beetles

Science and Teaching for Field Instructors

Student Activity Guide

Fungi Exploration

Weird and wild fungi are everywhere, especially when it's wet out. Given the chance to explore and observe fungi, students will notice them everywhere. Exploring fungi will also lead students to appreciate how fungi function in ecosystems as decomposers and other important roles. Recent discoveries in science have found that huge underground networks of thin, branching tubes of mycelium, the white tubes that are the main growing part of a fungus, provide key links between plants and the rest of the ecosystem.

In this Focused Exploration activity, students begin by observing fungi. Then, they learn that mushrooms are the fruiting bodies of fungi. Students use a simple key to identify types of fungi, record data, then regroup, and discuss patterns of where fungi grow. Next, they learn about how fungi digest what they live on, discuss fungal impacts on ecosystems, and reflect on fungi roles in decomposition.

Students will...

- **Observe differences and similarities in structures of fungi.**
- **Learn the function of mushrooms in spore dispersal.**
- **Identify types of fungi and observe patterns of growth in fungi.**
- **Discuss fungal roles in ecosystems and reflect on their roles as decomposers.**

Grade Level:
Grades 4–8. Adaptable for younger or older students.

Timing:
55–75 minutes

Related Activities:
Decomposition Mission; Case of the Disappearing Log; other Focused Explorations; *Food, Build, Do, Waste*

Materials:
Fungi Keys (1 per 2-3 students); Fungus Chart (1 per 2-3 students); Fungi diagram; Mycelium Photos; pencils & journals for students
Optional: Discussion Cards (cut out, 1 set per 4 students)

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

Setting:
An area where there are several fungi growing, and ideally, several different types of fungi.

NEXT GENERATION SCIENCE STANDARDS

FEATURED PRACTICE

Obtaining, evaluating, and communicating information
Constructing explanations

FEATURED CROSSCUTTING CONCEPT

Patterns

DISCIPLINARY CORE IDEAS

Organisms have different conditions for survival
Matter and energy in ecosystems

For additional information about Connections to NGSS, go to page 13 of this guide.

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Fungi Exploration

ACTIVITY OVERVIEW

Fungi Exploration	Learning Cycle Stages	Estimated Time
Introducing the Activity	Invitation	5 minutes
Searching for and Observing Fungi	Exploration	10–15 minutes
Exploring Fungi with a Key	Concept Invention, Application	10 minutes
Observing Patterns of Growth	Concept Invention, Application	5 minutes
Discussing Fungal Impacts on Ecosystems	Concept Invention, Application	10–20 minutes
Wrapping Up	Reflection	5 minutes
TOTAL		**45+ minutes**

TEACHING TIPS

Field Card. On pages 25-26 of this guide is a pocket-sized version of this lesson that you can use in the field.

Read the Instructor Support Section. Beginning on page 10, you'll find more information about pedagogy, student misconceptions, science background, and standards.

Check for fungi ahead of time. This activity depends on having different kinds of fungi for students to check out—the more, the better! It's a great activity for the rainy season, or right after the snow recedes, wherever you are. Scout ahead of time to make sure you've got an area with different types of fungi for students to explore, and don't do the activity if you can't find at least a few types of fungi for students to explore.

Different keys for different groups. There is a range of ways to use the Fungi Key. Choose the approach that will work best with your students. For younger groups, or those who struggle with reading or focus, give out just the first page of the key so they can focus on identification through pictures. If you think students might have trouble with the idea of "evidence of fungi", you can do the *Case of the Disappearing Log* or *Decomposition Mission* activities first to give them more expsoure to evidence.

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Introducing the Activity

1. **Get students pumped to check out fungi.** Tell students they'll be observing a mysterious and fascinating organism. Build the suspense and pique their interest.
   - *What if I told you there was something in this forest that digests itself after it dies? And eats weird things like wood and dead leaves? And that's connected to the trees you see around you? What if I told you that you've eaten it? And that maybe, some of you have them growing on you? It's not an animal and kind of like a plant—since it stays in one place—but it's not a plant, because it can't make its own food. Does anyone have any ideas about what it is?*
   - *It's a fungus!*
2. **Point out or hold up a fungus (or photo of a fungus), then ask students to briefly *Turn & Talk,* making observations about the fungus, then discussing what they know or have heard about fungi in general.** Ask students to share a couple of observations of the fungus with their partner. Then ask students to discuss their prior knowledge about fungi.
3. **Call on a few students to share what they talked about.** After students discuss for a moment, call on a few students to share out with the whole group.

Searching For and Observing Fungi

1. **Tell students that in pairs, they'll look for different kinds of fungi, observing and making comparisons between them, and thinking about what each fungus reminds them of.** Tell students they'll explore the area and check out different types of fungi, and that they might have to look carefully to find fungi. When they find a fungus, they should make observations, share what it reminds them of, and notice similarities and differences (in shape, texture, location, color, structure, etc.) to the other fungi they've seen.
2. **Model the kinds of conversations students might have while exploring.** Give an example of the types of observations students might make while exploring:
   - *Well, this type has a round cap, but this one doesn't. It's all squiggly and looks squishy. And this one is shaped kind of like a broken cup. They look kind of the same color, but this one is all dusty, and this one isn't.*
3. **Set boundaries, give safety warnings, pair students, and send them to explore.** Set clear natural boundaries and give any warnings about safety, poison oak or ivy, areas to avoid, etc.
4. **As students explore, circulate and engage them in conversation, and support anyone who's struggling to find or observe fungi.** Check in with students as they explore, and ask them questions about what they wonder about fungi, what they notice, or similarities they observe between different types of fungi. Help engage students who could use support.

TEACHING NOTES

How do you know if it's a fungus? If your students seem confused initially about what a fungus is and what it isn't (i.e., they identify lichen as fungi), ask them to share what makes them think what they're looking at is or isn't a fungus. If they are struggling to know, explain some distinctions between fungi and what they think might be a fungi.

Harmful to touch? Mushrooms are not harmful to touch, but some are very harmful to eat. Make it clear that students shouldn't eat any parts of mushrooms they have found. They should wash their hands after touching mushrooms before touching food they are eating.

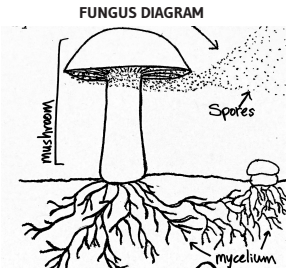
Supporting English Language Learners. Modeling the types of discussions you want students to have after giving a set of instructions is a way to support English Language Learners, or younger students.

Finding Mycelium. As students are exploring, look in the area for some mycelium. It's often easy to find on leaves just under the surface of leaf litter, in dirt underneath leaves or a log, or in a decomposing log. If you find some, collect a piece to show to students during the next section. If you don't find any, you can just show them the photo of mycelium instead.

TEACHING NOTES

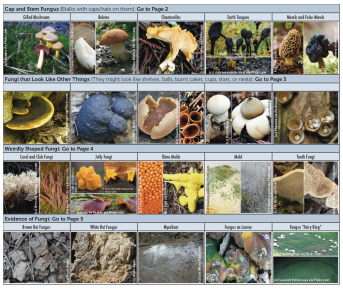
Incorporating Structure and Function. If you're focusing on the Crosscutting Concept Structure and Function during your field experience, you could ask students to make explanations about how the structures of different fungi might help them disperse their spores.

Fungus Diagram, page 17



Want to know more about fungal connections to plants? Check out the Background Section, and listen to the Radiolab podcast, "From Tree to Shining Tree." Mycelium does some pretty darned cool stuff, and if students find this interesting, you can share a little more information with them here.

Fungi Key, starting on "Fungi Key: Page 1" on page 20



5. **After about 7–10 minutes (but before they get bored), call students back and ask them to share their observations with another pair.** After students have had time to explore, call them back *before* they become disengaged. As students arrive back to the circle, ask pairs to connect with another pair to make a group of four, and to briefly share observations they came up with.

6. **Lead a short discussion in which students share observations about fungi shape, color, texture, where they were growing, etc.** Prompt students who observed similar things to use hand signals or snaps to show agreement. Ask follow-up questions as students share. For example:
   - *OK, so Ariana saw some fungi with caps, and some others that looked like blobs. Ariana, could you describe the 'blobs' in more detail? What color were they? How big?*
   - *Edmund, you saw something sticking out of the ground you thought might be a fungus, but you weren't sure it was a fungus. Could you say more about why you think it might or might not be a fungus?*

7. **Show spore print (if you have one), and explain that all the fungi parts students just observed have the same function: to disperse spores.**
   - *All of the parts of fungi you observed have the same function, which is to spread spores (kind of like tiny, really light seeds), to grow more fungi.*

8. **Show the fungus diagram and explain that the different kinds of fungi students observed are only one part of a fungus, like apples are to apple trees.** Explain that students were actually only observing part of what a fungus is. The part they observed is the fruiting body of the fungus, kind of like apples are the fruits of apple trees. See Fungus diagram on page xx.

9. **Tell students most of the fungus is actually underground (or under wood, skin, etc.)** so it's hard to see, but they can imagine a massive network of white threads underground.

10. **Point out mycelium on the diagram, show a sample if you have one (or the "Mycelium Photographs" on page 18), and explain some of the functions of mycelium.** After you point out mycelium, tell students that scientists have recently discovered that mycelium are often connected to plant roots, and transfer things like water and nutrients to plants.

Exploring Fungi with a Key

1. **Tell students they'll go check out fungi again, using a key to identify different kinds of fungi.** Show students the Fungi Key, and tell them they will again go explore and look at different types of fungi.

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2. **Briefly go through each page of the key, describe each category, and how to use the key, and explain that students probably won't find every type of fungus shown on the key.** Show students the key and explain how it works. For example:
   - *There are five pages of this key. The first page shows all the categories of fungi you might see: cap and stem, fungi that look like other things, weirdly shaped fungi, and evidence of fungi. When you find a fungi, scan this page briefly to try to figure out the overall category it goes in.*
   - *Cap and stem fungi have a stalk, which is kind of like a stem, and a cap, which is some kind of bigger thing at the top, kind of like a little hat. You can see how each of the cap and stem fungi look different from each other, but they all have some kind of cap and stem.*
   - *Let's say you're looking at a fungus and you figure out it has a cap and stem. You'll flip to that page and use the pictures and description to decide with your partner which type of fungus it is. It might not look exactly like the picture, so use the written description, too!*
   - *You probably won't find every single type of fungus shown on the key. Observe carefully and ask other students or the instructor if you're not sure about what category a fungus goes into.*

3. **Show students the Fungus Chart, and explain that after they identify a fungus, they will write down what type it is, what it's growing on, and any other interesting or surprising observations.** See page 18.

4. **Hand out keys, charts, and pencils, remind students they probably won't see every kind of fungus on the key, then send them to explore.**

5. **Circulate, troubleshoot, and engage students who need support.** As you circulate, ask students questions like, "What are some different things fungi are growing on?" "What do you notice about where they're growing?" "Where are they not growing?" "Which kind of fungus do you think this is? What's your evidence?" Notice students' interest, and follow it.

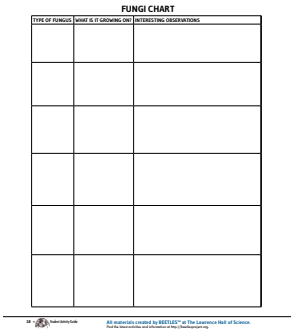
Observing Patterns of Growth

1. **Call the group back together, and ask students to share what they noticed.** Ask students to share what they observed, where fungi were growing, where they weren't growing, and anything else they wrote on their sheets. Listen to student responses. Encourage students to use hand signals or snaps to show agreement if they observed the same thing someone else shares.

2. **After students share some, help summarize observations as pattern statements.** Challenge students to make pattern statements about where they noticed fungi growing (or not growing) in this area.
   - Here's an example of a pattern statement you might make:
     - There seems to be a pattern that fungi grow on dead wood.
   - Examples of other pattern statements students might make:
     - There seems to be a pattern that:
     - They grow in wet dirt.

TEACHING NOTES

Fungus Chart, page 19


FUNGI CHART

TYPE OF FUNGUS	WHAT IS IT GROWING ON?	INTERESTING OBSERVATIONS

Use both drawing and writing. Let students know they can record these observations using drawing, writing, or a combination of the two.

Recording in journals. Students can also record this information in their journals. If you do the activity this way, give students a moment to write down the categories of information in their journal before they go back to explore.

TEACHING NOTES

- They grow in wet areas.
- Shelf fungi grow on living trees.
- Shelf fungi grow on both dead and living wood.
- Gilled mushrooms were growing in a ring.
- X fungus grows near X type of tree.
- Fungi don't grow on rocks.

3. **Ask if students noticed anything that didn't fit these patterns they just described.** Ask if they can think of any that were growing on something different than these patterns they just talked about, like an example where we only found one growing somewhere.
   - Here's an example of a statement you might make:
   - ▶ *We found only one growing on scat, so it didn't seem to fit the patterns of where other fungi were growing.*

4. **Explain that scientists often look for patterns, because it can help understand things, such as what an organism needs to survive and its role in the ecosystem.**
   - ▶ *Patterns is a crosscutting concept, or "thinking tool," scientists use to understand things. In this case, noticing patterns of where fungi grow and don't grow helps us understand what fungi need to survive, and their role in an ecosystem.*

Cause and effect. If you are highlighting the crosscutting concept of Cause and Effect, this is an opportunity to point it out to students.

5. **Ask students to *Turn & Talk* and discuss possible explanations for the patterns they observed.** Ask them to come up with possible explanations for the patterns of where fungi were growing and not growing. For example:
   - ▶ *I think the reason we found them in wet areas is because they are squishy and slimy, and might dry out and shrivel up if it was dry.*
   - Ask a few students to share their ideas, reasoning, and evidence, then summarize what they said. Ask other students to agree, disagree, or share different ideas. After a few students share their ideas, briefly summarize what they talked about.

Energy and matter. This is an opportunity to connect with the crosscutting concept of Energy and matter: Flows, cycles and conservation, if you are using that "thinking tool" with students during your field experience.

6. **Explain that one thing affecting where fungi can grow has to do with how they get matter and energy they need to live, and fungi digest what they grow on.**
   - ▶ *Every living thing needs to get matter and energy to survive. Animals get theirs from food they eat. Plants get theirs from air and water with sunlight. Fungi digest whatever they grow on. (Whoa!)*

Conditions that affect fungal growth. Scientists are still figuring out what other conditions affect fungal growth. We do know that fungi are more likely to grow where there's moisture. If students are curious, or if they share misconceptions about what might affect fungal growth (e.g., stating that access to sunlight is an important factor), then consider sharing how moisture is one of the factors that can affect it, and that scientists are still figuring out others.

7. **Show students mycelium and the diagram of fungi again, and explain:**
   - ▶ *Fungi put out a "digestive juice" through their mycelium onto what they're growing on/in.*
   - ▶ *Then, the fungi "suck up" the digested stuff through their mycelium.*
   - ▶ *Certain fungi only have the "digestive juice" to digest certain things. For example, some can digest wood, but not leaves. Others can digest one type of wood, but not another type."*
   - ▶ *Fungi only grow on what they can digest, so noticing what they're growing on/in tells us what they consume ("eat").*

Discussing Fungal Impacts on Ecosystems

1. **Lead a discussion about how fungi impact ecosystems.** This discussion could be brief or more involved depending on student interest and ability to focus at the moment. Pose the following questions and ask a few students to share their ideas. Ask follow-up questions and ask students to explain their reasoning. If the discussion takes hold, keep it going, incorporating a few *Turn & Talks* to keep the discussion lively. Remind students what you've shared about mycelium and connections to plants, and prompt them to use this as evidence in the discussion.

   If the discussion wanes or students don't seem to have ideas about how fungi impact ecosystems, you might want to try reading one of the cards from the Optional Discussion section (if you're planning on skipping that section) and ask students to discuss it, or share an idea from the Background Section and ask students to use it as evidence in their explanations.

   - *How might this place be different if there weren't any fungi in it?*
   - *How might fungi impact other living and non-living things around them?*
   - *How might they impact the forest?*
   - *How do fungi impact ecosystems?*

Note: If you are not doing the optional section, skip to "Wrapping Up."

Optional: Small Group Discussion of Fungal Impacts on Ecosystems

1. **Tell students they'll work in small groups to learn more about ways fungi interact with and impact their surroundings.** Explain that they'll learn more about ways fungi interact with parts of an ecosystem, and how that impacts things in the ecosystem.

2. **Make groups of four, then explain that students will read one card about fungi, discuss how it impacts the ecosystem, then do the same with the next card.**

   - *You'll receive a set of cards. Each card has information about a type of interaction fungi have with another living or nonliving part of this forest. Read a card aloud to your group, then discuss: How does this impact the things directly involved in the interaction? How does this affect other parts of the forest? How might things be different here if fungi weren't doing this?*

3. **Using one card as an example, model the kind of discussion a group might have.** Play all parts of the conversation about one of the cards.

   - *I'm going to demonstrate how you might have this kind of discussion as a group. OK, let's read out loud the card titled Protect, Then Digest Leaves.* [Read the card.]
   - Example of a model discussion:
   - *Wow! I didn't realize most living leaves had fungi growing on them. I just thought fungi would be bad for leaves.*
   - *Yeah, and it says they protect them from things that eat leaves. I wonder if the leaves on trees in the forest would be all chewed up if fungi weren't protecting them.*

TEACHING NOTES

Discussion Norms. If you have already gone over discussion norms with your group, remind students of those norms before sending them off to discuss in small groups. Discussion norms include:

- Listen actively and share ideas
- Share and ask for evidence
- Build on ideas of others
- Keep an open, curious mind
- Disagree respectfully to increase understanding
- Pay attention to participation

Advantages of this discussion. This is a great opportunity for students to continue to refine their understanding of how fungi interact with other parts of an ecosystem, and to engage in the practice Constructing Explanations. If you choose not to do this discussion, skip to Wrapping Up and finish up the activity.

Discussion Cards, page 25

TEACHING NOTES

That which protects them later consumes them (how heavy is that?). Most living leaves on trees have fungi growing on them. Those fungi protect the leaf against insects or other things that might eat the leaf. After the leaf dies and falls off the tree, that fungi digests the leaf, breaking it down into smaller and simpler pieces.

Language of uncertainty. In scientific dialogue, language of uncertainty is used to reflect an open-mindedness, and the awareness that any explanation could potentially be shown to be inaccurate if a better explanation is proposed, or if new evidence is found. "I wonder if..." "The evidence seems to show that..." "Maybe..." are examples of sentence starters that use language of uncertainty.

Wrapping up a discussion. At the end of a discussion about complex science ideas, it can sometimes feel like the group didn't get anywhere. When a leader summarizes ideas the group talked about and any conclusions they did come to, it can help the discussion feel more cohesive and productive.

Cause and effect. Cause and effect is a thinking tool scientists use to look at the world, and that's what you just did by making explanations about the impact of an organism in an ecosystem. You may want to point out that students were thinking about cause and effect about the presence of an organism in an ecosystem, just like scientists might.

- *It says fungi digest the leaves after the leaves fall off the tree. What do you think the ground here would look like if fungi didn't do that?*

4. **Pass out the cards, circulate, support struggling groups, and ask questions about student thinking.** As students discuss cards, circulate among groups and help out if they're having trouble understanding a card or discussing ideas as a group. Ask students to share their thinking as they react to the cards, and help them focus on the main question: How do fungi impact ecosystems? / What would it be like if fungi weren't here?

5. **After groups have had time to discuss at least a few cards, but before they lose interest, ask groups to wrap up their discussions.** Pay attention to the group's interest in the discussion topics. If some groups run through their cards quickly, ask them to go through them again and try to choose one topic to discuss more deeply.

6. **Get the group's attention, ask a few students to share some interesting ideas they talked about, and if the group is up for it, lead a short whole-group discussion about fungal impacts on ecosystems.** As students share their explanations of possible impacts, remind them to use scientific language of uncertainty, and to ask for evidence. Ask if others agree or disagree. Ask students to notice patterns in how fungi impact ecosystems.

Wrapping Up

1. **Briefly summarize ideas about fungal impacts on ecosystems that the group discussed.** Don't go into as much detail as in the discussion; just remind them of what they discussed, and highlight any explanations the group agreed on or questions they still have. For example:
   - *It seems like we all agree that fungi have a lot of impacts on ecosystems. When we talked about different organisms that eat fungi, we realized the fungi provide more food than we expected. We also talked about how many things seem to be decomposed by fungi. We discussed how fungi break down wood while other decomposers can't, and how there would be a lot of wood that never decomposed without fungi. We wondered if fungi ever compete with each other for food, or with plants for water during a drought. We also are still wondering if any other decomposers compete with fungi for similar food sources.*

2. **Emphasize the importance of any roles fungi play in ecosystems that the group didn't bring up.** For example:
   - *Fungi are the main decomposers of dead wood and leaves that other decomposers can't digest.*
   - *Fungi help transfer nutrients and water to networks of plants.*
   - *In some cases, fungi are the only food that certain invertebrates eat.*
   - *Scientists are just beginning to understand impacts of some complex interactions between fungi and other organisms.*

3. **Connect the activity to your theme for the day (or other topics you'll be teaching about).** Take the opportunity to tie in student thinking about fungi to other topics you will teach, such as decomposition, interdependent relationships in ecosystems, etc.

4. **Pump students up to keep looking for fungi as they explore.** Tell the group they can keep looking for fungi as they hike, and when they find fungi, they can observe what it's growing on, and look for evidence of interactions. Keep a key handy while hiking so students can identify whatever fungi they find.

5. **Ask students to *Walk & Talk, Turn & Talk,* or write in response to a few of the following reflection questions:**
   - *Where might you find fungi growing in your hometown ? Why do you think it would grow there?*
   - *Take a moment to imagine the huge underground network of thin, white threads connecting plants and nonliving things in this ecosystem.*
   - *What helped you to learn during this activity?*
   - *What do you still wonder about fungi?*

TEACHING NOTES

Mycelium hunt. You might want to encourage your students to find mycelium in an area, then try to gently dig around it to see if they can trace where it goes.

TEACHING NOTES

Instructor Support

Teaching Knowledge

Scientific Language. Science is about coming up with the best explanation for all the available evidence. It's also about being open-minded when examining other explanations that might be better. In science, nothing is ever finally "proven." This is why scientists tend to use language that demonstrates a healthy amount of uncertainty when discussing their ideas and explanations.

To help students maintain this mindset, try to offer sentence starters, such as "Maybe...," "I wonder if...," "That evidence makes me think...," and "The evidence seems to show..." Use this type of language yourself when discussing ideas, and encourage students to phrase their statements this way, particularly while they suggest possible explanations about fungal impacts on ecosystems.

Pacing for This Activity. Although this is written as a one-session activity, it also can work to stretch it over the course of a day (or even a week!). Early in a field experience, you can encourage students to discover and explore, then do the later parts of the activity as written, once curiosity is piqued and you're at a fungi-rich site. Since this activity alternates between student exploration and gradually introduced bits of interesting information, it allows the instructor to spread the experience out over the course of a full day's field experience. Be aware that if you introduce the content too early, it can discourage student exploration, instead of stimulating and extending their curiosity about fungi.

Conceptual Knowledge

Fungal Life Cycles

There are many different kinds of fungi and diverse life cycles. Some fungi only reproduce asexually, some reproduce sexually, and some use both methods of reproduction during their lifespan.

Growth. Fungi can grow at alarming rates. This growth involves two important structures: spores and hyphae. Spores are fungi's dispersal mechanism. Fungi can produce millions, or even billions of spores in a single day! Usually these float in the air, and by making a lot of spores, fungi increase the odds that some of them will fall on surfaces where they can germinate, absorb food, and grow into hyphae. Hyphae are the miraculous thread-like structures of fungi, which can both grow on top of solid surfaces and penetrate into whatever they're growing on.

Hyphae grow into the ground, wood or other substrates by secreting enzymes that help break down materials into matter that fungi can more easily digest. By growing into substrates and making complex and extensive webs of hyphae underground (or under wood or tissue) fungi increase the area from which they get food, supporting even more growth. The majority of fungal growth is hidden from view, and the network of hyphae, collectively called the mycelium, is mainly underneath the surface. It's only when fungi grow fruiting bodies that we can more easily notice their presence.

TEACHING NOTES

Asexual reproduction. Fungi reproduce asexually in two ways. They can produce spores that clone themselves and disperse, usually by floating in the air. Additionally, some fungi's mycelia (the mass of hyphae under the surface) can break apart into pieces that become their own separate mycelia.

Sexual reproduction. Sexual reproduction happens when the hyphae of two individuals meet and fuse into an interconnected mycelium. Sometimes the cells of these hyphae fuse without their nuclei joining, and can exist this way for years. In these cases, it's often an environmental trigger, such as a change in temperature, humidity, or availability of resources, that causes the fungus to grow a fruiting body (the mushrooms we see aboveground) that produces spores (with joined nuclei), which get released to the environment, fall on new surfaces, germinate, and grow hyphae. These hyphae can fuse with other fungi's hyphae and repeat the cycle.

Symbiosis, mutualism, and other types of interspecies relationships. The term symbiosis was originally used to describe people living together, who provide benefits to the whole community (called communal relationships). There are some scientists who use the term symbiosis only to describe relationships in which both species benefit from the relationship. But it's now more common in science to use the term for any type of close, ongoing relationship between different species. Whatever you call it, the important thing is that students understand how some species live together in mutually beneficial relationships.

Below are the scientifically accepted definitions of the most commonly used terms describing various types of communal relationships between different species of organisms:

- **Symbiosis**—A close and often long-term interaction between two or more separate biological species.
- **Mutualism**—A symbiotic relationship in which each individual benefits. Examples are lichen, clownfish/anemone, rhizobia bacteria/legumes, plant roots/fungi, pollinator/flower, ant/aphid, and humans/gut flora.
- **Commensalism**—A symbiotic relationship in which one organism benefits without adversely affecting the other. Examples are remora/shark, whale/ barnacles, and orchids/trees.
- **Parasitism**—A symbiotic relationship in which one organism benefits at the expense of the other. Examples are athlete's foot, vertebrates/tapeworms or fleas, mistletoe/trees, cuckoos/cowbirds, and viruses, bacteria, protozoa/other organisms.

Mycorrhizal Relationships

The partnership between fungi and plants, referred to as mycorrhizal symbiosis, is one of the most important symbioses on Earth. Mycorrhizal symbiosis has been around for a *long* time, at least 400 million years(!), and around 80 percent of plant species depend on it. In this symbiosis, the mycelium grows around actual plant roots underground. The mycelium takes up nutrients and water from the soil, and passes them to the plant. Because the mycelium covers a much larger area than the plant's roots, and has

TEACHING NOTES

more surface area, this allows the plant to get a lot more nutrients than it would without the fungus. Some plants get almost all their nutrients through mycorrhizal fungi.

Mycorrhizae can also connect plants to each other underground, enabling different plants to share resources. Fungi can also help protect plants from predators and diseases, and increase their resistance to pollution and other environmental stresses, like droughts. In return for providing the plant with these benefits, the fungus gets sugars that the plant makes through photosynthesis. Most mycorrhizal relationships are mutualistic (they benefit the plant and the fungus), but sometimes they're parasitic, such as when the plant relies on the fungus for food without providing anything in return, or the fungus is mildly detrimental to the plant.

Fungi as Endophytes

In addition to symbiosis with plants' roots, fungi have another major, though less understood role, as endophytes (from the Greek words for "in plants")—virtually all living leaves have fungi inside them! Some research suggests that these endophytic fungi live within the plant cells and cause the plant to alter its chemical composition to deter herbivores (plant eaters) and decrease other stresses. Another explanation is that these fungi set themselves up to digest the leaves as soon as they die, as compared to fungi that live on the ground.

Fungi as Decomposers

Perhaps the most important role of fungi is as decomposers. Along with bacteria, fungi break down most of the dead material—leaf litter, fallen trees, and dead animals— on the forest floor. Fungi are especially important decomposers because, unlike bacteria, which can only feed on the outer surfaces of dead material, fungi can penetrate into the material and break it down from the inside. Additionally, fungi are some of the only organisms that can digest wood. As fungi break down dead material, they turn it into simpler forms that other organisms can more easily digest. If it weren't for fungi (and bacteria) other organisms would not have access to these nutrients that help to sustain them. And there would be piles of dead material covering the forest floor!

Common Relevant Misconceptions

Misconception. Fungi get energy from the sun.

More accurate information. Though fungi have some characteristics that resemble those of plants—they sometimes have stem-like stalks, they're mainly immobile, they sometimes grow from soil—unlike plants, fungi are not autotrophic, which means they do not use energy from the sun to produce food. Fungi are heterotrophic, meaning they get their food from external sources. In particular, fungi get food by absorbing nutrients from whatever they are growing on. Fungi grow networks of thread-like hyphae (collectively called a mycelium), which penetrate the surface on which they are growing, secrete enzymes that help digest the material, and then absorb the broken-down products.

Misconception. Lichen are fungi.

More accurate information. Lichen are not a type of fungi, but are a symbiotic partnership between fungi and algae. The fungal filaments surround and grow into the algal cells, and make up the majority of the lichen's physical bulk. The algal cells photosynthesize and provide food to the fungi, and the fungi absorb water and nutrients, and deliver some of these to the algae. This relationship is so well-established that lichen are given scientific names as if they were a single organism. For more about this weird and awesome organism, see the BEETLES activity, *Lichen Exploration*.

Misconception. Fungi are always harmful to plants, animals, and insects.

More accurate information. Though some fungal diseases harm plants, such as Dutch elm disease that has devastated populations of elms, many plants rely on fungi to survive. The mycelium of fungi surround and grow on plant roots underground and reach out into the area around the roots. The mycelium absorbs nutrients and water from the soil and passes them to plants, playing an important role in helping plants get what they need to survive.

Similarly, some fungi can harm animals or insects. For example some human diseases, such as athlete's foot and ringworm, are caused by fungi, and some mushrooms are poisonous—even fatal!—when eaten. Certain types of fungi, like the zombie ant fungi, even eat insects! These fungi attach to insects as they walk by and secrete a chemical to penetrate the insect's armor. Once inside the insect, the fungus begins to eat the insect's insides, while simultaneously keeping the insect alive secreting an antibiotic and a fungicide. Finally, the fungus infests the insect's brain, causing the insect to climb to the top of a plant, where the fungus eats the remainder of the insect, then uses its high-up post as an ideal place to release and disperse its spores.

On the other hand, fungi provide an important food source to some animals and insects. Lots of insect and mite species *only* eat fungal fruiting bodies, and some insects such as certain species of ants and termites even cultivate fungi, like farmers. They eat the fungi they grow and the fungi help them digest other food sources such as wood or leaves by releasing chemicals that help break them down.

There's also the crucial role fungi play as decomposers in the forest, which directly and indirectly benefits other living things in the ecosystem.

Connections to Next Generation Science Standards (NGSS)

BEETLES student activities are designed to provide opportunities for the "three-dimensional" learning required in the NGSS. To experience three-dimensional learning, students need to engage in Science Practices to learn important science ideas (Disciplinary Core Ideas) and deepen their understanding by relating that content to overarching Crosscutting Concepts. Students should be exploring and investigating rich phenomena, and figuring out how the natural world works.

TEACHING NOTES

About the Next Generation Science Standards (NGSS). The development of the Next Generation Science Standards 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 towards engaging students 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 students 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 www.nextgenscience.org/ and ngss.nsta.org/.

TEACHING NOTES

In *Fungi Exploration,* students engage in the science practices of C*onstructing Explanations* and *Obtaining, Evaluating, and Communicating Information*, as they use the crosscutting concept of *Patterns* to explore different types of fungi and discuss the impact of fungi on ecosystems. They build a foundation for developing disciplinary core ideas related to *Structure and Function, Interdependent Relationships in Ecosystems*, and *Cycles of Matter and Energy Transfer in Ecosystems.*

Featured Science and Engineering Practices

Importance of teaching science practices. "Engaging in the practices of science helps students understand how scientific knowledge develops...It can also pique students' curiosity, capture their interest, and motivate their continued study..." -National Research Council, A Framework for K-12 Science Education. Focus on these science practices will help to ensure a more scientifically literate public who will be better able to make thoughtful decisions.

Engaging Students in Obtaining, Evaluating, and Communicating Information. According to the NGSS, it's important for scientists and for students to encounter scientific information from many sources to interpret this information, communicate their own ideas in written and spoken form, and discuss their observations and explanations with their peers. Students are exposed to multiple sources of information throughout *Fungi Exploration*. Their initial source of information is their own observations as they explore and compare fungi in the surrounding area. Students then interpret a diagram to better understand the structures of fungi, especially those which are underground (or under wood, skin, etc.) and harder to observe.

Then students receive a key, and using the key along with their firsthand observations, record information about the fungi of the surrounding area in a data table—the Fungi Chart. Finally, in the optional small group discussion, students interpret information about fungi interactions from cards to discuss the impact of fungi on ecosystems. These different sources of information provide students with a rich base of evidence for constructing explanations.

Engaging Students in Constructing Explanations. According to the National Research Council's (NRC) *A Framework for K-12 Science Education,* a major goal of science is to deepen human understanding of the natural world through making explanations about how things work. It follows that students should develop their understanding of science concepts through making their own explanations about natural phenomena. In *Fungi Exploration*, students have multiple opportunities to construct explanations about fungi. First, after searching for and exploring fungi, students may make explanations about how the structures of different fungi help them to disperse their spores. Then, after exploring fungi with a key and noticing where different fungi grow, students make explanations about why different fungi might grow in different places. Finally, using their observations and/or the optional Fungal Impacts on Ecosystems cards as evidence, students make explanations about how fungi affect other organisms and impact ecosystems overall.

In each part of the activity, make sure students have sufficient time to explore and observe fungi—these observations are an important basis of evidence for students' explanations. In order for students to be fully engaged in this practice, they need to go beyond creating an explanation as described above. They also need to consciously use language of uncertainty ("I think that..."), base their explanations on evidence, and consider alternative explanations based on that evidence. Encourage students to include their evidence and reasoning when they share an explanation, and to be open to other ideas.

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

Featured Crosscutting Concepts

Learning science through the lens of *Patterns*. The idea that patterns can be found everywhere and that taking note of them can lead to interesting questions about why they occur is an important lens for scientific investigations. According to the NRC's *A Framework for K–12 Science Education*, students should be using patterns to think about their observations and explanations across different disciplines of science (and mathematics!). Recognizing patterns can be a step toward using classification systems to make sense of the natural world.

In *Fungi Exploration*, students look for patterns in how and where fungi grow, which leads them to think about the relationships between fungi and other parts of the ecosystem. Be sure to point out to students that looking for patterns is something scientists do to lead them to make interesting observations or ask useful questions about the relationships between living and nonliving things. This will help emphasize the idea that pattern recognition is a useful skill in any field.

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. The NGSS make it clear that students need multiple learning experiences to build their understanding of disciplinary core ideas. *Fungi Exploration* gives students an opportunity to develop understanding of some disciplinary core ideas related to LS1.A: *Structure and Function*, LS2.A: *Interdependent Relationships in Ecosystems*, and LS2.B *Cycles of Matter and Energy Transfer in Ecosystems*.

When students interpret the fungus diagram, they make sense of how the different parts of a fungus play a role in how it survives (LS1.A). As they observe and discuss the significance of interactions between fungi and other organisms, students develop an understanding of the interdependence of living and nonliving things in ecosystems (LS2.A). Finally, learning about fungi's unique way of obtaining food and their important role as decomposers in ecosystems supports students in understanding how matter cycles through an ecosystem (LS2.B).

You can informally assess student understanding of these concepts during different stages of the activity through individual interactions with students, and by listening carefully during the group discussions. This information can help you determine which ideas to focus on in future lessons, so follow-up activities or discussions can be used to deepen student understanding.

Performance Expectations to Work Toward

When examined closely, it's clear that the NGSS represent complex knowledge and multifaceted thinking abilities for students. No single activity can adequately prepare someone for an NGSS performance expectation. Performance expectations are examples of things students should be able to do, after engaging in multiple learning experiences or long-term instructional units, to demonstrate their understanding of important core ideas and science practices, as well as their ability to apply the crosscutting concepts.

As such, they do not represent a "curriculum" to be taught to students. Below are some of the performance expectations that this activity can help students

TEACHING NOTES

About Crosscutting Concepts in the NGSS. Crosscutting concepts are considered powerful thinking tools for how scientists make sense of the natural world. The seven "big ideas" listed as crosscutting concepts are: Patterns; Cause & Effect; Scale, Proportion & Quantity; Systems and System Models; Energy & Matter: Flows, Cycles and Conservation; Structure & Function; and Stability & Change. These concepts may sound familiar, as they are quite similar to the themes referred to in science literacy documents as being important ideas that unify all disciplines of science and engineering.

Translating the codes used in the NGSS. Each standard in the NGSS is organized as a collection of performance expectations (PE) for a particular science topic. Each PE has a specific code, provided here so that they can be easily referenced in the NGSS documents. The first number or initial refers to the grade level: K - kindergarten, 1 - first, 2 - second,etc...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-LS4-4 means it's 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, that deals with Biodiversity and Humans. It's also the fourth performance expectation (4) that makes up the complete LS4 standard at this grade level.

TEACHING NOTES

work toward.

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

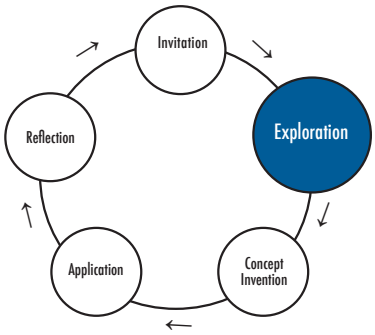
5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

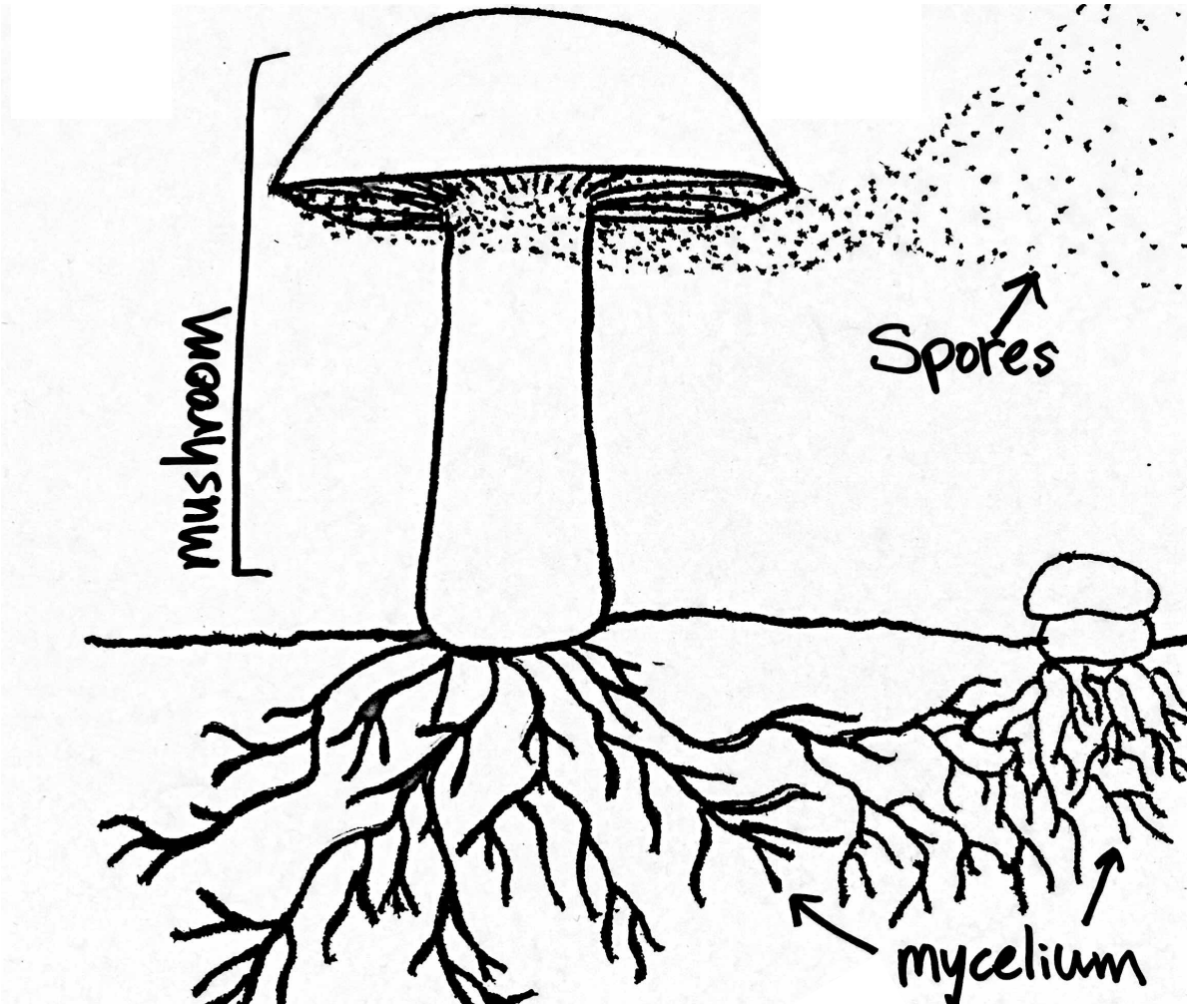
Activity Connections and Additional Ideas

Other BEETLES "Exploration" type activities include *Bark Beetle Exploration, Lichen Exploration*, and *Spider Exploration*. To deepen students understanding of content related to *Interdependent Relationships in Ecosystems*, use activities such as *Case of the Disappearing Log, Discovery Swap*, or *Exploratory Investigation*. To deepen students understanding of content related to *Cycles of Matter and Energy Transfer in Ecosystems*, use activities such as *Case of the Disappearing Log, Decomposition Mission*, or *Food, Build, Do, Waste*.

Learning Cycle stage for this entire activity as part of an extended learning experience.



Fungus Diagram



Mycelium Photographs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Fungi Chart

TYPE OF FUNGUS	WHAT IS IT GROWING ON?	INTERESTING OBSERVATIONS

Fungi Key: Page 1

Cap and Stem Fungus (Stalks with caps/hats on them): Go to Page 2

Gilled Mushroom

Boletes

Chanterelles

Earth Tongues

Morels and False Morels

Fungi that Look Like Other Things (They might look like shelves, balls, burnt cakes, cups, stars, or nests): Go to Page 3

Weirdly Shaped Fungi: Go to Page 4

Coral and Club Fungi

Jelly Fungi

Slime Molds

Mold

Tooth Fungi

Evidence of Fungi: Go to Page 5

Brown Rot Fungus

White Rot Fungus

Mycelium

Fungus on Leaves

Fungus "Fairy Ring"

Fungi Key: Page 2

Cap and Stem Fungus

Gilled Mushroom

Almost always have a cap and stem. The "gills" are on the underside of the cap, and look kind of like bicycle wheel spokes.


(cc) onnola via Flickr.com

Boletes

Have a cap and stem. Look like gilled mushrooms from above, but do not have gills. The underside of the cap looks like a sponge filled with holes.


(cc) Juha Haataja via Flickr.com


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Chanterelles

Grow on the ground. Have a trumpet-shaped cap and stem. Have small ridges under the cap and the top part of the stem; these ridges are wrinkled or "zig zag-ey" in shape.


(cc) Ken-ichi-Udea via Flickr.com

Earth Tongues

Small single stemmed fungi. Grow out of the ground or rotting wood.


(cc) H. Krisp via Flickr.com


(cc) dutchmasterdutchie via Flickr.com

Morels and False Morels

Morels: The cap is honey-combed with open pits.


(cc) term priest via Flickr.com

False morels: do not have open pits, and look wrinkled kind of like a brain, or like old trees.


(cc) Tab Tannery via Flickr.com

Fungi Key: Page 3

Fungi that Look Like Other Things

Bracket or Shelf Fungi

Look like shelves growing on trunks, stumps, or logs.
Some have growth rings that can be counted like tree rings to tell the age.

Carbon Ball Fungi

Black or partially black, tough and charcoal like. Grow on wood. Look kind of like dog noses.

Cup Fungi

May be shaped like a cup, ear, spoon or small plate. Grow on wood, dung, or soil. Do not have a stem.

Puffballs or Earth Stars

Round ball-like shape, or a round ball with star "petals" around it. No stalk. Shoot out their spores in a sudden "puff" when triggered by a raindrop or similar jolt. This is sometimes called, "pixie farts."

Birds Nest Fungi

Look like tiny bird's nests with one or more "eggs" inside. Most start out with a lid on top of the "nest."

Fungi Key: Page 4

Weirdly Shaped Fungi

Coral and Club Fungi

Look like branching coral or like simple stalks sticking out of the ground. Most grow in soil. Can also grow on rotting plants, or on dead wood.

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Jelly Fungi

Jellylike or rubbery. Come in many different shapes. Usually grow on wood. One kind that looks like melting butter is called "witches butter."

Slime Molds

Sometimes these look like slime or a pile of goop.

(This one is called Dog Vomit Slime Mold. Yep, really.)

Mold

Look fuzzy, powdery, filmy, or a different color than what they are growing on.

Tooth Fungi

May have "teeth" hanging like icicles. May have a cap and stalk with a layer of teeth under the cap, or may grow in a single layer on a piece of wood with "teeth"

Fungi Key: Page 5

Evidence of Fungi

Brown Rot Fungus

Certain types of fungi break down and consume the white cellulose in wood, leaving behind the brown parts of cell walls (lignin) in brown cubic sections.

White Rot Fungus

Certain types of fungi break down and consume the brown parts of cell walls, leaving behind the spongy, stringy, yellow & white cellulose in wood.

Mycelium

The mushrooms we see are just the "fruits" of fungi. Most of the fungus is underground, looks like white threads, and is called mycelium. Mycelium are thin and small, and absorb nutrients and water from whatever they are growing in. Fungi often have relationships with plants, where plant roots are connected to the mycelium which pass nutrients to the plant.

Fungus on Leaves

Because fungi tend to grow out in rings, roundish spots on leaves are usually from fungi. Most living leaves on trees have fungi growing on them. The fungi defend against insects or other things that might eat the leaf. After the leaf dies and falls off the tree, the same fungi begins to digest the leaf, making it break down.

Fungus "Fairy Ring"

Fungi tend to grow out in rings. Sometimes you can see a ring of mushrooms which are all fruits on the same fungus. You can't see it, but you can imagine the white threads of the fungus in an underground ring

Above, a "fairy ring," without the mushrooms.

Discussion Cards

PROTECT, THEN DIGEST LEAVES

Most living leaves on trees have fungi growing on them. Those fungi protect the leaf against insects or other things that might eat the leaf. After the leaf dies and falls off the tree, that fungi digests the leaf, breaking it down into smaller and simpler pieces.

DIGEST WOOD

Fungi are some of the only organisms that can digest wood. Once the fungi digest and break down the wood into smaller and simpler parts, it can become a part of the soil, or other decomposers can eat it to break it down further.

DIGEST PIECES OF LEAVES AND OTHER DEAD THINGS

Fungi digest LOTS of little bits of leaves and other dead material, breaking it down further into smaller and simpler parts that become a part of the soil.

HELP PLANTS GET NUTRIENTS AND WATER FROM THE SOIL

Plant roots are connected to mycelium (threads of fungi) underground. The mycelium are thin and small-smaller than plant roots. They are able to absorb nutrients and water from the soil very easily, then pass the nutrients and water on to the tree.

INFEST LIVING TREES

Some fungi enter living trees where branches have broken off, or through another weak part of the tree. The fungi begin to break down the living tree. This can weaken the tree, making the tree more likely to be attacked by bark beetles or other parasites that could kill the tree.

TURN INSECTS INTO ZOMBIES

Some fungi digest insects! A spore lands on an insect, and the fungus grows inside the living insect. The fungus controls the insects' brain and makes it climb to the top of a small plant. When the insect dies, the fungus fully digests the insect, and then the spores poof off up into the air.

FIELD CARD

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

Fungi Exploration

Introducing the Activity

1. Get students pumped to check out fungi. Explain:

   ▶ *What if I told you there's something in this forest that: digests itself after it dies; eats wood & dead leaves; is connected to trees; you've eaten; may be growing on you; is not an animal and stays in one place like a plant—but it's not a plant, because it can't make its own food? Any ideas what it is? [fungus]*
2. Point out or hold up fungus (or photo). *Turn & Talk* observations. about the fungus & discussing what they have heard about fungi.
3. A few students share out.

Searching For & Observing Fungi

1. Explain: In pairs, you'll look for different kinds of fungi, observing, making comparisons, thinking what each fungus reminds you of.
2. Model kinds of conversations students might have while exploring.
3. As students explore, circulate & engage them in conversation, & support anyone struggling to find or observe fungi.
4. After 7–10 minutes, pairs share observations with other pair, then share out.
5. Lead short discussion in which students share observations about fungi shape, color, texture, where they were growing, etc.
6. Show spore print (if you have), and explain all fungi parts they observed have the same function: to spread spores.
7. Show fungus diagram, & explain: the different kinds of fungi observed are only one part of a fungus, like apples on apple trees.
8. Explain: Most of the fungus is actually underground (or wood, skin, etc.) so it's hard to see. Imagine a massive network of white threads underground.
9. Point out mycelium on diagram & real (if you have), & explain some functions of mycelium (connected to plant roots, transfer things like water & nutrients to plants).

Exploring Fungi with a Key

1. Explain: You'll check out fungi again, using a key to identify.
2. Briefly go through each page of the key, describe categories, & how to use the key, & explain they probably won't find every type on the key.
3. Show Fungus Chart, & explain: After identifying a fungus, you'll write what type, what it's growing on, & other interesting observations.
4. Hand out keys, charts, and pencils, then send them to explore.
5. Circulate & troubleshoot.

Observing Patterns of Growth

1. Call group back & ask what they noticed.
2. Help summarize observations as pattern statements, such as *There seems to be a pattern that fungi grow on dead wood.*
3. Ask if they noticed any that didn't fit patterns.
4. Explain: Scientists look for patterns, because it can help understand things, such as what an organism needs to survive & its role in the ecosystem.
5. *Turn & Talk* possible explanations for patterns they observed.
6. Explain: One thing affecting where fungi can grow has to do with how they get matter & energy to live. Fungi digest what they grow on.
7. Show mycelium & diagram again, & explain:

   ▶ *Fungi put out "digestive juice" through mycelium onto what they're growing on/in.*

   ▶ *Then, they "suck up" the digested stuff through their mycelium.*

   ▶ *Certain fungi only have "digestive juice" to digest certain things.*

   ▶ *Fungi only grow on what they can digest, so noticing what they're growing on/in tells us what they consume ("eat").*

(continued on next page)

FIELD CARD

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

(continued from previous page)

Discussing Fungal Impacts on Ecosystems

1. Lead discussion about how fungi impact ecosystems.
   - *How might this place be different if there weren't any fungi in it?*
   - *How might fungi impact other living and nonliving things around them?*
   - *How might they impact the forest?*
   - *How do fungi impact ecosystems?*

Optional: Small Group Discussion of Fungal Impacts on Ecosystems

Note: If you're not doing the Optional section, skip to "Wrapping Up."

1. Explain: You'll work in small groups to learn more ways fungi interact with & impact their surroundings.
2. Make groups of four, then explain that students will read one card about fungi, discuss how it impacts the ecosystem, then do the same with the next card.
3. Using one card, model the kind of discussion a group might have.
4. Pass out cards, circulate, support struggling groups, & ask questions about student thinking.
5. After groups discuss at least a few cards, groups wrap up discussions.
6. Get group's attention, ask a few students to share interesting ideas they talked about, & if group is up for it, lead short whole group discussion about fungal impacts on ecosystems.

Wrapping Up

1. Briefly summarize ideas about fungal impacts on ecosystems that group discussed.
2. Emphasize importance of roles fungi play in ecosystems that the group didn't bring up. For example:
   - *Fungi are the main decomposers of dead wood & leaves that other decomposers can't digest.*
   - *Fungi help transfer nutrients & water to networks of plants.*
   - *Scientists are just beginning to understand impacts of complex interactions between fungi & other organisms.*
3. Connect to your theme for the day.
4. Pump students up to keep looking for fungi as they explore.
5. *Walk & Talk, Turn & Talk*, or write:
   - *Where might you find fungi growing in your home town? Why do you think it would grow there?*
   - *Imagine the huge underground network of thin, white threads connecting plants & nonliving things in this ecosystem.*
   - *What helped you to learn during this activity?*
   - *What do you still wonder about fungi?*

ABOUT BEETLES™

BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) is a program of The Lawrence Hall of Science at the University of California, Berkeley, that provides professional learning sessions, student activities, and supporting resources for outdoor science program leaders and their staff. The goal is to infuse outdoor science programs everywhere with research-based approaches and tools to science teaching and learning that help them continually improve their programs.

www.beetlesproject.org

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Principal Investigator and Articulate Beetle: Craig Strang
Project Director, Lead Curriculum & Professional Learning Developer, and Idea Beetle: Kevin Beals
Project Manager, Professional Learning & Curriculum Developer, and Beetle Herder: Jedda Foreman
Curriculum & Professional Learning Developer and Head Fireball: Lynn Barakos
Curriculum & Professional Learning Developer and Champion-Of-All-The-Things: Emilie Lygren
Research and Evaluation Team: Bernadette Chi, Juna Snow, and Valeria Romero
Collaborator, Super Naturalist, Chief Scalawag and Brother-from-Another-Mother: John (Jack) Muir Laws
Project Consultants: Catherine Halversen, Mark Thomas, and Penny Sirota
Advisory Board: Nicole Ardoin, Kathy DiRanna, Bora Simmons, Kathryn Hayes, April Landale, John Muir Laws, Celeste Royer, Jack Shea (emeritus), Drew Talley, & Art Sussman.
Editor: Lincoln Bergman
Designer: Barbara Clinton

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To contact BEETLES™, email beetles@berkeley.edu