beetles

Science and Teaching for Field Instructors

Student Activity Guide

Lichen Exploration

Looking at lichen through a hand lens can be like looking at life-forms from an alien planet. In this activity, students focus closely on lichen and get turned on to its different strange and interesting forms. One reason for spending time to learn about lichens is that they can be found just about anywhere, so it's something students can keep investigating after they leave your program. Students observe and explore this "weird organism," growing on rocks and trees, and wonder what it is. They learn that it's a lichen, use a key to identify three types of lichen, reflect on the symbiotic relationship of fungi and algae that make up lichens, and finally search for evidence of lichen succession. After this activity, students will likely begin to notice lichens everywhere, and will be motivated to continue their explorations.

Learning Objectives: Students will...

- **Become curious about lichens and where they grow, and recognize the diversity of lichens.**
- **Identify three main categories of lichen: crusty, leafy, and shrubby.**
- **Understand lichens as a symbiotic relationship between two organisms: fungi and algae.**
- **Observe patterns of how different lichen species tend to grow in relation to each other.**

Grade Level:
Grades 5-8. Adaptable for younger or older students.

Timing:
about 45 minutes (in one session or 3 15-minute chunks)

Related Activities:
Thought Swap
NSI: Nature Scene Investigators

Materials:
For instructor: Whiteboard; Marker. For each student pair: 1 lichen key, page 13. For each student: *(optional, but highly recommended)* Hand lens.

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

Setting:
Choose an area with a variety of interesting lichen. Ideally, it will have the three main types: crusty, leafy, and shrubby.

NEXT GENERATION SCIENCE STANDARDS

For additional information about *NGSS*, go to page 10 of this guide.

FEATURED PRACTICE	FEATURED CROSSCUTTING CONCEPT	DISCIPLINARY CORE IDEAS
Constructing Explanations	Patterns	Interdependent Relationships in Ecosystems

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Lichen Exploration

ACTIVITY OVERVIEW

Lichen Exploration	Learning Cycle Stages	Estimated Time
Introducing this "weird organism"	Invitation	5 minutes
Exploring Lichens	Exploration	10 minutes
Sharing Lichen Observations	Concept Invention, Application	5 minutes
Introducing the Symbiotic Relationship in Lichens	Concept Invention	10 minutes
Using the Lichen Key	Concept Invention, Application	10 minutes
Talking about Where Lichens Grow	Application	10 minutes
Wrapping Up	Reflection	5 minutes
TOTAL		**45+ minutes**

TEACHING TIPS

Field Card. On page 14 of this guide is a pocket-sized version of this lesson that you can use in the field.

Before the field experience, make color copies of the Lichen Key (found on page 13 of this guide). Each page has 4 keys. Cut them apart, but hold onto them until you're ready to do the activity.

Lichen Keys. Print and cut out enough keys for each student pair to have one before you begin the activity.

Importance of hand lenses. When viewed under a magnifier (and even with the naked eye), lichens look like strange alien-planet plant life. If your students have hand lenses, encourage them to use them to look closely, and imagine that they were in such a strange landscape.

Read the Instructor Support Section. Beginning on page 8, you'll find more information about pedagogy, student misconceptions, science background, and standards.

When to introduce the name, "lichen." It's usually best to introduce names for things *after* students have explored them a bit, when they have a need for a name, and that's how this activity is written. But some find it helpful to give students the "lichen" name right away, or do so by confirming it, if students bring up the name "lichen" themselves.

Hold off explaining the symbiotic relationship. It's generally more effective to introduce concepts after learners have had even a little time to explore and become curious, which is why concepts are introduced after exploration in this activity.

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

Introducing this "Weird Organism"

1. **Group Chat: Check out this weird organism!** Find some interesting lichen and gather your group around. Tell them it's a living organism.

   - Have you ever seen anything like this before? What does it remind you of?
   - This is actually a living organism.

Exploring Lichens

1. **Pairs observe, describe, compare lichens up close, & see how many different kinds they can find.** Students explore in pairs. Tell them when they see different kinds of this organism, they should compare and describe them to their partner. If you're using hand lenses, be sure each student or pair has one. Say,

   - There are over 10,000 different kinds of this organism. Let's see how many different kinds we can find here and what we can notice about them.
   - Describe them out loud & make comparisons between different kinds you see.

2. **Students explore these "weird organisms" in this area.** Give them ~10 minutes to find and observe as many different kinds of the stuff as they can. Emphasize that they should not harm or remove it, but to observe it where it is growing. *Optional:* If it's growing on a portable stick or rock, they may bring it to share after exploration.

3. **Circulate, troubleshoot, & be a co-explorer.** Check in with students and ask what they notice. Ask them to compare different kinds of the organisms they find. Engage disinterested students by directing them to a specific rock, tree, or stick that's rich with good examples, and ask questions to encourage further exploration.

Sharing Lichen Observations

1. **Group chat: What did you find?** Gather students in a circle. If they collected sticks and rocks with lichen on them, have them place these in the circle to guide discussion. Listen as they explain their observations. Ask occasional follow-up questions, or take the whole group to see something of particular interest as described by students.

   - What did you notice?
   - How many different kinds did you find? How are they similar to or different from each other?
   - How would you describe one of the most interesting ones?
   - What does that one look like to you? What does it look like through your hand lens?

TEACHING NOTES

Prior exposure to algae & fungi. If you tell students that lichens are a relationship between an alga and a fungus, it probably won't mean much if the students haven't had previous experiences with algae and fungi. It's helpful if they have a chance to explore fungi and algae (not allergy, which kids sometimes confuse it with) before taking part in this investigation focused on lichens.

Collecting sticks and rocks. Discourage students from damaging the lichen by pulling it off sticks and rocks, but you may want to have them bring some still attached to the sticks or rocks back to the circle to share. If you decide to allow this, explain safety concerns, such as, not throwing sticks or rocks, and only picking up those smaller than a certain size. Make time for students to return sticks and rocks back to where they found them.

TEACHING NOTES

Less gender-specific hetero-normative names. We intentionally chose "Andi Algae," instead of the more commonly used "Alice Algae," to be less gender-specific. Use this with your group or choose your own gender-neutral alliterative names.

More silly Freddy/Andi humor. Some instructors like to add more lines about Freddy and Andi later on, such as, "some say their relationship is 'on the rocks,'" or "I've heard that Freddy was drivin' Andi up a tree."

Symbiotic or mutualistic? Symbiotic relationships include: parasitic, commensal, & mutualistic. Although we are focusing here on mutualistic relationships, those crazy lichens can have all three types. See the Instructor Support section for more info.

Introducing vocabulary. Literacy researchers advise that introducing a bunch of hard words—and only using them once or twice—can confuse students. It's more effective to choose a few key vocabulary words and use them multiple times, both verbally and in writing. If the terms *lichen, fungi, algae, succession, organism, adaptation* and *mutualistic relationship* are all new to your students, it's probably waaaaay too many to introduce in one activity. Informally assess which words your group is already familiar with, and use this information to decide which scientific vocabulary words to introduce to them and to use repeatedly during the activity.

Beatrix Potter and Lichen. Hailed by some to be the discoverer of the symbiotic relationship that makes up lichen, Potter, the author of *Peter Rabbit*, was not the first to hypothesize about this relationship. But she may have been the first to provide evidence by cultivating algal cells and fungal spores in her kitchen.

2. **Introduce the name "lichen."** Tell students this weird organism is called a "lichen," and write out the name for them to see. Point out that it looks like it might be pronounced to rhyme with "kitchen," but it's actually pronounced to rhyme with "hikin.'" Use the word in context many times during the field experience, and encourage students to use it.

Introducing the Symbiotic Relationship in Lichens

1. **Group Chat: So, what exactly is a lichen?** Ask the following questions and listen to student ideas. Help them make connections to their prior knowledge and experiences with plants and plant-like organisms (particularly the need for sunlight), and fungi.

   - Let's talk about lichens and what kind of organisms they are. What do you know about plants? Do you see any evidence that lichens are plant-like?
   - What do you know about fungi? Do you see any evidence that a lichen could be a fungus?

2. **"Freddy Fungus & Andi Algae took a likin' to each other" in a relationship that benefits both species.** After students share their ideas, explain that lichens are actually two organisms, a fungus and an alga, that often depend on each other. Freddy Fungus collects water and nutrients, attaches to a surface, and protects Andi Alga from the environment. By photosynthesizing, Andi Alga makes food that provides the matter and energy both Andi Alga and Freddi Fungus need & use to grow and survive.

3. ***Optional:* Introduce the term: "symbiotic."** Explain that close relationships between different species, such as the algae and fungi in lichens, are called ***symbiotic***. If you want students to learn this word, use it multiple times, encourage students to use it, and challenge them to think of other species that have symbiotic relationships (e.g., clownfish/anemone, rhizobia bacteria/legumes, plant roots/fungi, pollinator/flower, ant/aphid, and humans/gut flora).

4. **Explain that the relationship between fungi & algae helps them both survive in their habitat.** Tell students the relationship in lichens helps both organisms survive in their habitats. If you've discussed how structures and behaviors can be ***adaptations***, you can tell students that, in this case, the adaptation is the *relationship* between fungi and algae that enables these organisms to survive in their habitat.

Using the Lichen Key

1. ***Turn & Talk:* Students recall one type of lichen they saw and describe it to someone next to them (not the person they were exploring with).** Give students a couple minutes to *Turn & Talk* to describe the different kinds of lichen they saw to a neighbor. Remind them to take turns talking and listening.

2. **Introduce key with three main types of lichen: crusty, leafy, & shrubby.** Show students the Lichen Key, and tell them that even though there are

thousands of kinds of lichen, most lichens can grouped into one of three main types: crusty, leafy, or shrubby. Show students each photo on the key while also holding up (on a stick or rock) or pointing to a real sample of that type of lichen. Add verbal descriptors:

- *Crusty lichens are like a scab or like paint that is attached to the surface everywhere they touch it.*
- *Leafy lichens have little flaps like lettuce and attach to the surface in one place.*
- *Shrubby lichens look like a bush or beard.*

3. **Explain that the lichens won't look exactly like the ones pictured.** Say that the lichens they find might look different than pictures on the key–such as differences in color or shape. Leafy lichens can look "leafy" in many ways. There are different ways lichens can look crusty or shrubby too.

4. **Ask students to explore, identify lichen types using the key, and look for patterns about where & on what surfaces it grows.** Tell them to return to their explorations, pay attention to where and on which surfaces the lichens are found, and see if they can notice any patterns as to where different types of lichen grow.

   - *As you explore and try to identify the lichen, pay attention to where the lichen is growing and to look for patterns. Scientists often look for patterns to learn more about what's going on with an organism.*

5. **Give some examples of growth patterns to look for.**

   - *To find patterns of where lichens grow, you can look at what surfaces it grows on, and which it doesn't. For example, ask: Does it grow in rocks? On wood? On tops of rocks or on the bottom side? Where don't you see any lichens?*
   - *You can also look for patterns in the different types of lichen: Do different types of lichen grow in different places? Do crusty lichens only grow on one kind of surface, and not on others? Do you see more of one kind of lichen higher up in the trees?*

6. **Students use Lichen Key to explore in pairs.** Pass out one Lichen Key to each pair. Tell them to try to identify as many lichens as they can, as crusty, leafy, or shrubby. Tell them to focus on observing and looking for patterns related to where lichens grow. Circulate and trouble-shoot.

Talking About Where Lichens Grow

1. **Group chat: What did you find?** Gather students. Ask what kinds of surfaces lichens grow on. Then ask other follow-up questions, such as those below, to uncover student thinking and move the discussion along:

   - Where did you find or not find lichens, or different kinds of lichens?
   - Did you notice any patterns for the surfaces different types of lichen grow on? Where did the crusty lichens tend to grow? What about shrubby?

TEACHING NOTES

Separating the algae from the fungi. With some lichen, like shrubby, you can actually pull the green algal sheath covering off of the white fungus. Pretty cool.

Defining and broadening the idea of "patterns." Students may have only encountered the idea of patterns in mathematics, when it's used to describe repetitive number sequences or tessellating shapes. They may not be familiar with how the detection of patterns can be applied in many other branches of science (and life!). In this case, how making observations about possible patterns in lichen growth can help to predict where to find the organism. Share some examples with students who might be confused, like, "Do you see how there's more lichen on the branches farther from the trunk? That seems like it might be a pattern to me."

The Coolest Lichen. Ask students to choose one lichen, draw it, name it, then share it with another person. Encourage students to make up descriptive names for lichen (actually descriptive–not names like "Ralph" or something else silly). The name should describe something about the lichen that could help a person to identify it.

Lichen in Biological Soil Crust. On most soil types, but especially in desert areas, there is a living crust on the soil, made up of fungi, lichen, cyanobacteria and bryophytes.

TEACHING NOTES

Freddy Fungus & Bobby Bacteria? Lichens are usually a relationship between a fungus and an alga, but sometimes it's between a fungus and a cyanobacteria (which can photosynthesize), or a three way relationship between a fungus, alga and bacteria (oo la-la!). Black, dark grey, or brown parts you see on some lichens are probably bacteria.

More on lichen succession. As each different type of lichen grows on top of another, they may "adopt" the algae from the lichen they land upon. If the concept of succession fits in with your curriculum, and the students are somewhat familiar with it, the idea of lichen succession can be a nice way to emphasize the idea. This way you can mention it multiple times, and compare the lichen example with other examples of succession in nature. Otherwise, just explaining the concept–without demanding that they learn another challenging word–is probably plenty for most students.

Extra Challenge for Older Students. Instead of telling them, challenge your students to figure out the order in which most lichens grow.

IMPORTANT NOTE: Lichens don't always grow in this order in every place where you might find three types of lichen. It's possible that your students may not be able to observe this succession directly. If that's the case in your area, skip steps 5-8.

- Did you find different kinds of lichen growing on or near each other?
- What did you find underneath the lichen?

2. **Students *Turn & Talk* about possible explanations for why different types of lichen might grow in certain places and not others.** Ask students to make a possible explanation for why a lichen might grow in some places but not others. Encourage them to use tentative language, and to base their explanations on evidence.

   - *When you discuss with your partner why lichens might grow in some places and not others, share what makes you think that. Try to take into account what lichens need to survive. For example, we know lichens need sunlight, so the amount of sunlight might affect where lichens grow.*

[Students might say: "they need sunlight, and maybe they don't get enough sunlight down on the ground," or "I think that shrubby lichen doesn't grow right on rocks because it can't hang on to it."]

3. **Call for the group's attention and ask a few students to share their explanations, & encourage discussion.** Remind them to share evidence, use tentative language (like "I think that…") and share the reasoning behind their thinking. Encourage students to build on each others' ideas, and ask for agreement and disagreement.

4. **Explain that each type of lichen (& any organism) has specific environmental conditions where it survives best.** Explain that certain environments meet the needs of organisms better than others, and they can survive more easily in those places. This is also true with different kinds of lichens.

5. **Point out that all organisms change the environment a little as they grow.** As each type of organism grows, it changes the environment a little, which over time can change the living conditions for other organisms. Lichens can trap soil, adding a surface for other organisms to grow upon.

6. **Explain lichens often grow on surfaces in this order: crusty, leafy, shrubby, sometimes followed by moss, then other plants.** Explain that scientists have noticed a common pattern in lichen growth. First, crusty lichen colonizes a bare rock, then leafy grows on top of the crusty lichen, which dies in the area beneath it. Then shrubby lichen grows on top of the leafy lichen. After that, mosses can grow, and sometimes even plants with roots or trees.

7. **Pairs search for evidence of this order of lichen growth.** Tell pairs to spread out again to do a quick search and see if they can find evidence of this pattern in the area. Ask them to notice: What is growing on top of what?

8. **After ~5 minutes of exploration, bring group together to discuss findings.** Ask students if they found any examples of lichens growing in this order. Ask if they found any examples of lichens growing in a different order. Ask if they found anything new or surprising.

Wrapping Up

1. **Encourage students to keep looking for lichens on different surfaces (rocks, roads, trees, fences, sticks, fallen branches, etc) & to notice patterns.** Let students know they'll probably see lichens again during their field experience, and will definitely see them again at some point after they leave. Encourage them to keep observing, and to try to notice patterns relating to what surfaces lichens grow on, where they're found, and where different types of lichens grow in relation to one another. If you find a branch that's fallen from high in a tree, you can see what lichen growth at the tops of trees is like, and compare it with growth of lower branches or on the trunk.

2. ***Thought Swap* (formerly known as *Walk & Talk*): Students reflect on learning.**

   - *What are you still curious about? What do you wonder about lichen?*
   - *What did you do today that helped you learn about lichens?*
   - *Describe to your partner how you might tell a younger brother or sister what you learned about lichen.*

Optional Investigation: Lichen and Air Quality

1. **Explain that lots of leafy & shrubby lichens can mean clean air.** Tell students that crusty lichens can survive when air quality is poor, but leafy and shrubby lichens are more sensitive. Lots of leafy and shrubby lichens in an area is an indicator that the air quality is high. **NOTE:** The inverse is not true. The absence of these types of lichens doesn't necessarily mean the air is unclean.

2. **Students ask questions & develop an investigation.** Ask students if there's anything they can find out about the area's air quality based on this knowledge. Use the scaffolding in the BEETLES activity, *Exploratory Investigation* to help students choose a testable question and develop an approach for investigating it.

Optional Debate: Is Moss a Lichen?

1. **Find some moss & ask students whether they think it is a lichen.** Hold up a piece of moss and ask students:

   - *Based on what you now know about lichens and your observations, do you think this is a lichen?*

2. **Allow students time to talk with each other as they make comparisons between moss & lichen.** Ask students to observe samples of a moss and a lichen and make comparisons between the two. Tell them to talk with the people around them about whether their observations would lead them to believe that the moss is a lichen, or something different.

3. **Facilitate a group discussion about moss & lichen.** Ask students to say whether they think the moss is a lichen or not, and to share their evidence. Encourage respectful disagreement, and remind students it's OK if they change their minds based on evidence another student shares. For more information on moss, see the background section starting on page 8.

TEACHING NOTES

See BEETLES activity *Thought Swap* (formerly known as *Walk & Talk*) for logistics of this routine.

Lichens and niches. Lichens provide a great example of how if there is an available niche, organisms will likely evolve to survive there. If an organism can grow on bare rock, like many lichens do, there would be much less competition from other species than in fertile, damp soil.

Moss and Lichen. Mosses are non-flowering plants, and lichens are not plants. Lichens do not have stems and roots, but mosses do have tiny leaves and thread-like rhizoids that anchor them like roots. Students may confuse a moss with a lichen, or wonder about the differences. If so, you could explain this to them, or, guide them in investigating the question for themselves.

Instructor Support

Teaching Knowledge

Pacing for This Activity. Although this is written as a one-session activity, it also works well 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 lichen-rich site. The way this activity alternates between student exploration and gradually-introduced bits of interesting information 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 lichens.

Content Knowledge

Lichen

Lichens are a partnership between a fungi and an alga. The fungal filaments surround and grow into the algal cells, and compose the majority of the lichen's physical bulk. A fungus can often form a relationship with several different types of algae. The algae can usually live in nature without the fungal partner, but the fungus cannot survive without the alga.

The fungal partner reproduces sexually through spores, but the algal partner reproduces asexually. Many lichens reproduce by sending out ***diaspores*** that contain both algal and fungal cells. Others start out their little lichen lives as fungal spores that must find algal partners wherever they land. If one species grows on top of another, it may be able to adopt the algae of the first lichen. Lichens can also reproduce asexually when a piece of a lichen breaks off, then forms a new individual. Some have cup- or plate-like structures that produce spores.

Hardy Lichens

Lichens are hardy creatures able to survive in scorching deserts and frosty tundra. Two key features are suggested as having important roles in their success: (1) their ability to survive drying and (2) their complex chemistry.

Lichens may dry completely when moisture is unavailable, and can endure a complete loss of body water without dying. The lichen becomes temporarily brittle when dry, then when moisture is available again, it quickly absorbs water, resuming its soft and fleshy form. Not only can lichens handle drying, but, while they're dry and brittle, pieces may flake off and later grow into new lichens. Plants and animals could never survive such an extreme water loss.

The chemistry of lichens is complex but well-studied. They manufacture a host of chemicals that presumably serve to reduce predator attacks. Only a few insects feed on lichens, among them some moths and beetles. Banana slugs and reindeer also feed on lichens. Lichens slowly break down rock, both chemically and physically, thus contributing to the weathering of rock into soil.

The most serious threat to lichens is not predation, but the increased pollution of the past 100 years. Several studies have shown serious impacts

TEACHING NOTES

on the growth and health of lichens resulting from factory and urban air pollution. Because some lichens are so sensitive, they are now being used to quickly and cheaply assess levels of air toxins in Europe and North America.

Identifying types of lichen

There is a fourth main type of lichen sometimes used, called ***squamulose***, or "scaly." We've found that the three main types are easy for kids to identify, and adding the fourth is a bit more challenging. Properly classifying lichen is not the primary goal of this activity. The emphasis here is on students sharpening observation skills, noticing differences and similarities between lichens, and becoming intrigued with looking at this extraordinary organism wherever they go. Identifying lichen *species* is quite complicated, and a key to lichens of North America would be unwieldy. You might choose to make a key to common species in your area, by photographing them and adding the common names and descriptions. Otherwise, you can encourage kids to make up their own descriptive names for local lichen species.

"Lichens are fungi that have discovered agriculture" —Trevor Goward

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. With lichen, the term *symbiosis* was first used in 1877 to describe the relationship between fungi and algae. There are some scientists who use the term symbiosis *only* to describe *mutualistic* affiliations, in which *both* species benefit from the relationship. However, 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.

Lichens function as mini-ecosystems. Some scientists describe lichen as miniature ecosystems, which may have microorganisms living in a system with the fungi, algae, and/or cyanobacteria.

Symbiosis—a close and often long-term interaction between two or more distinct 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: vertebrates/tapeworms or fleas, mistletoe/trees, cuckoos/cowbirds, and viruses, bacteria, protozoa/other organisms.

Sustaining the suspense. Morgan Dill, naturalist at Santa Cruz Outdoor Science School, has kept students on "the edge of their seats" about lichen for an entire week, without telling them anything about it, but instead allowing students to keep up an ongoing exploration and discussion about this strange stuff.

Naming lichen relationships. Many lichen relationships are ***obligate***, which means the two organisms cannot survive on their own–which also qualifies them as being mutualistic. There are cyanobacteria, however, that can form relationships with fungi in a lichen, but can also survive very well without a fungal partner. These bacteria actually reproduce more readily when they are not part of a lichen relationship. There are also algae that can sustain a lichen relationship, even though some of the algae are destroyed as a result of sharing nutrients with the fungus, only because their reproductive rate stays one step ahead of the ongoing cellular destruction. In both of these cases, the

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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 toward 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 form a deeper understanding of science concepts and better recognize how science applies to everyday life. 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 (DCIs). The DCIs 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 http://www.nextgenscience.org/ and http://ngss.nsta.org/

disadvantaged algae and cyanobacteria are being parasitised. Because lichen can involve mutualistic, commensal, or parasitic relationships—all different forms of symbiosis—some instructors choose to just call the relationship "symbiotic," which keeps it both simple and accurate. With older students, you may choose to dig into the other terms and reveal more details about their intriguing relationships.

Common Misconceptions

- **Misconception:** Lichens are a type of moss.
  More accurate information. Mosses are non-flowering, non-vascular plants, and are a type of bryophyte. Moss have tiny leaves, stems, and, although they don't have roots, they have threadlike rhizoids that anchor them to a surface like roots do. Lichens are not plants, and although they photosynthesize, they don't have stems, roots, or leaves.

- **Misconception.** Lichens are parasites on trees.
  More accurate information. Lichens can grow on almost any stable and reasonably well-lit surface. They can absorb minerals from the soil, rock, or trees on which they grow, but aren't parasitic to these living surfaces. Lichens growing on trees don't harm the trees, but are simply using them as a surface to grow on. The bulk of the matter in the body of a lichen comes from photosynthesis; the algal cells make food for the lichen to produce its structures.

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.

In *Lichen Exploration*, students engage in the practice of *Constructing Explanations* to build understanding of disciplinary core ideas related to *Interdependent Relationships in Ecosystems* and they have the opportunity to connect those ideas to the crosscutting concept of *Patterns.*

Featured Science and Engineering Practices

Engaging students in Constructing Explanations. According to the *NRC's A Framework for K–12 Science Education*, a major goal of science is to deepen human understanding of the world through making explanations about how things work. It follows that students should develop their understanding of science concepts by making their own explanations about natural phenomena. In *Lichen Exploration,* initially students spend time observing lichen and learning how it functions, before they begin making explanations about where it grows and why.

It's important not to rush the observational part of the activity, because this encourages students to collect evidence and to wonder about lichen enough to make some tentative explanations about why it might grow in some places and not others. When you ask students to make tentative explanations in the "Talking About Where Lichens Grow" section, don't miss the opportunity to coach students as they share their explanations with the large group. 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 tentative language ("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.

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 *Lichen Exploration,* students begin by trying to find as many different kinds of lichen as possible and making comparisons between them. Although the word "pattern" isn't used, students are looking for characteristics by which to determine what's a lichen and what's not, and to differentiate between different kinds of lichen. This is an important basis for pattern recognition. Students aren't formally introduced to the term "pattern," until they're challenged to look for patterns related to where lichens grow. 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 organisms. 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. *Lichen Exploration* provides students with an opportunity to develop understanding of some disciplinary core ideas related to LS2.A *Interdependent Relationships in Ecosystems.*

When students learn about lichens and how they survive, they develop an understanding about how mutually beneficial relationships between species can lead to this specific type of interdependence (LS2.A). Through observing where lichens grow, making explanations about why that is, and learning about lichen succession, students also encounter the idea that organisms survive only where their needs are met, and that populations with similar environmental requirements may compete for resources (LS2.A).

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 group discussions. This information can help you determine which ideas to focus on in future lessons, so follow-up activities

TEACHING NOTES

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, hopefully, be better able to make thoughtful decisions.

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 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...5-LS2-1 means it's part of a fifth grade standard (5) for life science (LS), addressing the second core idea (2) Biological Evolution: Unity and Diversity, within the life science standards. It's also the first performance expectation (1) that makes up the complete LS2 standard at this grade level.

or discussions can be used to further improved student understanding.

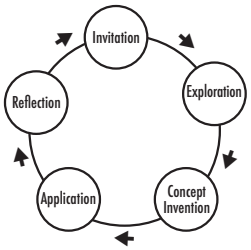
Performance Expectations to Work Toward

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 work toward:

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

MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.



This activity takes students through a full learning cycle. Within a sequence of many activities, it is primarily an *exploration*.

Activity Connections

Other BEETLES "Exploration" type activities include *Bark Beetle Exploration* and *Spider Exploration.* To deepen students understanding of content related to *Interdependent Relationships in Ecosystems,* use activities such as *Discovery Swap* or *Exploratory Investigation.*

Lichen Key

Decide if your lichen most closely resembles one of these three kinds:

http://beetlesproject.org

Leafy

leafy-shaped, usually attached to rock or wood in just one place

image © A.J. Silverside @ lastdragon.org

Crusty

flat edges, stuck to rock or wood like paint

image courtesy of Roger Roantrum/Wikimedia Commons

Shrubby

often like a beard, hangs down, looks like a small bush

image © A.J. Silverside @ lastdragon.org

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FIELD CARD

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

Lichen Exploration

Introducing this "weird organism"

1. Group chat: What the heck is this weird organism?
   - ▶ Have you ever seen anything like this before?
   - ▶ What does it remind you of?
   - ▶ This is actually a living organism.

Exploring Lichens

1. Pairs observe, describe, & compare lichens up close and see how many different kinds they can find.
   - ▶ There are over 10,000 different kinds of this organism. Let's see how many different kinds we can find here and what we can notice about them.
   - ▶ Describe them out loud & make comparisons between different kinds you see.
2. Students explore these "weird organisms" in the area.
3. Circulate, troubleshoot, & be a co-explorer with students.

Sharing Lichen Observations

1. Group chat: What did you find?
   - ▶ What did you notice?
   - ▶ How many different kinds did you find? How are they similar to or different from each other?
   - ▶ How would you describe one of the most interesting ones?
   - ▶ What does that one look like to you? What does it look like through your hand lens?
2. Introduce the name "lichen" and encourage students to use it.

Introducing the Symbiotic Relationship in Lichens

1. Group chat: So, what exactly is a lichen?
   - ▶ Let's talk about lichen and what kind of organism it is. What do you know abut plants? Do you see any evidence that lichen is plant-like?
   - ▶ What do you know about fungi? Do you see any evidence that lichen could be a fungus?
2. "Freddy Fungus and Andi Algae took a likin' to each other" in a relationship that benefits both.
3. *Optional:* Introduce term: *symbiotic*
4. Explain that the relationship between fungi and algae is an adaptation that helps them survive in their habitat.

Using the Lichen Key

1. *Turn & Talk*: Students recall one type of lichen they saw & describe it to a partner (not the person they explored with).
2. Introduce the key with 3 main types of lichen: crusty, leafy, & shrubby.
   - ▶ *Crusty lichens are like a scab or paint attached to the surface of rocks or wood. Leafy lichens have little flaps like lettuce & attach to the surface in one place. Shrubby lichens look like a bush or a beard.*
3. Explain that lichens won't look exactly like the pictures.
4. Ask students to explore, identify types of lichen using the key, and look for patterns about where & on what surface it grows.
5. Give some examples of growth patterns to look for.
6. Students use Lichen Key to explore in pairs, pass out lichen keys.

Talking about Where Lichens Grow

1. Group chat: What did you find?
2. Students *Turn & Talk* about possible explanations for why different types of lichen grow in certain places and not others.
3. Ask a few students to share their explanations–encourage discussion.
4. Explain each type of lichen has specific environmental conditions where it survives best.
5. Point out that all organisms change the environment a little as they grow.
6. Explain: Lichens often grow on surfaces in this order: crusty, leafy, shrubby, sometimes followed by moss, then other plants.
7. Pairs search for evidence of this order of lichen growth.
8. After ~5 minutes of exploration, bring group together to discuss findings.

Wrapping Up

1. Encourage students to keep looking for lichens & to notice any patterns.
2. *Thought Swap* (formerly known as *Walk & Talk*): Students reflect on learning.
   - ▶ *What are you still curious about? What do you wonder about lichens?*
   - ▶ *What did you do today that helped you learn about lichens?*
   - ▶ *Describe to your partner how you might tell a younger brother or sister what you learned about lichens.*

ABOUT BEETLES™

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

www.beetlesproject.org

Lawrence Hall of Science is the public science center of the University of California, Berkeley.

www.lawrencehallofscience.org

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