EXPLORING BIODIVERSITY'S BIG IDEAS IN YOUR SCHOOL YARD

BY CORNELIA HARRIS, ALAN BERKOWITZ, JENNIFER DOHERTY, AND LAUREL HARTLEY

We love taking students outside and investigating what lives beneath a log or under a rock in a stream. Students' excitement at and interest in the small creatures they find is something to be cherished and nurtured. Exploring biodiversity in your school yard is an excellent way to engage students in learning about the natural world and provides them with skills and knowledge that will support students to successfully understand ecosystems. You don't have to be an expert at identifying organisms in order to help students see that diversity exists everywhere, and there are many simple ways to explore biodiversity in your school yard.

Biodiversity is a rich and complex idea that scientists use to frame the organizing principles of ecology (see Figure 1 for a definition). However, we have noticed that it is often used vaguely in science classrooms, focusing only on species diversity in faraway places such as rain forests and coral reefs. And although biodiversity is an important component of state and national science content standards (see Figure 2), we have observed that the concept is minimized or misrepresented in many textbooks and classroom exercises.

In our work with K–12 students across the nation, we have identified three big ideas about biodiversity that are critical for student understanding and yet not well grasped: (1) All ecosystems contain representatives of all kingdoms, including microbes and fungi; (2) variation exists within larger groups in any ecosystem; and (3) both species and genetic variation are critical for shaping how ecosystems function.

In this article, we focus on a simple way you can assess (pre- and post-instruction) your students' understanding and several activities that you can use to get your students outside to explore these three big ideas about biodiversity.

Student understanding of biodiversity

As a pre-assessment to teaching about biodiversity, ask your students what types of things live in their backyard, neighborhood park, or school yard. We've asked hundreds of middle and high school students to describe life in their backyards, and what we've found is that they don't have a very good understanding of the variety of life that exists, nor the complexity within the large, familiar groups (see Figure 3 for the results of our survey).

Most students ignore microbes and fungi, even though these organisms make up most of the life on Earth and are responsible for incredibly important ecological functions. Students who mention plants or animals use very broad categories to describe what they know—trees, grass, bugs, or birds. Few students can identify specific species unless they are extremely familiar to them, such as a blue jay or a chipmunk.

From students' response to the pre-assessment, you will know whether they're aware of more than just the most common groups and whether they know something about the diversity within groups. We believe that unless students recognize that biodiversity exists everywhere, and that there are important differences within large groups of taxa, they cannot begin to explain how biodiversity persists and that diversity is important for ecosystem function. Fortunately, students are incredibly curious about living things, and middle school is the perfect time to allow them the time and space to explore and to become excellent observers of living things.

FIGURE 1 **A definition of biodiversity**

Biologists view biodiversity as a unifying, central theme of how we understand the structure of ecosystems. It is a multifaceted concept that includes the number (richness) and proportional representation (evenness) of species in a defined area, the interactions among species, the structure of communities, the diversity of genetic material in populations, and the changes in these metrics over space and time.

Recognition of biodiversity

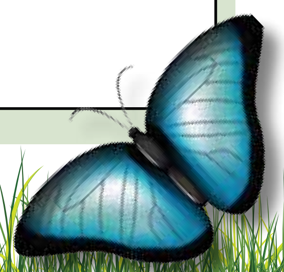
Recognizing that biodiversity exists, and that the world isn't just covered by a few familiar organisms (e.g., plants, bugs), requires careful observation. If students ignore entire kingdoms of life in the pre-assessment, we suggest beginning with one of several activities that will help them build an awareness of the existence of biodiversity at its broadest level (big idea #1). We often run these activities in stations and complete a school-yard "bio-blitz" (Figure 4), a great way to have a field trip to your school yard (see Figure 5 for outdoor safety tips). You can find the protocols for the activities, including video how-to directions for teachers, on our website (see Resources). We usually include the following bio-blitz stations: tree identification, sweep netting for ground invertebrates, beat sampling for invertebrates on bushes, pitfall traps for ground-dwelling invertebrates, and track plates for larger organisms. Remember to follow all middle school safety guidelines when conducting investigations with students (see Figure 5).

Plants

An Outdoor Biology Instructional Strategies activity (see Resources) in which students search for and organize as many samples of plants in a segment of their school yard as they can is a perfect way to introduce plant diversity (see Figure 6 for a brief descrip-

FIGURE 2 Ideas from *A Framework for K–12 Science Education* that relate to biodiversity (NRC 2012)

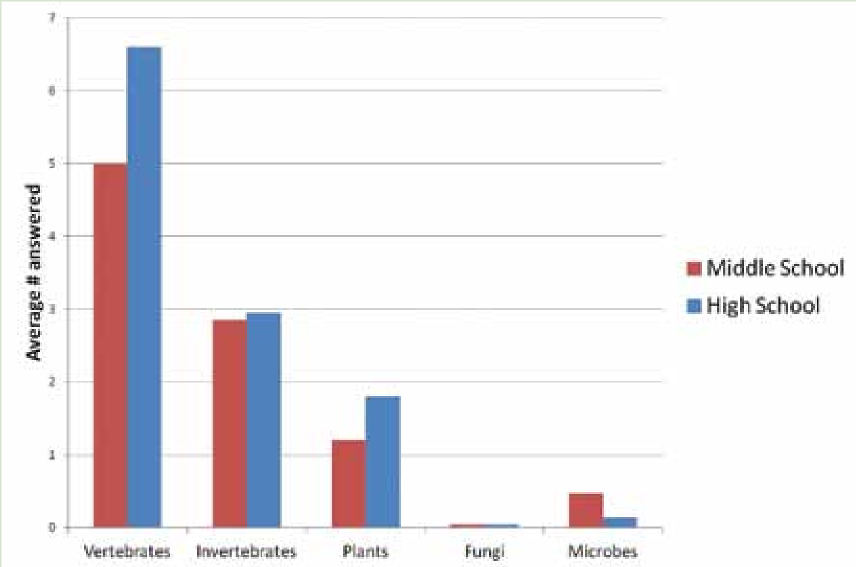
Core idea LS2 Ecosystems: Interactions, Energy, and Dynamics How and why do organisms interact with their environment and what are the effects of these interactions?	**LS2.A: Interdependent Relationships in Ecosystems** How do organisms interact with the living and nonliving environments to obtain matter and energy?	**LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** How do matter and energy move through an ecosystem?	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** What happens to ecosystems when the environment changes?
By the end of grade 8	Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.	Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.	Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations. Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.



tion of the activity). Students are almost always surprised by the sheer number of different plant species collected in their school yard, and asking students to sort all of the plants into groups encourages close observation of the morphological similarities and differences among plants. Making a dichotomous key is the next step to having students pay careful attention to the differences among organisms (see Making Your Own Tree Key in Resources). In this activity, students working indoors in small groups receive two tree twigs with leaves (this ensures that you are capturing how the leaves grow from the stem along with compound leaves, allowing for accurate identification). Students are challenged to create their own tree key using the characteristics that they see in the leaves in front of them. (See also "Modeling the Forest" in this issue.)

FIGURE 3 **Survey results**

We asked 776 students (369 middle school and 407 high school) in five states to name as many organisms as they could that lived in their backyard or school yard. The most common type of organism students mentioned was vertebrates (birds, squirrels, dogs, and cats), followed by invertebrates (most common answer: bugs), and then plants. Very few students mentioned fungi or microbes; when they did, students simply said "microbes." Additionally, it was much more common for students to provide the names of big groups of taxa, such as "trees" or "bugs," rather than specifics like "sugar maple" or "ladybug."



Invertebrates

Every school yard has invertebrates, which are incredibly motivating for students, require few materials to collect, and are wonderfully diverse. You can sample invertebrates crawling on the ground; living in plants, water, or soil; or flying through the air (see Our Sampling Protocols and the Aquatic Ecosystem lesson in Resources for details on how to conduct these activities). Soil is often overlooked as a living part of any ecosystem, but the diversity of life in the soil is incredible, and once students have seen a pseudoscorpion (Figure 7), they'll be hooked. (See also "Having Phun With Soils" in this issue.)

Bacteria and fungi

An easy first introduction to fungi in the school yard is to have students observe fungal hyphae in the soil. Look for soil samples that have the distinctive white threads of fungal hyphae, and allow students to view them with a document camera or projecting dissection scope in the classroom (see Resources for a video that can be used to explore fungi). A cup of water from a pond will yield lots of interesting organisms to view under the microscope, or you can order slides from any scientific supply company that will showcase a wide range of bacteria and fungi. If you don't have an aquatic ecosystem on your school property, it is still relatively easy to bring in a cup or two of pond water and create an indoor, sealed "micro-pond" for your students to observe throughout the year. Make sure to return this pond water to the ecosystem where you obtained it, or freeze the sample before disposing of it down the sink to kill any live organisms within.

Appreciating functional differences

If your students think that there are only broad groups of things living in the school yard (i.e., to address big idea #2), we suggest picking one group or taxon and

FIGURE 4 Students identifying invertebrates during a daylong schoolyard "bio-blitz"

asking students to become very familiar with those organisms. This will allow students to learn about the ecological functions of different organisms and encourage an understanding of big idea #3, which includes understanding how niches, trade-offs, and functional redundancy relate to ecosystem structure and composition.

Aquatic invertebrates lend themselves extremely well to investigating functional differences, and we have been exploring these ideas with a group of colleagues for several years (see Biodiversity and Evolution in Resources). After collecting macroinvertebrates from a stream or pond, return to the classroom and ask students to sort them into similar groups. There are many free invertebrate keys available online (see the Stroud Water Research Center Leaf Pack Network resources as an example), which will allow students to identify their organisms to a coarse level (usually to order). Then the careful observation begins.

Feeding relationships

Eating, and avoiding being eaten, are key interactions within the environment and between organisms. If students look carefully at the mouthparts of macroinvertebrates, they should be able to identify the key differences between major groups of organisms—mouthparts from predators, such as dragonflies or dobsonflies, look very different from the mouthparts of scrapers, such as snails (there is a PowerPoint featuring mouthparts in the Biodiversity and Evolution materials; see Resources). This is another way to help students recognize the diversity within large, familiar groups that students may have earlier classified as one "bug" group.

Movement

If you are able to keep the invertebrates alive, students can view their movement in a small aquarium. Seeing both movement and morphological differences will allow students to really understand that even when organisms seem to belong to the same broad "group," they can be very different. For example, there are several different types of mayflies (e.g., burrowers, swimmers, clingers), which exploit different

FIGURE 5 Safety tips and protocols for outdoor investigations

- Walk around the area you will use prior to bringing your students outside to ensure that you are aware of any dangerous areas. Pay attention to things like poison ivy and poison oak, and designate those areas as off limits. Giving students exploration boundaries should be part of every activity outside.
- Make sure your administrator knows and approves of your outdoor plans.
- Check with school health staff to make sure you know how to deal with potential problems in the field—are there students who are allergic to pollen, bee stings, etc.?
- Consider creating groups before heading outside.
- Give students clear instructions before going out, and again once you are outside and before they conduct their investigation.
- Highlight humane treatment of living things: Do not allow students to kill organisms for fun, fear, or spite.
- Make sure you set clear behavioral expectations and that all students are aware of what is and isn't acceptable to do while outdoors.

FIGURE 6 **A plant diversity activity**

1. Instruct students to take one leaf (you may want to explain simple and compound leaves before starting) from each unique plant that they find in their designated exploration space. Remember to follow appropriate safety guidelines, and supervise students carefully for appropriate outdoor behavior. Allow students to spend several minutes collecting their samples, and then have them return the samples to you.
2. Place a grid made on large poster paper or a white sheet on the ground (or, if the weather is uncooperative, complete this part inside). We use a grid where each square is 15.2 cm (6 in.), and there are 56 squares on our grid. We often bring more than one grid with us in case we need more space for the plants. Then ask one student to put all of his or her leaves on the grid, placing a unique leaf in each square. Other students then add matching leaves and place new, unique leaves in a new square.
3. Once all students have added their leaves, ask them to critique the groups and pay attention to whether the groups are accurate. Allowing students to construct this knowledge is important so that they begin to pay attention to morphological differences.
4. At the end of this activity, count how many different plants there are on your grid—students are usually surprised by the sheer numbers of plants collected. This is a good time to introduce the term *species richness*, which will tell students how many different species they have found. You should also point out differences among plants that look very similar; for example, many school yards contain different species of oak or maple. Having students recognize that there are many different kinds of trees, and not just "trees," is an important step in their learning. You could repeat this activity in another part of the school yard and compare the species richness, or you could make predictions about how other places (a parking lot, forest, or beach) might compare.

niches through evolutionary trade-offs. Mayflies that are excellent swimmers cannot escape predation by burrowing in the gravel or sand, and vice versa. A good exit-ticket question that encourages students to think about these ideas is "Why are there many kinds of insects living in a stream, instead of one best adapted insect?" You can change this question to focus on trees, birds, etc. We want students to begin to think about the different parts of an ecosystem that might support different organisms while at the same time being realistic about the constraints of the ecosystem, such as food or light availability.

Decomposition

Focusing on decomposition is a great way to help students understand the functional importance of biodiversity, both at the largest and within group scales. Unfortunately, decomposition is often overlooked in outdoor investigations (we also find it important to stress that there are many more "good" or harmless bacteria than there are "bad" or pathogenic ones). You may want to highlight the major differences between bacteria and fungi. Bacteria are in their own domain of life, unicellular, and without a nucleus, whereas fungi are in the same domain we are, have a nucleus, and are multicellular. Having students complete a graphic organizer like the one in Figure 8 may help them understand some of these differences.

The majority of true decomposition (i.e., the conversion of dead organic material back into inorganic components such as CO^2 and ammonium nitrate) is

FIGURE 7 **Pseudoscorpions, which are often found in soil**

FIGURE 8 An example of a completed graphic organizer; students draw organisms in the spaces and fill in information in the boxes

Kingdom	Organism(s)	Type of locomotion	Number of cells	Energy source	Cell type
Animalia		Can move on its own	Multicellular	Consumer	Eukaryotic
	Sponges				
	Flatworms (tapeworm)				
	Roundworm (hookworm)				
	Jelly fish				
	Insects				
	Starfish				
	Fish				
	Lions/tigers/ bears				
Plantae		Cannot move on its own	Multicellular	Producer	Eukaryotic
	Moss				
	Ferns				
	Flowering plants				
	Trees				
Protista		Can move on its own	Unicellular	Producer/ consumer	Eukaryotic
	Amoeba				
	Paramecium				
Fungi		Cannot move on its own	Multicellular	Consumer (absorption)	Eukaryotic
	Mushrooms				
	Molds/mildews				
	Yeast				
Archaea		May/may not move on its own	Unicellular	Producer	Prokaryotic
	Methanogen	Chemosynthetic (needs no light to produce food)			
Eubacteria		May/may not move on its own	Unicellular	Producer/ consumer	Prokaryotic
	"True" bacteria				
	Cyanobacteria (blue-green algae)	Photosynthetic (needs light to produce food)			

performed by bacteria and fungi. The way in which bacteria and fungi accomplish this task is different from animal metabolism—we have our digestive enzymes inside us, whereas these microorganisms excrete their enzymes into the environment. Once the enzymes are out in the environment, they act on the detritus, releasing smaller, soluble organic molecules that these microorganisms can transport into their cells, where they (like us) use those compounds for energy and to build biomass. In general, bacteria "prefer" to eat easier-to-digest compounds like sugars, while fungi can handle more complex compounds like wood.

After watching a few time-lapse videos from the Cornell University site (listed in Resources), students should be able to explain the answer to this exit question: What happens to the mass of a dead leaf over time? Discussing the conservation of mass is a great extension, as students usually do not realize that the carbon in the leaf is being used not just for energy or to build mass in the decomposer but also being returned back to the atmosphere through respiration. Understanding decomposition as a key ecosystem function related to feeding will help students see the importance of not just species diversity but functional diversity.

Bringing it all together

Once students have a sense of what lives in their schoolyard, and some of the processes at work, it is time to put it all together. As a culminating activity and post-assessment, have students create an interaction web for their schoolyard biodiversity, paying attention to finer groups, microbes, and fungi. Including abiotic components in the diagram adds complexity and richness and encourages students to think beyond feeding relationships in ecosystems (see example of a stream interaction web in Figure 9). After sustained exploration with schoolyard organisms, students recognize many more specific organisms and begin to pay attention to microorganisms. If students can be successful at recognizing that diversity exists, and some of the key important roles that different organisms play, they can then begin to investigate how ecosystems are structured, along with the underlying principles that govern the emergence and persistence of biodiversity. ■

Acknowledgments

The assessment results and curriculum described in this paper are a result of the National Science Foundation Math and Science Project Targeted Partnership: Culturally Relevant Ecology, Learning Progressions and Environmental Literacy no. 0832173. Thank you to Andy Anderson and John Moore for discussions and guidance on biodiversity ideas and to Shawna McMahon for working on the decomposition information in our lesson plans. We thank the teacher leaders in Colorado working with Laurel Hartley for providing Figure 2, Michelle Guthrie and Liz Ratashak for providing the basis for Figure 8, and Sarah Hastings for producing the videos of our protocols.

Reference

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

Resources

An aquatic ecosystem—*http://bit.ly/Sh6JQR*

Biodiversity and evolution (an exploration using leaf packs, which includes feeding relationships and microbial investigations)—*http://bit.ly/PFW5GK*

Comfrey mulch/decomposition video—*http://bit.ly/12GMzb7*

Cornell University time-lapse movies—*http://bit.ly/WUJizL*

Fungi video—*http://bit.ly/12GLqjT*

Making your own tree key—*http://bit.ly/Rp7uZZ*

Our sampling protocols, including beat sampling, pitfall traps, sweep netting, and track plates—*http://bit.ly/TW7jSS*

Outdoor Biology Instructional Strategies plant hunt—*http://bit.ly/RvBwrK*

Stroud Water Research Center Leaf Pack Network (includes online keys)—*http://bit.ly/Q8Lrs9*

Who eats what: A guide to food web clues in schoolyard habitats (terrestrial guide)—*http://bit.ly/WZwcna*

Cornelia Harris (*harrisc@caryinstitute.org*) is the education program leader and ***Alan Berkowitz*** is the head of education at the Cary Institute of Ecosystem Studies in Millbrook, New York. ***Jennifer Doherty*** is an education researcher at Michigan State University in East Lansing, Michigan. ***Laurel Hartley*** is an assistant professor of biology at the University of Colorado at Denver in Denver, Colorado.