converted into energy in life systems on Earth. Almost all our energy comes from the sun. Through photosynthesis, plants and other photosynthesizing organisms make use of a tiny portion (less than 10%) of the incoming sun energy. Through photosynthesis, they bind this energy and matter together into packages that they and animals can use as food. At each stage of the food chain, an organism is able to make use of some of that energy, but most of

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the energy at each stage leaves the ecosystem and eventually flows into outer space. The matter in food never becomes energy. When organisms eat, some of the matter becomes part of their bodies (they gain weight, gain muscles, repair body damage, grow taller, etc.). The rest of the matter gets released when organisms breathe, sweat, pee, poop, etc.

Misconception. All invertebrates are decomposers.

More accurate information. Some invertebrates are not decomposers. Invertebrates are included in this activity because many of them serve that function in an ecosystem. Examples of common invertebrates that are not decomposers include bees, ladybugs, and spiders.

Misconception. All decomposers eat only dead stuff.

More accurate information. Decomposer is a definition of a role within an ecosystem. Decomposers are named as such because they help to decompose matter, making it accessible for plants. However, some decomposers may also eat living material or whatever else is needed to survive (e.g., banana slugs can eat living or decaying leaves). There are some scientists who consider only bacteria and fungi to be true decomposers. From this point of view, worms would not be considered the decomposers; rather, the bacteria in their digestive tracts that further break down matter are the actual decomposers.

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

More accurate information. Decomposers consume dead organisms to get the matter and energy they need to survive. As far as science knows, decomposers are not concerned with supporting the ecosystem, except in the sense that these interconnections support their survival. This kind of language can perpetuate the people-centric idea that nature and its systems exist primarily for our benefit or for the benefit of the charismatic creatures we care about.

Misconception. Soil is no big deal. Soil is just dirt.

More accurate information. Soil is much more than dirt! It's a mixture of mineral particles, living and dead organisms, air, and water. Soil also contains inorganic materials from rock and often some broken down human-made materials. Life on land depends on soil. It provides substrate, nutrients, and homes for many organisms and can be considered the living skin of the land on our planet. In this sense, soil plays a vital role in sustaining human welfare and assuring future agricultural productivity, textile production, and environmental sustainability. In the ocean, seawater is the equivalent of soil on land. Seawater carries the nutrients and gases that photosynthesizers need to survive.

Misconception. Decomposers turn dead things into soil. Or, the only product of decomposition is soil.

More accurate information. As decomposers consume dead organisms and deposit the resulting "poop" into the soil, they do contribute to the organic constituents found in soil. However, soil also contains inorganic

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materials from rock and often some broken down human-made materials. During the chemical process of decomposition, gases such as CO_2 and water vapor are also released into the surrounding air, thus contributing to the atmosphere as well as the soil. Most decomposition takes place in the ocean where there is no soil. In the ocean, decayed material becomes dissolved and/or suspended in the water, resulting in nutrient-rich seawater.

Supporting Equitable, Inclusive, and Culturally Relevant Learning Experiences

This BEETLES student activity has been intentionally designed to create an equitable, inclusive, and culturally relevant learning experience for a community of learners. BEETLES design principles [http://beetlesproject.org/about/how-do-we-approach-teaching/] ensure that each activity is learner-centered and nature-centered. This enables all learners to access, participate, and engage in the learning experience.

When learners engage directly with nature, they all have access to learning, regardless of their prior knowledge or experiences. Centering learning on learners' in-the-moment observations of nature builds an inclusive learning experience by focusing the conversation on an experience shared by every learner, as opposed to relying on learners' prior knowledge or past experiences. As learners engage with nature, instructors are in the role of the "guide on the side." This approach shifts power from the instructor to learners, challenges the typical learning situation in which the instructor is the only expert, encourages learners to share their ideas and experiences, and makes learning a more decentralized and collaborative experience.

"Classroom studies document the fact that underserved English learners, poor students, and students of color routinely receive less instruction in higher-order skills development than other students." (Allington and McGill-Franzen, 1989; Darling-Hammond, 2001; Oakes, 2005) –Zaretta Hammond, *Culturally Responsive Teaching & the Brain*

When learners think like a scientist and practice academic language, they develop critical thinking skills that support them to become more independent learners—learners who have skills and thinking tools they use to learn, regardless of the level of support available from a teacher or instructor. Giving learners the opportunity to think like a scientist by making observations, asking questions, and constructing explanations supports learners' growth as learners and offers them the opportunity to build critical thinking skills and learning behaviors they can apply in any context. Many learners in schools that have historically been under-resourced due to racist school funding policies, redlining, income inequality, and police profiling have fewer opportunities to develop as independent learners. Specifically ensuring that learners in these kinds of schools have opportunities to develop as independent learners is an issue of equity. Learning and practicing critical thinking skills in an engaging outdoor context supports learners to succeed back in their classrooms, in science, and in other academic disciplines. Offering opportunities for learners to discuss ideas with their peers and knowledgeable adults makes science more accessible by connecting it to learners' own actions and discoveries in the moment—not just to knowledge they may not have or experiences they may not have had.

Through discussion, learners make connections to prior knowledge, share their lived experiences, listen to different perspectives, and have time to process the material. Productive discussions in which many voices are heard, and the group builds off one another's ideas, create an experience in which learners see themselves and one another as sources of expertise. This ensures that instructors don't fall back on positioning themselves as the only source of accurate or important information. Participating in discussions also supports learners to develop cognitive rigor and the ability to take on more advanced learning tasks. Discussions make learners' thinking and ideas visible to the instructor. When instructors value, appreciate, better understand, and connect to learners' lived experiences, they create a more inclusive and culturally relevant learning space. Finally, multiple opportunities for discussion provide time and space for neurodiversity—allowing learners to process information in different ways. Using discussion strategies such as *Turn & Share* or *Thought Swap* (formerly known as *Walk & Talk*) that are part of every BEETLES student activity can help ensure that learners have these kinds of opportunities for discussion.

Specifically, *Decomposition Mission* promotes an equitable, inclusive, and culturally relevant learning experience by:

- scaffolding scientific thinking skills—such as modeling, which supports learners' visual literacy and language acquisition—supports them to be independent learners; visual literacy and language acquisition are also critical pieces of the Common Core State Standards.
- connecting learners' in-the-moment learning behaviors to practices of working scientists, which contradicts the exclusionary ideas that science is a list of facts to memorize or that only people who are good at memorizing facts can be good at science.
- using broad questions to invite learners to share their observations, prior knowledge, expertise, and experiences with one another and with the instructor.
- focusing the group's learning on a common experience everyone has access to, so learning is accessible regardless of prior experiences or comfort level outdoors.
- providing space for learners to come up with connections between what they are observing and prior experiences and knowledge, which supports their learning and retention.
- engaging learners in meaning-making discussions that prepare them to take on increasingly rigorous learning tasks in the future.
- providing a lesson structure for the instructor to act as a "guide on the side" and build a collaborative learning environment in which learners make observations, share ideas, and see themselves and one another (not just the instructor) as sources of expertise.
- offering multiple ways for learners to process and engage with ideas, including small-group work, pairs, large-group discussion, and journaling.

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Resources on unconscious bias. There are many great resources on understanding and shifting unconscious bias. Here are a few books and organizations we have looked to consistently to work on our own unconscious bias and to better understand how it can affect teaching and learning in the outdoors:

- *White Fragility: Why It's So Hard for White People to Talk About Racism* by Robin DiAngelo
- *Culturally Responsive Teaching & the Brain* by Zaretta Hammond
- Youth Outside [http://www.youthoutside.org/]
- The Avarna Group [https://theavarnagroup.com/]
- Center for Diversity & the Environment [https://www.cdeinspires.org/]

Overall, these factors contribute to creating a learner-centered approach in which "the ultimate goal . . . is to help students take over the reins of their learning." (Zaretta Hammond, *Culturally Responsive Teaching & the Brain*, 2014). This approach to teaching supports learners in becoming independent learners who are able to succeed, regardless of any individual teacher or learning context. BEETLES has intentionally designed the sequence and structure of this activity to support learning experiences in which all learners feel capable of success and have the tools to carry that success into other domains.

Using learner-centered and nature-centered learning approaches is just one piece of the work we can do to create equitable, inclusive, and culturally relevant learning experiences. Instructors must also work to become more aware of their own unconscious biases and triggers around culture, identity, and race that impact their interactions with learners and affect their learners' sense of inclusion.

Connections to Next Generation Science Standards (NGSS)

BEETLES student activities are designed to incorporate the three-dimensional learning that is called for in the NGSS. Three-dimensional learning weaves together Science and Engineering Practices (what scientists do), Crosscutting Concepts (thinking tools scientists use), and Disciplinary Core Ideas (what scientists know). Learners should be exploring and investigating rich phenomena and figuring out how the natural world works. The abilities involved in using Science and Engineering Practices and Crosscutting Concepts—looking at nature and figuring things out, using certain lenses to guide thinking, and understanding ecosystems more deeply—are mindsets and tools learners can take with them and apply anywhere to deepen their understanding of nature, and they're interesting and fun to do!

Decomposition Mission engages learners in the Science and Engineering Practice of *Developing and Using Models* to build a foundation for understanding disciplinary core ideas related to *Cycles of Matter and Energy Transfer in Ecosystems* and connect those ideas to the Crosscutting Concept of *Energy and Matter: Flows, Cycles, and Conservation*.

Featured Science and Engineering Practice

Engaging learners in *Developing and Using Models*. According to the National Research Council's *A Framework for K–12 Science Education*, scientists use conceptual models to investigate parts of complex systems that can be difficult to observe directly to better visualize and understand phenomena. Learners scan models that represent their current understanding of a system or process under study to support their conceptual understanding, develop explanations, and communicate ideas to others.

- In *Decomposition Mission*, the displays that learners create serve as their initial models for the process of decomposition as they discuss how increasingly decomposed matter may look over time.

- The displays represent learners' current understanding of the process of decomposition. Throughout the activity, learners build understanding of the factors involved and may revise their own internal models for and understanding of decomposition.
- Later, learners make diagram models that integrate their thinking from the display models, their prior knowledge, and their observations of decomposers, creating a more complete conceptual framework and explanation for the process of decomposition.
- Referencing concrete examples in their discussion of the diagram model with a partner is an opportunity for learners to deepen their understanding of decomposition and adjust their own mental models.

Featured Crosscutting Concept

Learning science through the lens of *Energy and Matter.* Tracking the transfer of matter and energy in and out of, as well as within, a system enables scientists to learn about the relationship between the various elements that make up and drive all kinds of systems. The *Framework* states that a significant part of inviting learners to see the value in this Crosscutting Concept is discussing how thinking about matter and energy transfer in ANY system helps you to understand more about how that system works.

- *Decomposition Mission* focuses on describing how matter cycles through ecosystems, specifically through the role of decomposers and the decomposition process.
- We suggest encouraging learners to apply this lens to other contexts, such as water in a stream, to offer continued opportunities for understanding and for learners to "own" this thinking tool.
- As learners discuss how matter in decomposing organisms is broken down into smaller bits of matter that can be used by plants, learners have an opportunity to identify important connections within the ecosystem, as well as realizing that matter is always conserved (i.e., neither created nor destroyed).
- Though this lesson focuses less on energy, it can offer learners a solid foundation for how matter cycles and energy flows in ecosystems. Framing the activity by tracing how matter cycles through an ecosystem and thinking about how it changes form can help us to learn more about the process of decomposition.

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. The NGSS make it clear that learners need multiple learning experiences to build their understanding of Disciplinary Core Ideas. *Decomposition Mission* provides learners with an opportunity to develop understanding of some life science core ideas related to *Cycles of Matter and Energy Transfer in Ecosystems* (LS2.B).

- When learners create their decomposition displays and discuss the characteristics that led them to organize those displays, they have an opportunity to engage with the idea that matter from dead organisms

TEACHING NOTES

About the Next Generation Science Standards (NGSS). The development of the NGSS followed closely on the movement to adopt nationwide English language arts and mathematics Common Core standards. In the case of the science standards, the National Research Council (NRC) first wrote *A Framework for K–12 Science Education* that beautifully describes an updated and comprehensive vision for proficiency in science across our nation. The *Framework*–validated by science researchers, educators and cognitive scientists–was then the basis for the development of the NGSS. As our understanding of how children learn has grown dramatically since the last science standards were published, the NGSS has pushed the science education community further toward engaging learners in the practices used by scientists and engineers and using the "big ideas" of science to actively learn about the natural world. Research shows that teaching science as a process of inquiry and explanation helps learners to form a deeper understanding of science concepts and better recognize how science applies to everyday life. In order to emphasize these important aspects of science, the NGSS are organized into three dimensions of learning: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas (DCI's). The DCI's are divided into four disciplines: Life Science (LS); Physical Science (PS); Earth and Space Science (ESS); and Engineering, Technology, and Applied Science (ETS).

Read more about the Next Generation Science Standards at https://www.nextgenscience.org/ **and** https://www.nsta.org/nstas-official-positions/next-generation-science-standards.

TEACHING NOTES

Translating the codes for the NGSS Performance Expectations. Each standard in the NGSS is organized as a collection of Performance Expectations (PE's) for a particular science topic. Each PE has a specific code, which is provided here so they can be easily referenced in the NGSS documents. The first number or initial refers to the grade level: K = kindergarten, 1 = first grade, 2 = second grade, MS = middle school, and HS = high school. The next letters in the code refer to the science discipline for the standard: LS, PS, ESS, ETS. The number following the discipline denotes the specific core idea within the discipline that is addressed by the PE, and the last digit identifies the number of the PE itself. So, 3-LS4-3 means the Performance Expectation is part of a third-grade standard (3) for life science (LS), addressing the fourth core idea (4), Biological Evolution: Unity and Diversity, within the life science standards, which deals with Adaptation. It's also the third Performance Expectation (4) that makes up the complete LS4 standard at this grade level.

becomes part of the soil (LS2.B). In searching for decomposers and engaging in a discussion about different aspects of decomposition, learners can build understanding of the idea that matter is transferred between living and nonliving things in an ecosystem. Learners have opportunities throughout the activity to build understanding of the idea that matter cycles between air, water, and soil and among plants, animals, microbes, and all other living things (LS2.B).

- Through a series of discussion prompts and particularly by making their diagram models, *Decomposition Mission* provides learners with several opportunities to use their own observations to make sense of the process of decomposition and how it relates to the cycling of matter in ecosystems.
- Creating a diagram offers learners the opportunity to more fully work out their own understanding of the definition, characteristics, and examples of decomposition and decomposers—this is how significant learning can happen.
- You can also use the diagram models to assess learners' understanding and inform your decisions about what to focus on during discussions. Based on what is shown in learners' models, you might choose to reinforce concepts your group is struggling with or go deeper into a concept or idea that learners are intrigued with and have still more to learn about.

You can informally assess learners' understanding of these concepts during different stages of the activity in individual interactions with learners and by listening carefully during the group discussions. This information can help you decide which ideas to focus on in future lessons so follow-up activities or discussions can be used to further learner understanding.

Performance Expectations to Work Toward

No single activity can adequately prepare learners for an NGSS Performance Expectation. Performance Expectations are designed as examples of things that learners should be able to do to demonstrate their understanding of content and big ideas in science after engaging in multiple learning experiences and instruction over a long period of time. They are *not* the curriculum to be taught to learners. Following are a few Performance Expectations this activity can help learners work toward:

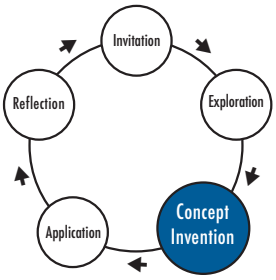
- **5-LS2-1.** Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.
- **MS-LS2-3.** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

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

Activity Connections

BEETLES has several activities on topics related to matter and energy in ecosystems that could precede or come after *Decomposition Mission*. *Matter and Energy Diagram* is meant to begin and finish a series of activities focused on ecosystems, matter, and energy. The *You Are What You Eat* Name Game is a good starting point for thinking about matter and energy before leading the *Matter and Energy Diagram* activity. We recommend following those activities with *Decomposition Mission*; *Card Hike*; and *Food, Build, Do, Waste*—all of which provide the hands-on experiences learners need to flesh out the concepts. *Case of the Disappearing Log* and *What Lives Here?* are also activities that will lead learners to think about matter cycling in ecosystems. The resource *Ecosystems (and Matter) Theme Field Experience* offers ideas on how to build these activities into a sequence and full learning experience that offers opportunities for learners to engage deeply in these concepts.

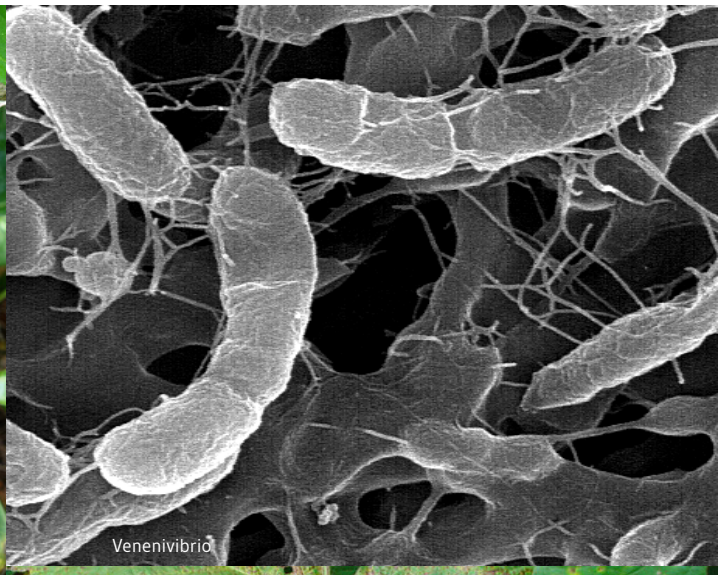
TEACHING NOTES



Learning cycle. In a sequence of activities focused on matter, energy, and ecosystems, this activity functions as Concept Invention.

Bacteria


Scot Nelson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International Institute of Tropical Agriculture,


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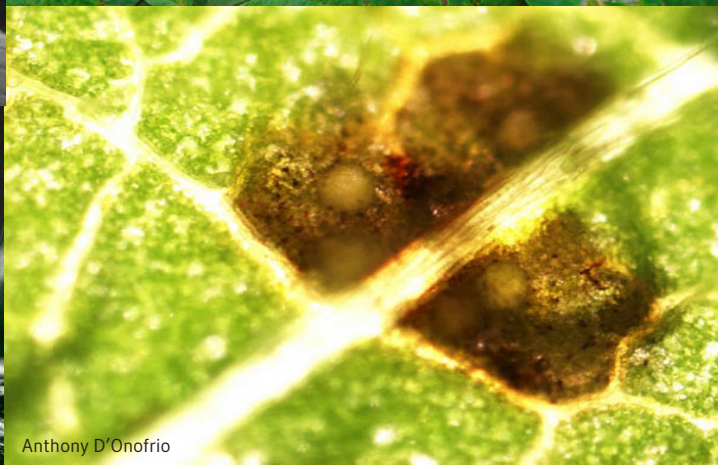
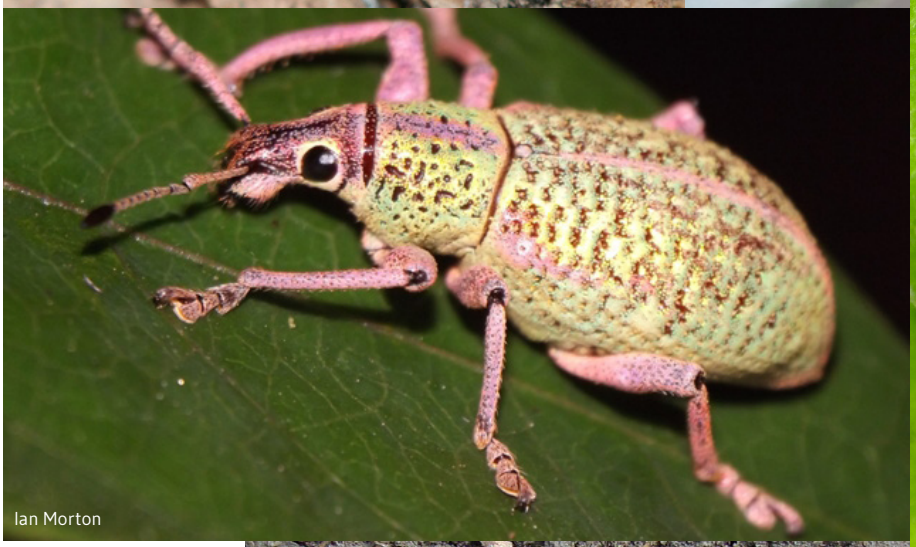

Anthony D'Onofrio

Invertebrates


Arthur Chapman


Kai Wei


Ian Morton


Andreas Kay


Starwatcher307

Fungi

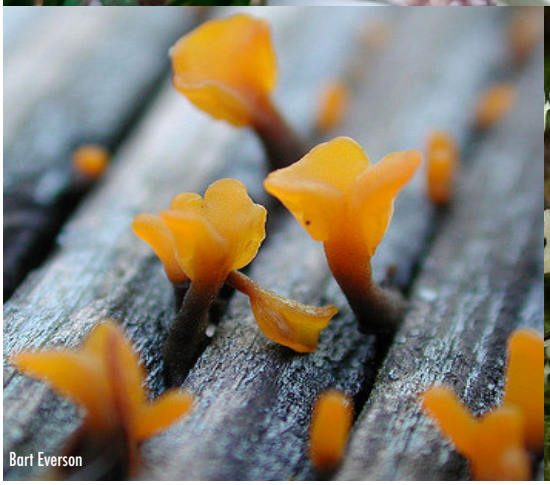

Scot Nelson


Kirill Ignatyev


Don McCullough


Monteregina (Nicole)


Scot Nelson


Bart Everson


Boobook48

Decomposition Statements Cards

Cut apart the cards before you teach this lesson. Don't introduce these cards randomly. If you feel the information on a card will further the discussion, pass it to a learner to read aloud. Support learners to integrate this new information into their discussion by asking questions or bringing learners back to the main topic.

All the stuff around us that takes up space is matter. All the leaves and wood we've looked at, all the fungi and invertebrates are made of matter. Even air, though it's hard to see and feel, is matter.	Decomposition is when things that used to be alive are broken down into smaller, simpler forms of matter, such as carbon dioxide, water, nutrients, and organic matter.
Just by breathing you lose about 2 pounds of weight every day from the carbon dioxide molecules you breathe out. That's about the same weight as a full water bottle.	Drink some water from your water bottle. The same molecules in the water you just drank have been cycling for millennia through plants, clouds, oceans, dinosaurs, ice, even saliva! MATTER CYCLES.

FIELD CARD

Cut out along outer lines and fold along the centerline. This makes a handy reference card that will fit in your pocket.

Decomposition Mission

Introducing the Activity

1. Ask learners what they think happens to the matter from dead organisms.
   - *If living things have been living and dying on Earth for millions of years, why aren't we hiking through all their dead matter right now? Where has all that stuff gone?*
   - If learners say "decomposition" or "they decomposed," ask what they mean.
2. Use a fresh leaf and soil to introduce early and late stages of decomposition.
   - *How could a leaf become part of the soil like this?*
   - Invite a few learners to share their ideas and then offer:
   - *Decomposition is the process of rotting or decaying. Decomposition breaks down dead organisms and their wastes into smaller and simpler forms of matter such as nutrients, carbon dioxide, water, and organic matter that all become part of soil, air, and water.*
3. Offer the idea that by looking closely at different stages of decomposition, learners can find evidence of how it happens.
   - *We're going to explore and study decomposition in action to try to figure out how it happens.*

Decomposition Displays

1. Groups of ~4 find and lay out stages of leaf/wood decomposition from "fresh" to very decomposed and part of soil, including as many stages as possible.
   - *Work with your team and discuss differences and similarities you observe between stages.*
2. Circulate, ask questions, and offer support. For example:
   - *What characteristics are you using to decide which things are more decomposed (e.g., dry, brittle, soft, with holes, more grayish)?*
   - *What is your reasoning for putting those pieces in that order?*
3. Groups present displays to the whole group and share characteristics they used to order decomposing materials.
4. *Turn & Share* with a member of another group about patterns/similarities in stages of decomposition in different displays.
5. Group shares patterns/commonalities of decomposing leaves and sticks from different displays. Add your thinking as appropriate.
6. Offer: Many of these—such as changing color, drying out, or tiny holes—are evidence of decomposition.
7. Ask learners about holes, sponginess of wood, or something missing and where those things may be now. For example:
   - *Feel how spongy this wood is. That's evidence that stuff that used to make it feel hard is missing. Where could that stuff be now?*
8. Share: Displays are models. Models are tools that scientists use to figure out and learn about complex processes, such as decomposition.

Searching for Decomposers

1. Learners make explanations for what might be causing decomposition, using evidence they observed in their displays or elsewhere.
2. Gather the whole group around a display that has clear evidence of decomposition (things breaking down into both smaller and simpler parts).
3. Share: One part of decomposition is breaking down things into smaller pieces.
4. Demonstrate breaking down something (e.g., a dead leaf or wood) into smaller pieces and point out that the pieces are smaller but are made of the same stuff.
5. Learners share examples of what might break down leaves or wood into smaller pieces. [Chewing, stomping, grinding, etc.]
6. Share: Another part of decomposition is usually through digestion breaking down things into *simpler* materials—different stuff—such as rotting plants, carbon dioxide (CO_2), and water (H_20). Point out examples in the displays.
   - *When bacteria living in the gut of a deer digest grass, the grass is changed into deer poop, CO_2, and water, which are different substances than grass.*

FIELD CARD (continued)

Cut out along outer lines and fold along the centerline. This makes a handy reference card that will fit in your pocket.

When a fungus breaks down a leaf, we observe round circles and dark patches on the leaf. Fungus is changing the leaf into a different form, releasing CO_2, gas, and nutrients that become a part of air/soil.

7. Learners share more decomposition examples of things broken down into simpler parts.
8. Share: Scientists put organisms in categories that describe the role those organisms play in an ecosystem and how they get food.

   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, a part of the air, or parts of bodies of water. Decomposers break down things into forms of matter that plants and algae can use to build and grow.
9. Introduce three categories of decomposers: bacteria, invertebrates, and fungi (BIF); show Decomposer Cards; and invite learners to describe their observations of the photographs of each organism on the cards.
10. Share: You get to search for decomposers and evidence of decomposers in the area.
11. Share: Decomposers leave evidence behind such as spots on leaves, holes, tunnels, poop, etc.
12. Offer ideas about where learners can find decomposers/evidence of decomposers.
13. Share boundaries and safety expectations for searching for decomposers.
    - Roll logs toward your body. (Demonstrate.)
    - Don't touch organisms without an instructor (except plants, if you know they're safe to touch).
    - Avoid putting fingers, hands, or limbs where you can't see to avoid accidentally touching harmful organisms, such as scorpions or spiders.
    - Gently return logs/rocks to their original position to preserve moist habitats.
    - Share warnings about harmful organisms in the area.
    - Share any physical boundaries for learners.
14. Learners search/instructor circulates. Example questions:
    - What evidence have you found? What might have caused it?
    - What organism could have made this happen to the wood or leaf?
    - What about this place might make it possible for the organism to live here?
    - What do you think the organism eats? Where might it get the matter it consumes?
    - Where did you find the most/least evidence of decomposers?
15. Gather the whole group and invite a few learners to share what they found, areas with more/fewer decomposers, possible explanations for it.

Making Decomposition Diagram Models

1. Share: Decomposition displays are one type of model for decomposition. Now, you'll make a different type.
2. Share: You'll make a diagram model by using drawings, lines, arrows, and words to share your ideas about what decomposition is and how it happens.
3. Share: Scientists use diagrams with drawings, lines, arrows, words, and numbers to explain a complex process, such as decomposition.
4. Write the following on paper or on a whiteboard and invite learners to use drawings, lines, words, and numbers in their diagram models:
   - example of decomposition
   - explain how decomposition happens
   - describe or show the role of decomposers
   - results of decomposition
5. Post this list where learners can see it as they work on their diagram models.
6. Briefly demonstrate making an example diagram model, using learners' suggestions.
7. Show examples of how learners might integrate drawings, lines, labels, arrows, and writing. Invite learners to use:
   - lines to show connections between different parts of the diagram.

FIELD CARD (continued)

Cut out along outer lines and fold along the centerline. This makes a handy reference card that will fit in your pocket.

- labels to describe something difficult to draw (such as air) or to say what something is.
- arrows to show when something changes into something else.
- writing to explain ideas/observations.

8. Invite learners to include examples or evidence of decomposition they've observed today and from other parts of their lives.
9. Learners make diagram models and discuss with a partner for ~5–10 minutes.
10. Ask each pair to join with another pair to share and compare.

Decomposition Discussion

1. Suggested questions for discussion:
   - *What are some questions or ideas you have about how decomposition works?*
   - *Where is the stuff that used to be a part of the wood now?*
   - *Why is decomposition important for ecosystems?*
   - *What other things can you think of that might help make decomposition happen?*
   - *How might the process of decomposition change during different seasons or in different ecosystems?*
   - *Can humans be considered decomposers? Why or why not?*
2. Optional: Incorporate information from the Decomposition Statements Cards when appropriate.
3. Reference a learner's diagram model or a nearby example and share that decomposers play an important role in ecosystems: breaking down dead things into CO_2, H_2O, and minerals that plants and algae use to grow.
4. Share that once matter becomes CO_2 gas, it takes many steps for it to change into matter that living things can consume again—it takes photosynthesizers.
   - *Plants and algae are important to ecosystems because they make matter available as food for living things.*
5. Learners reflect on how their ideas have changed during the discussion. Offer a few minutes for learners to add to/change their diagram models to show this.

Wrapping Up and Reflecting

1. *Turn & Share* or *Thought Swap*:
   - *Describe something new that you learned about decomposition and how you learned about it.*
   - *How would you describe decomposition to a younger sibling or relative?*
   - *How does a leaf become part of the soil? Part of the air? Part of water?*
   - *How might this area look different without decomposition?*
   - *What helped you learn today?*
2. Review the definition for *decomposition*:
   - *Decomposition is when dead organisms and their wastes are broken down into smaller and simpler forms of matter—such as nutrients, carbon dioxide, water, and organic matter—that all become part of soil, air, or bodies of water.*
3. Invite learners to find more decomposers/evidence of decomposition during the field experience.
4. Encourage learners to keep looking at the outdoors through the lens of matter cycling. For example:
   - *Stuff around us in nature is changing. Some stuff seems to be disappearing. What is changing it and what is it changing into?*
   - *Where do you think that lizard gets the matter it's made of? Where do you think the matter in the lizard will go after the lizard dies?*
   - *Breathe in air that used to be part of plants, animals, and soil. What you breathe out will cycle back into those things.*
   - *Look at the trees, other plants, wood, soil, and air around you. Imagine matter moving through them as they change. Think about how long this has been happening with the same matter changing from one thing to another, cycling round and round on Earth.*
   - *How might water in that stream become part of living or nonliving things? What other living or nonliving things do you think matter in the water has cycled through?*
5. Optional journal activity. Invite learners to write in their journals anything they're curious about this topic, using evidence to explain their thinking. Possible assessment journal prompt: "Are humans decomposers?"

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

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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**

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To contact BEETLES™, email beetles@berkeley.edu