Lesson 1— What is biodiversity?

Instructional Goal

At the end of this lesson, SWKABAT:

a. Recognize that diversity exists all around them.
b. Explain how organisms move from one place to another (dispersal).
c. Explain the difference between species richness, evenness, and abundance.
d. Explain why you need to know more than species richness in order to understand the biodiversity of an ecosystem.
e. Explain the importance of the diversity of invertebrates.

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Scale, Proportion, and Quantity

Common Core Standards Addressed

Mathematics:
Quantities- Reason quantitatively and use units to solve problems
Interpreting Functions- Interpret functions that arise in applications in terms of the context
Mathematical Practices- Reason abstractly and quantitatively

English Language Arts Standards- Science & technical Subjects:
Integration of Knowledge & Ideas- CCSS.ELA-Literacy.RST.11-12.8
Range of Reading & Level of Text Complexity- CCSS.ELA-Literacy.RST.11-12.10

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic E: Diversity

Materials

- Data boards (use a large posterboard or a bed sheet segmented into 16-24 squares)
- Flags (optional – used to mark the boundaries of your study site)
- Student copies of "The Little Things that Run the World" by E.O. Wilson.
- A display copy of the Bird Populations on Bird Island map showing the birds in each ecoregion. Use the first image in the Biodiv 2012 TE Les 4 Bird pop maps.pptx.
- Print out enough maps of the second image in the Biodiv 2012 TE Les 4 Bird Pop Maps Powerpoint so that each group of students can have a map (laminate these for future use). These maps have the bird population numbers on them.
- Individual student whiteboards

Advance Preparation

Make your data boards – these can be sheets or large posterboard divided into squares. An old sheet is a good option since you can reuse it, easily fold it, and use it just about anywhere. The plant diversity activity was adapted from OBIS (Outdoor Biology Instructional Strategies) and can be found online at http://www.outdoorbiology.com/ .

Lesson Procedure

1. Explain that you are going to do a lesson that helps students think about biodiversity in other contexts, leaves in a schoolyard and birds on an island. Tell them that they will later apply these concepts about biodiversity to their stream experiment.

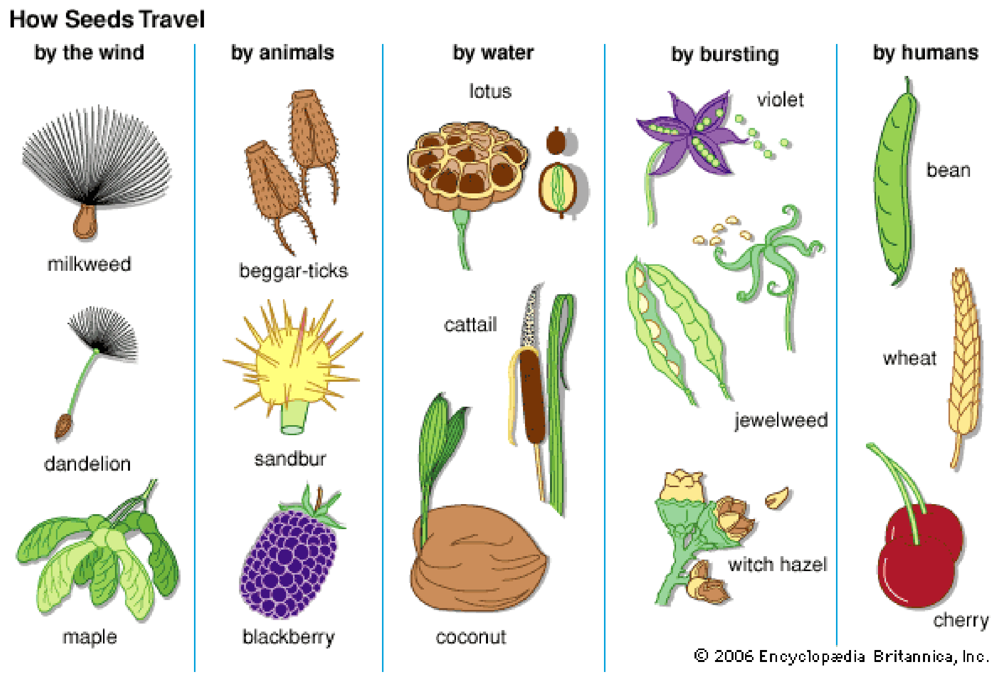
2. Head outside with students to your schoolyard. Split students into groups and determine the boundaries of your study.

3. Each team should take one leaf from as many different plants as they can within their study area, within a specified time limit (we suggest 5 minutes).

4. Teams should return to a central location (or head back inside), and one team at a time should place their leaves on the databoard (if it is windy, tape the leaves down). Once the first team is finished placing their leaves, ask other teams to add their leaves to the same square if they think their leaves match, and to start a new square if they think their leaf is different.

5. Ask students to explain how they decided how to group the leaves. What characteristics did they pay attention to? Make a list of all the relevant characteristics on the board. A fun way to encourage this is to make it a "game" – one student silently picks a leaf in their mind from the data board, and provides one characteristic that he/she thinks makes it identifiable. Other students try to guess which leaf it is, and then ask for additional characteristic "clues" if they need more help.

6. Introduce the term **species richness.** This refers to the numbers of different kinds of species in a given area. Ask students to find the species richness for their schoolyard study. Next, ask students to identify which leaves were the most commonly found in the schoolyard – in other words, which leaves do they have the most of? This is a way of explaining **abundance.** Ask students to explain why there are some plants that are more common than others. Students may include ideas such as habitat needs or preferences, competition, or dispersal. This is a good way to remind students of one of the big ideas of this unit: *Organisms have particular abiotic and biotic requirements. If you change the abiotic or biotic conditions or resources available (e.g. place in stream or leaf type) some needs of an organism **might** not be met and then they **might** not be able to be there*. It also allows you the chance to remind students about the idea of dispersal, which is key for this unit. Most students will have learned about seed dispersal in elementary school; however, they may need to be reminded. Seeds can be dispersed by water, wind, animals, or by bursting open. The graphic below shows these dispersal methods (although humans are separated from animals).



7. Ask students to predict, based on the results of what they have found in their schoolyard, which plants will live in a vacant lot 1 mile away. If students are unsure, ask them what they would need to know in order to be more confident in their answers –students may want to know about traits of the plant that they can't see right now, such as seeds or fruits, how tall the plants grow, whether they release toxins into the soil, etc. Ask them to propose how each of these plants could have arrived at the vacant lot.

8. Ask students whether they can be sure, based on the results of their schoolyard survey, how many of each type of plant will live in the vacant lot. Students should feel less confident about answering this question, since they did not do a quantitative, exact study of their schoolyard.

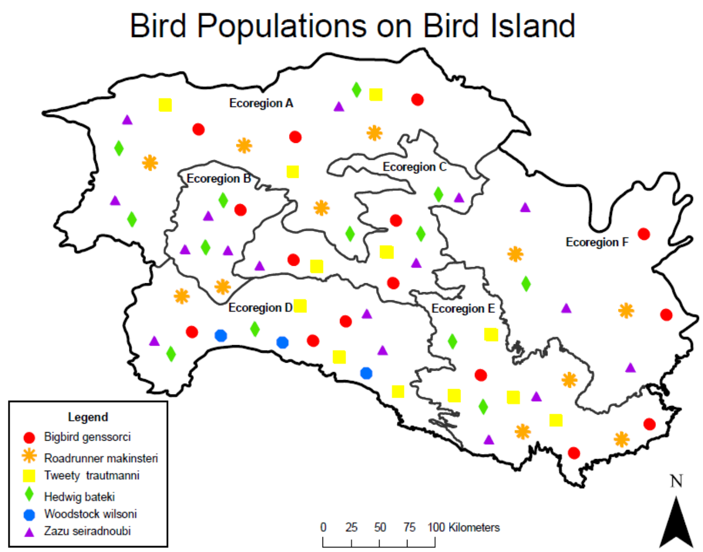
9. Set up a scenario for students to consider – post these on the board or project them. This scenario brings it back to the stream context. Explain that you heard two groups of students arguing over which stream is healthier. Gauge student responses by asking students to use the whiteboards to choose who they agree with and how confident they feel about their choice:

    a. STREAM A: Clarice and Bob think that their stream is healthier. They found 27 different kinds of macroinvertebrates in their stream. They didn't have time to count any of their organisms so they just counted how many different kinds they found.

    b. STREAM B: Tyrell and Shannon think that their stream is healthier. They found a lot of different organisms too, but they wanted to count how many of each organism they had, and so they only had time to count three different species. They found 104 mayflies, 78 stoneflies, and 149 black flies.

10. Students should recognize that from the data provided, you cannot tell which stream is healthier. Understanding the biodiversity of a system requires understanding both the richness and the evenness of a system.

11. Display the map of "Bird Populations on Bird Island". Ask students to vote on which Ecoregion has the highest biodiversity, based on the information provided. Again, use the whiteboards to gauge student responses. Students will likely point to Ecoregion A, D, or E, because those have a lot of different species (Ecoregion D has the highest species richness with all six species present).



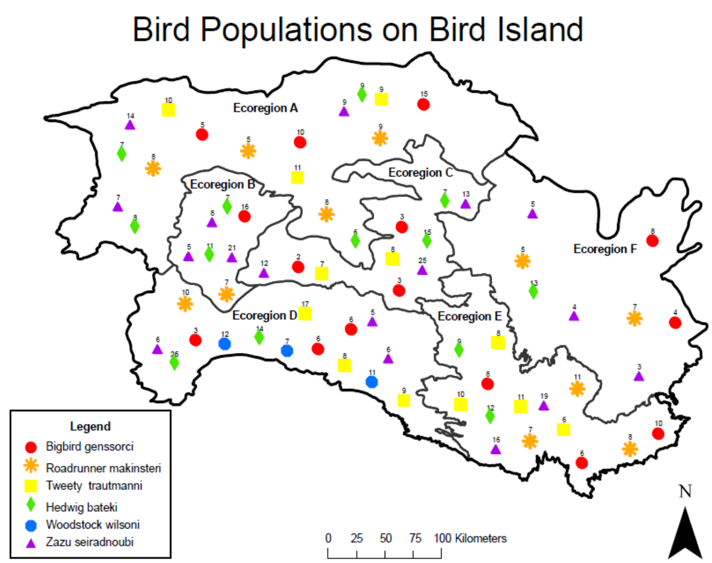
12. Create six groups. Pass out copies of the maps of Bird Island with the individual population numbers available, and ask each group of students to focus on a different ecoregion. Each group should create a graph of the abundance of each species in their region. Students can make these graphs on their whiteboards and then share the results with the class. Ask students to take notes on the similarities and differences between the ecoregions. As each group presents the results of the numbers of individuals in their ecoregion, ask students to revisit the earlier question – which ecoregion has the most biodiversity?

    a. Ecoregions A and E have the same species richness.

    b. Both ecoregions A and F have a similar number of individuals within each species of the respective ecoregions.

    c. Ecoregion D has the highest species richness.

    d. Ask students to notice other similarities and differences between the ecoregions – *Woodstock wilsoni* is only present in D, for example.



For a more in-depth explanation of this activity, go to: http://www.crossingboundaries.org/index.php and click on the Curriculum Resources, then "Bird Island".

13. Introduce the idea of **species evenness**. This is the second component of biodiversity which scientists often use to come up with a biodiversity index. Species evenness refers to how evenly different groups of species are distributed within a community. *Teacher note: While evenness can be calculated, in this lesson we use it as a general measure of ecosystem health instead of a quantitative measurement.* Provide students with the following example if students need help (or use this example as a formative assessment prompt):

Example: Species evenness tells us how evenly the species are distributed in the ecosystem, or the relative abundance of each species in an area. Look at the following example:

Tree Species	Habitat A (# of individuals)	Habitat B (# of individuals)
Pines	220	900
Oaks	300	50

Maples	380	50

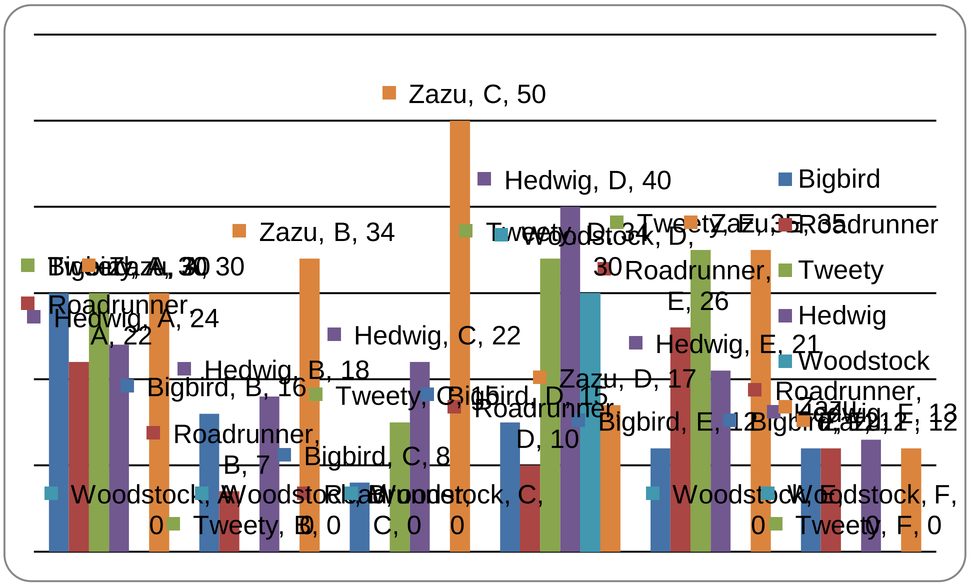
a. Using the example table, what is the species (tree) **richness** in each habitat?

A: _3_ B: _3_

b. Using the example table, which habitat has greater species **evenness**? _Habitat A_

c. Based on this information only, which habitat is "healthier"? Why? *Habitat A would be considered healthier because it has the same species richness as Habitat B, but it has greater species evenness.*

14. Ask students to display the graphs of the population numbers of the different ecoregions. Based on these graphs, which ecoregion(s) has the highest species evenness? Students should recognize that although not all species are present, regions A and F have the highest evenness because of the species that are present, they are present at relatively the same size. However, Ecoregion F has the smallest population sizes. If you graphed all of the ecoregions together on one graph, this is what it would look like.



15. Remind students of their earlier claims of which ecoregion had the most biodiversity, based only on species richness (Ecoregion D). Ask students whether they still think Ecoregion D has the most biodiversity, based on what they now know about species evenness and abundance. Ask students to think about where the Roadrunner species might be the most successful if an environmental change caused its population to dramatically decline. Students should recognize that Ecoregions A, D, and F may lose their Roadrunner populations first, since they have fewer of those populations. **Students may change their mind and focus on Ecoregion A, which has high evenness and abundance in addition to housing five species.**

16. If you think your students can handle the reading level, for homework, students should read "The Little Things that Run the World" by E.O.Wilson. Otherwise, use excerpts for a class reading and discussion. Suggested reading questions are included. This essay will allow students to think about the importance of invertebrates, as the next lesson begins students' explorations of the life in their leaf packs.

17. You have already measured the abiotic factors in the stream. Ask your students to write down the definitions of richness and evenness. Ask them to predict some differences in biodiversity that they will see in the pools and riffles based on the abiotic factors that they have measured.

Assessment Ideas:

Ask students: why is it important to know not just how many species are in a place, but how many of each species is present?

The Little Things That Run the World*
(The Importance and Conservation of Invertebrates)

On the occasion of the opening of the remarkable new invertebrate exhibit of the National Zoological Park, let me say a word on behalf of these little things that run the world. To start, there are vastly more kinds of invertebrates than of vertebrates. At the present time, on the basis of the tabulation that I have just completed (from the literature and with the help of specialists), I estimate that a total of 42,580 vertebrate species have been described, of which 6,300 are reptiles, 9,040 are birds, and 4,000 are mammals. In contrast, 990,000 species of invertebrates have been described, of which 290,000 alone are beetles—seven times the number of all the vertebrates together. Recent estimates have placed the number of invertebrates on the earth as high as 30 million, again mostly beetles—although many other taxonomically comparable groups of insects and other invertebrates also greatly outnumber vertebrates.

We don't know with certainty why invertebrates are so diverse, but a commonly held opinion is that the key trait is their small size. Their niches are correspondingly small, and they can therefore divide up the environment into many more little domains where specialists can coexist. One of my favorite examples of such specialists living in microniches are the mites that live on the bodies of army ants: one kind is found only on the mandibles of the soldier caste, where it sits and feeds from the mouth of its host; another kind is found only on the hind foot of the soldier caste, where it sucks blood for a living; and so on through various bizarre configurations.

Another possible cause of invertebrate diversity is the greater antiquity of these little animals, giving them more time to explore and fill the environment. The first invertebrates appeared well back into Precambrian times, at least 600 million years ago. Most invertebrate phyla were flourishing before the vertebrates arrived on the scene, some 500 million years ago.

Invertebrates also rule the earth by virtue of sheer body mass. For example, in tropical rain forest near Manaus, in the Brazilian Amazon, each hectare (or 2.5 acres) contains a few dozen birds and mammals but well over one billion invertebrates, of which the vast majority are not beetles this time but mites and springtails. There are about 200 kilograms dry weight of animal tissue in a hectare, of which 93 percent consists of invertebrates. The ants and termites alone compose one-third of this biomass. So when you walk through a tropical forest, or most other terrestrial habitats for that matter, or snorkel above a coral reef or some other marine or aquatic environment, vertebrates may catch your eye most of the time—biologists would say that your search image is for large animals—but you are visiting a primarily invertebrate world.

It is a common misconception that vertebrates are the movers and shakers of the world, tearing the vegetation down, cutting paths through the forest, and consuming most of the energy. That may be true in a few ecosystems such as the grasslands of Africa with their great herds of herbivorous mammals. It has certainly become true in the last few centuries in the case of our own species, which now appropriates in one form or other as much as 40 percent of the solar energy captured by plants. That circumstance is what makes us so dangerous to the fragile environment of the world. But it is otherwise more nearly true in most parts of the world of the invertebrates rather than the nonhuman vertebrates. The leafcutter ants, for example, rather than deer, or rodents, or birds, are the principal consumers of vegetation in Central and South America. A single colony contains over two million workers. It sends out columns of foragers a hundred meters or more in all directions to cut forest leaves, flower parts, and succulent stems. Each day a typical mature colony collects about 50 kilograms of this fresh vegetation, more than the average cow. Inside the nest, the ants shape the material into intricate sponge-like bodies on which they grow a symbiotic fungus. The fungus thrives as it breaks down and consumes the cellulose, while the ants thrive by eating the fungus.

The leafcutting ants excavate vertical galleries and living chambers as deep as 5 meters into the soil. They and other kinds of ants, as well as bacteria, fungi, termites, and mites, process most of the dead vegetation and return its nutrients to the plants to keep the great tropical forests alive.

Address given at the opening of the invertebrate exhibit, National Zoological Park, Washington, D.C., on May 7, 1987.

Much the same situation exists in other parts of the world. The coral reefs are built out of the bodies of coelenterates. The most abundant animals of the open sea are copepods, tiny crustaceans forming part of the plankton. The mud of the deep sea is home to a vast array of mollusks, crustaceans, and other small creatures that subsist on the fragments of wood and dead animals that drift down from the lighted areas above, and on each other.

The truth is that we need invertebrates but they don't need us. If human beings were to disappear tomorrow, the world would go on with little change. Gaia, the totality of life on Earth, would set about healing itself and return to the rich environmental states of a few thousand years ago. But if invertebrates were to disappear, I doubt that the human species could last more than a few months. Most of the fishes, amphibians, birds, and mammals would crash to extinction about the same time. Next would go the bulk of the flowering plants and with them the physical structure of the majority of the forests and other terrestrial habitats of the world. The earth would rot. As dead vegetation piled up and dried out, narrowing and closing the channels of the nutrient cycles, other complex forms of vegetation would die off, and with them the last remnants of the vertebrates. The remaining fungi, after enjoying a population explosion of stupendous proportions, would also perish. Within a few decades the world would return to the state of a billion years ago, composed primarily of bacteria, algae, and a few other very simple multicellular plants.

If humanity depends so completely on these little creatures that run the earth, they also provide us with an endless source of scientific exploration and naturalistic wonder. When you scoop up a double handful of earth almost anywhere except the most barren deserts, you will find thousands of invertebrate animals, ranging in size from clearly visible to microscopic, from ants and springtails to tardigrades and rotifers. The biology of most of the species you hold is unknown: we have only the vaguest idea of what they eat, what eats them, and the details of their life cycle, and probably nothing at all about their biochemistry and genetics. Some of the species might even lack scientific names. We have little concept of how important any of them are to our existence. Their study would certainly teach us new principles of science to the benefit of humanity. Each one is fascinating in its own right. If human beings were not so impressed by size alone, they would consider an ant more wonderful than a rhinoceros.

New emphasis should be placed on the conservation of invertebrates. Their staggering abundance and diversity should not lead us to think that they are indestructible. On the contrary, their species are just as subject to extinction due to human interference as are those of birds and mammals. When a valley in Peru or an island in the Pacific is stripped of the last of its native vegetation, the result is likely to be the extinction of several kinds of birds and some dozen of plant species. Of that tragedy we are painfully aware, but what is not perceived is that hundreds of invertebrate species will also vanish.

The conservation movement is at last beginning to take recognition of the potential loss of invertebrate diversity. The International Union for the Conservation of Nature has an ongoing invertebrate program that has already published a Red Data Book of threatened and endangered species—although this catalog is obviously still woefully incomplete. The Xerces Society, named after an extinct California butterfly, was created in 1971 to further the protection of butterflies and other invertebrates. These two programs are designed to complement the much larger organized efforts of other organizations on behalf of vertebrates and plants. They will help to expand programs to encompass entire ecosystems instead of just selected star species. The new invertebrate exhibition of the National Zoological Park is one of the most promising means for raising public appreciation of invertebrates, and I hope such exhibits will come routinely to include rare and endangered species identified prominently as such.

Several themes can be profitably pursued in the new field of invertebrate conservation:

It needs to be repeatedly stressed that invertebrates as a whole are even more important in the maintenance of ecosystems than are vertebrates.

Reserves for invertebrate conservation are practicable and relatively inexpensive. Many species can be maintained in large, breeding populations in areas too small to sustain viable populations of vertebrates. A 10-ha plot is likely to be enough to sustain a butterfly or crustacean species indefinitely. The same is true for at least some plant species. Consequently, even if just a tiny remnant of natural habitat exists, and its native vertebrates have vanished, it is still worth setting aside for the plants and invertebrates it will save.

The *ex situ* preservation of invertebrate species is also very cost-effective. A single pair of rare mammals typically costs hundreds or thousands of dollars yearly to maintain in a zoo (and worth every penny!). At the same time, large numbers of beautiful tree snails, butterflies, and other endangered invertebrates can be cultured in the laboratory, often in conjunction with public exhibits and educational programs, for the same price.

It will be useful to concentrate biological research and public education on star species when these are available in threatened habitats, in the manner that has proved so successful in vertebrate conservation. Examples of such species include the tree snails of Moorea, Hawaii, and the Florida Keys; the Prairie sphinx moth of the Central States; the birdwing butterflies of New Guinea; and the metallic blue and golden ants of Cuba.

We need to launch a major effort to measure biodiversity, to create a complete inventory of all the species of organisms on Earth, and to assess their importance for the environment and humanity. Our museums, zoological parks, and arboreta deserve far more support than they are getting—for the future of our children.

A hundred years ago few people thought of saving any kind of animal or plant. The circle of concern has expanded steadily since, and it is just now beginning to encompass the invertebrates. For reasons that have to do with almost every facet of human welfare, we should welcome this new development.

EDWARD O. WILSON

Museum of Comparative Zoology
Harvard University
Cambridge, Massachusetts, 02138–2902

After reading the article, answer the following questions:

1. How many more invertebrates are there in the world than vertebrates?
2. What reasons does the author give for the large number of invertebrates when compared to other organisms?
3. Why are invertebrates so important for ecosystems, and for life in general?
4. What are some of the questions that remain unanswered about invertebrates?
5. Do you agree with the author that zoos and conservation groups should spend time and money saving invertebrates? Why or why not?

Lesson 2— What lives in leaves in a stream? Making a stream interactions web poster

Instructional Goals

At the end of this lesson, SWKABAT:

a. Describe where producers, consumers, decomposers each get their food
b. Explain how matter and energy are related to why organisms need food
c. List biotic and abiotic factors relevant to a stream ecosystem
d. Recognize the existence of a variety of different categories of stream organisms, including decomposers

Next Generation Science Standards Addressed

Science & Engineering Practices:
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS1: From Molecules to Organisms: Structures and Processes
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Structure and Function
Energy & Matter

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic A: Cycling of Matter & Energy

Materials

- Large (11 X 17 or more) pieces of paper and different colors of markers (1 for each pair or group of students, 2 or 3 for class lists or posters)
- Pictures of local streams projected or printed
- Dissolved oxygen resources (Reading and Lab), *optional – Appendix B*
- Black markers
- Colored pencils or markers
- Large sheets of paper
- Scissors
- Glue or tape

Advance Preparation

You may also want to read some background information http://www.stroudcenter.org/lpn/LPNmanual/index.htm on the freshwater stream ecosystem or the invertebrates that live there http://www.epa.gov/bioiweb1/html/benthosclean.html. These resources are also good for advanced students to read further on their own as the unit progresses.

Lesson Procedure

1. Ask students to work together in pairs or small groups to define ecosystem and abiotic factors. An ecosystem is all the living/biotic and non-living/ abiotic things in a given area and their interactions. If students do not understand the difference between biotic and abiotic, you may need to do an additional lesson that allows them to investigate these differences.
2. Show students a picture of stream (make sure picture includes the water, and tree line along the bank of the

Check Student Understanding: Lower level students may only: mention coarse groups of organisms (e.g birds, bugs), so help them notice finer groups and specific species (e.g robins, blue jays); mention macroscopic organisms, so help them notice the microscopic as well; have a hard time mentioning aquatic producers (e.g., algae); help students understand that plants are not just scenery, they are living organisms that play roles in the ecosystem.

stream). Discuss the stream in general terms – location, things the students notice based upon the picture.

3. Give each student group a black marker and a piece of large white paper (11”x17”). Have each group list as many organisms and abiotic factors that would be in/or next to a typical local stream (using the picture for reference). If you are going to have students cut up and use these words and glue to make their food webs, have student write fairly large (not small regular size printing). Alternatively, you can have students re-write the terms in their web (steps 5 and 6). Students may remember some of the organisms from Lesson 1 or from the field trip in Lesson 2.
4. Have a brief discussion of food webs (this should be review from earlier grades). How are the organisms arranged in a food web? How do you show the relationship between the organisms? In what direction do those arrows go? What does this say about energy moving and types of energy (light energy and chemical energy)?
5. Have each group cut out the words on their list. Arrange the cut out words (organisms and abiotic factors) into a food web (plus abiotic interactions) on a new sheet of large paper. Don’t glue yet!
6. After each group has arranged their food web, allow them to send out 1 “scout”. The scout is allowed to visit other student groups, view their food webs, and to write down what their group is missing. The scout returns to their group. As a group, discuss what the scout has discovered as missing info and decide whether these things should be added to the food web. If they need to be added, the group should write out these new items and include them on their own web. Glue down the items on the food web and make sure arrows are included to show interactions.
7. As a whole class group, discuss the types of feeding relationships (e.g. producer, consumer: predator, prey, herbivore, omnivore, parasite, decomposer) the students know about and come to a class consensus. Some students may need more than a short discussion about this.
8. Give the students colored markers/pencils – one color for each of the terms you choose for the students to include on their food web. Decide as a class which color and what shape will represent each term (i.e. red circle = carnivore, etc.)
9. Have the students color code their food web. Don’t forget to have each group draw a key on their food web (so they, and you, don’t forget the colors and shapes you have decided upon)!
10. Refer to the web and ask students:
    A. Did your food webs include trees on the bank of the stream?
    B. What happens to the leaves on the trees over the course of a year?
    C. What happens to the leaves that fall into the stream?

    Ask students to diagram the decomposition process of leaves that fall in a stream. Pay attention to students’ answers here- do they include decomposers? Or, are they simply showing the process without understanding the organisms involved?
11. Refer back to the “What Lives in Leaves in a Stream” worksheet. Discuss with students the following parameters, and how they might impact the results of the experiment.
    A. How do abiotic factors affect what lives in the stream? (light, temp, O2, N, P and S)
    B. How do biotic factors affect what lives in the stream? (dispersal, food, competition, predators, diseases, etc.)
    C. How might different locations in the stream be different?
    D. Dissolved O2 discussion
        i. How does O2 get into the water (photosynthesis of aquatic plants, diffusion)?
    E. Discuss different leaf types (conifer and deciduous) and what are leaves made of (optional link to carbon).
        i. Dry mass of leaves are, approximately:

> **Check student Understanding:** Novice students don’t recognize decomposers at all. Some may think that decomposers exist to provide a service (i.e. breaking down waste) to other organisms. Help students to recognize that decomposers, just like all heterotrophs, consume food to obtain matter to grow and reproduce and energy for life’s processes. Assess students’ knowledge of where the carbon (e.g. cellulose, starch) and other minerals (e.g., Nitrogen, Phosphorus) each go in decomposition, noting that many are likely not to trace carbon into the atmosphere as CO_2 after cellular respiration by decomposers.

42.3% carbon atoms
6% hydrogen atoms
1.4% nitrogen atoms
0.2% phosphorus atoms
48.3% oxygen atoms
0.1% sulfur atoms

Lesson 3— What lives in leaves in a stream? Experiment design

Instructional Goals

At the end of this lesson, SWKABAT:

a. Explain how matter and energy connect different parts of a riparian ecosystem
b. List abiotic factors relevant to stream ecosystem
c. Define dispersal as the ability to travel to a new habitat
d. State that biotic interactions, abiotic resources and conditions, and dispersal are all important structuring elements of communities
e. Plan an investigation to compare the biotic communities found in different leaf pack treatments

Next Generation Science Standards Addressed

Science & Engineering Practices:
Asking Questions
Planning & Carrying Out Investigations

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Systems and System Models
Energy & Matter

Maryland Environmental Literacy Standards Addressed

Standard 1: Environmental Issues Topic A: Environmental Issue Investigation
Standard 4: Populations, Communities, & Ecosystems Topic B: Population Dynamics

Materials

- Introduction powerpoint
- A living organism: a classroom "pet" or an outdoor bug will do!
- Large piece of poster paper or projector to record student generated list of stream organisms and to make a poster summarizing the experimental design
- Pictures of local streams projected or printed
- What lives in leaves in a stream? - worksheet

Lesson Procedure

1. Draw students' attention to the living organism that you have brought in. Ask students to brainstorm what the living organism needs in order to survive – the ideas will vary depending on whether the organism is aquatic, terrestrial, etc. Then, ask students what would happen if we dramatically changed the abiotic conditions of the organisms' ecosystem. Would the organism survive? Would all members of this organisms' population survive? Why or why not? Explain to students that through this experiment, they will be investigating which conditions and resources are important for the presence and survival of aquatic organisms.
2. Project the picture of a local stream. As a class, create a list of organisms that might live there on the board or a new sheet of poster paper.

> **Check Student Understanding:** Many students may understand dispersal when you ask them about it, but we find that most students don't think about dispersal as something important that determines what species live where. Students also need help seeing how the traits of an organism affect their ability to disperse to a new environment. Ask them how the traits of a bird and the traits of a tree affect their ability to disperse to new habitats.

3. Have students choose one of the organisms they listed in #2. Ask students to brainstorm what the organism eats, and how the organism gets its food (i.e. how they get matter for growth and reproduction and energy for life's processes). Students may tend to focus on large animals; if so, remind them to think about smaller animals and organisms that are not animals. Keep this list of stream organisms; you will update and refer to it periodically throughout the unit. Provide students with "What lives in leaves in streams?" Worksheet if students need more guidance. This worksheet is designed for lower level students who are only comparing one treatment (stream location) but can be expanded to include both comparisons.

4. Ask students to brainstorm what might provide habitat, or shelter, for the organisms in the stream.

5. Tell the students that leaves fall into the stream and make habitat for stream organisms. You may need to remind students what a habitat is: the physical place that surrounds a community of organisms. Talk about how leaves get into a stream when they fall from trees and build up in piles in the stream called *leaf packs*, and explain how leaf packs start out with few things living in them and slowly become colonized by many types of organisms (e.g. insects, algae). Also help students see that these leaves become the base of the food web in the river. Talk to students about how the stream and the surrounding forest are connected. Matter and energy move between them. When leaves fall into the stream, they become a source of matter and energy for the organisms that eat them. Organisms like aquatic insects can leave the stream and become food for animals in the forest, moving matter and energy back out of the stream and into the forest. The main point is that the stream and the riparian zones are connected through matter and energy,

> **Check Student Understanding:** Lower level students may not understand the difference between abiotic and biotic. Some students may see plants as abiotic instead of biotic. Students may be able to say that temperature, DO etc. are important, but they should be encouraged to think about how the abiotic factor **specifically** interacts with the traits of the organism to affect its growth, survival, or reproduction.

6. Hand out some empty plastic leaf packs for students to observe and discuss.

7. In small groups or pairs ask students to brainstorm about what could affect whether, and which, organisms colonize the leaf packs. The abiotic conditions (e.g. temperature, pH, dissolved oxygen), the leaves themselves (i.e. shape, size, chemical composition for more advanced students), and what types of organisms are in the stream will influence what will live in the leaves. You may need to prompt students to focus their thinking. When thinking about what might live in a certain place students should ask themselves the following three questions, in this order:

    A. **Ask the students about dispersal - Can the organism get there?** (e.g., direct organism movement, water, wind) Organisms can't live in a specific time or location if they can't get there; we call this "dispersal," the ability to travel to a new habitat.

    B. **Ask the students about Abiotic resources and conditions - Can the organism survive and reproduce given these abiotic resources and conditions?** (e.g. light, water, dissolved oxygen, nitrogen, phosphorus, temperature, etc.) Abiotic resources and conditions influence whether organisms are able to survive and reproduce in a specific time or location. In addition, organisms can influence the abiotic environment around them, such as by altering the oxygen or mineral content of the water.

    C. **Ask the students about Biotic resources and interactions - Can the organism survive and reproduce given the range of biotic resources and interactions**? (Does it have food, does something eat it, what are the competitors, mutualists, habitat forming organisms, diseases, etc.) Biotic resources and interactions also influence how successful

> **Check Student Understanding:** Lower level students may not recognize biotic interactions at all or they may see interactions in very anthropomorphic ways (e.g. snakes are enemies of mice). Upper level students see predator-prey and other types of interactions like competition for resources. They also see interactions in terms of movement of matter and energy for growth and reproduction rather than simply as a matter of life or death.
> .

organisms are in a specific time or location.

TEACHER'S NOTE: Organisms have particular abiotic and biotic requirements that are required for survival and reproduction. Conditions are physical or chemical aspects of the environment that cannot be consumed by an organism (temperature, pH, soil conditions, climate and weather, etc). Resources are consumed by organisms (carbon dioxide, oxygen, sunlight, water, other organisms for food). Organisms can alter both the conditions and resources in their environment (plants create shade decreasing sunlight for other organisms, living things respire reducing oxygen for other organisms, beavers make dams and change stream flow, etc). Biotic interactions are when organisms act on one another such that they effect or influence the others' behavior, reproduction or survival. These can be beneficial (i.e. mutualism), detrimental (i.e. competition) or neutral to both organisms in the interaction or neutral to one while beneficial or detrimental to the other organism in the interaction (e.g. predation).

8. After the small group discussion, start a list on the board of the students' ideas. With the students, group their ideas in three categories: things that might affect dispersal of organisms, abiotic factors, and biotic interactions.

9. Tell the students that they are going to see what colonizes leaf packs by making experimental leaf packs and placing them in a stream. They will compare two places in a stream: riffles and pools. If you teach advanced high school students, you may also choose to compare two types of leaves from the local area conifer (pine, spruce, etc) v. deciduous (oak, maple, hickory, etc).

   Explain, or allow students to form through discussion, the following experimental design: place in stream, riffle or pool (and leaf type for advanced HS) will be the variable in their experiment. The type of leaves, size of leaf packs, amount of time leaf packs are in the water, and method of placing the leaf packs in the stream will be kept constant in their experiment.

10. Discuss with students what they think would be different between the two places in the stream (or leaf types).

    BACKGROUND ON DIFFERENT LEAF TYPES: Deciduous and coniferous leaves differ in their chemical composition, which affects what can and will eat them. Deciduous leaves are made of compounds that are easy to break down (e.g. cellulose) and have a relatively low C:N ratio (i.e. there is more N per unit C). Both of these characteristics make them easy for microorganisms to break down. Coniferous needles, on the other hand, contain more compounds that are difficult to break down (e.g. lignin & tannins) and have a higher C:N ratio (i.e. less N per unit C). As they break down, they also release organic acids, which lower the pH of the surrounding environment. Not all organisms are equally tolerant to acid, so the community that can live on coniferous needles could be different from deciduous leaves. Deciduous leaves will break down faster the coniferous leaves, so students might also see differences in abundance of organisms living in the packs.

    Students can probably reason with some guidance towards some of these differences, especially if they are provided with an analogy to food they might eat. For example, deciduous leaves might be likened to a potato chip and coniferous leaves to Brussels sprouts (or some other stinky green vegetable). Please keep in mind that these are very broad generalizations.

11. Discuss with students how they think those differences in the places in the stream or leaf types could affect the types of organisms who live there. Record these ideas on a poster to refer to at the end of the unit.

12. Ask students to think about how they will compare the types of organisms in the different leaf packs (they will be counting the number of each type of organism in their leaf packs). Tell students they will also be measuring some of the abiotic factors they mentioned above (at a minimum you should collect temperature, dissolved oxygen, turbidity—see Lesson 2 for experimental procedure details).

13. Write on the board or the poster:

    very similar ---*very different*

    Ask students to vote by putting an X on this continuum in response to the following question: *Do you think you will find* ***very similar*** *or* ***very different*** *organisms in the leaf packs we are comparing? Or do you think we'll find something in between?* After students vote, go around the room and ask a couple of students from each clump of X's who voted each way to explain why they voted the way they did. Get as many reasons as possible. Give students an opportunity to be convinced by their peers and change their vote. Prompt students to think of differences in abiotic, biotic and dispersal factors discussed above and whether they think those differences will be large enough to matter to organisms that live in the stream. Advanced HS students should think about both the comparisons they will be doing: different places in the stream and different types of leaves. You can do this by voting once comparing all 4 types of bags or multiple times, once for each comparison.

This is a good place to start introducing one of the core themes of this unit: *Organisms have particular abiotic and biotic requirements. If you change the abiotic or biotic conditions or resources available (e.g. place in stream or leaf type) some needs of an organism* ***might*** *not be met and then they* ***might*** *not be able to be there*.

14. Summarize the experimental design with the students. You may consider adding this to the predictions poster from above i.e.: there will be packs of leaves placed in your local stream and after 3/4 weeks you will count how many of each different kind of organism lives in each pack. To help get the students excited, you should then tell them that many schools locally and in other states will be doing the same experiment.

Assessment Ideas:

1. Exit ticket (or Bell Ringer[1]): What are the feeding groups, groups of organisms that get their food the same way, that make up a food web? How do you think they will be represented in your leaf pack?

2. Exit ticket: What is your prediction about how the biotic communities will differ in the two treatments of our experiment? Explain why you think that.

[1] Questions marked exit ticket are also appropriate for quizzes or bell ringers.

Name ___________________________________ Date ____________

Lesson 3: What lives in leaves in a stream?

(student worksheet)

In this experiment, you will be investigating the diversity of aquatic life in different parts of a stream. You will be placing plastic mesh bags, full of dried leaves, into a stream or river. These leaf packs will act as "habitat" for organisms in the stream. After several weeks, you will collect the bags and investigate the kinds of organisms you find living in them.

1. What do you think you will find living in the stream?

2. Choose two organisms you listed in question #1, and explain how these organisms get their food.

   Organism a: ______________ gets its food by: ____________________________________

   Organism b: ______________ gets its food by: _____________________________________

3. What do you think might affect what lives in the leaf packs you will put in the stream? Pick ONE of the organisms you mentioned in question #1. In order to answer this question, it will help to think about each of the following aspects of the ecosystem:

Ecosystem Component	Name of the one organism you picked:
Dispersal – a .Can your organism get to the stream? b. Can it move from one part of the stream to another?	a. b.
Abiotic resources and conditions – does your organism have specific requirements for survival?	Temperature: Hot…………Medium………….Cold Light: High………….Medium…………..Low Dissolved Oxygen: High………….Medium…………..Low Do you know if it requires anything specific?
Biotic resources and interactions a. Does your organism have enough food? b. Are there competitors or diseases? c. Are there predators to worry about?	a. b. c.

4. During this experiment, you will be testing leaf packs in two different parts of the stream – a part of the stream that is quiet, deep and calm (a pool), and a part of the stream that is moving quickly and is shallow (a riffle). Do you think you will find different kinds of organisms in the leaf packs in the different parts of the stream? Why or why not?

5. Do you think you will find very similar or very different organisms in the leaf packs you are comparing? Using the diagram below, place an "x" on the line to show what you think you will find.

   very similar --very different

   Explain your answer:

6. Write a prediction for your experiment.

7. Outline the procedure you will follow for this experiment:

Lessons 4 and 5— Experiment in-class set-up (Lesson 4) and Field trip (Lesson 5)

Instructional Goal

Students will set-up leaf pack experiment by making leaf pack bags during class, putting bags in a stream on a field trip and measuring stream characteristics.

Next Generation Science Standards Addressed

Science & Engineering Practices:
Asking Questions
Planning & Carrying Out Investigations
Using Mathematics and Computational Thinking

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Cause and Effect
Patterns
Systems and System Models

Common Core Standards Addressed:

Mathematics:
Quantities- Reason quantitatively and use units to solve problems
Interpreting Functions- Interpret functions that arise in applications in terms of the context
Mathematical Practices- Reason abstractly and quantitatively
Attend to precision

Maryland Environmental Literacy Standards Addressed

Standard 1: Environmental Issues Topic A: Environmental Issue Investigation

Materials

Experimental set-up in class[2]:

- One empty leaf pack (mesh bag made of plastic mesh, such as an onion or seafood bag) per student group
- One or two different types of dried leaves (e.g. maple, oak, pine needles) (one-deciduous- for MS and Early HS, two for Advanced HS)
- Scale to weigh leaves or cup to measure volume

Field Trip:

- Waders or appropriate shoes
- String to close bags and anchor litter bags in stream
- Waterproof tags to label leaf packs (could use paper inside of small ziplock bag)
- Flags or flagging tape to mark leaf pack sites
- Thermometer
- Water quality test kits: dissolved oxygen, turbidity (optional), nitrate (optional), ammonia (optional)
- Stream flow measurement tools: orange, meter tape, stopwatch
- Copies of **Stream Characteristics Data Sheet, Calculating Stream Flow** Data Sheet, clipboards

Advance Preparation

[2] If you don't do the set up in class, you will still need these supplies to set up the leaf packs yourself.

Prepare for in-class experimental set-up by collecting leaves and prepare for field trip by ensuring students' familiarity with water test kits. General chemical safety protocols should be followed by students participating in water quality testing. These protocols include the use of goggles and proper disposal of chemicals.

You do not have to take students outside to set up their packs, if you need to save time. *However, it is strongly suggested that you do so if possible, both to improve their motivation and to help them understand how the different experimental locations are different. Students will be much more engaged in the results if they are allowed to participate in the setup of the experiment.* If students are not able to accompany you to the stream you may want to take pictures for students of stream and the packs in the stream. If conducting a field trip, address safety issues (e.g. appropriate attire, sunscreen, life preservers, first aid, water bottles and snacks etc.) prior to the trip.

Students participating in this lesson will interact directly with a stream or river and some of them will enter into the water. Students should not enter the fast moving part of the stream/river, and if they do fall over while in the river, they should relax, point their feet down-stream and let the current carry them to an area where they can stand up. A throw rope should be present at all water sites and be in a position where it can be thrown to a victim.

Lesson Procedure

Experimental set-up

1. If you are having your students prepare the leaf packs for the stream, they should now begin working through the **Experimental Set-up Procedure** (project on screen or hand out to students). Students should create two leaf packs, one of each leaf type. In both cases, half of the leaf packs will be placed in a riffle and half will put them in a pool in the stream. It is OK to put all riffle packs together and all pool packs together though you can also replicate that by having half of the riffle packs in one riffle and the other half in another and so on. However, for advanced high school groups who are comparing two different types of leaves, the packs for each student group should always be in the same riffle or pool. To create the leaf packs student should fill each pack with 25 g or 2 cups of loosely packed leaves and close the pack. Spend some time talking with students about the need to standardize the packs; if the amount of leaves in each pack isn't standardized, you introduce another variable that would lead you to ask the question, "to what extent does the amount of space or amount of food affect the biological community?" Leaf packs should be labeled with student group names, stream location, and leaf type.
2. Students should then secure the leaf packs at the edge of a stream by tying them to a tree or bush with the string and placing a rock or brick on top of the pack to keep the bag underwater. If there are no trees to secure the pack near the edge of the stream, you can tie the packs to several bricks or rocks and sink them. In a high flow stream, you can bury the bricks (with the packs attached on a longer string) in the ground along the edge of the stream, making sure the packs are securely tied to the brick prior to burial. If a field trip isn't possible, you could have a group of students help you after school or go yourself. Plan to leave the packs in the stream for 3-4 weeks.
3. Collect the appropriate stream data using the **Stream Characteristics data sheet** during your site visit if you do not plan to collect it when you collect the packs. You don't have to collect the stream characteristics data twice (you only need to collect the data as a class). Make sure you collect data for each riffle or pool your students use. At a minimum you should collect water temperature, dissolved oxygen, stream flow, and turbidity (if possible). Consider measuring pH, nitrate, and ammonia if you can. Make sure that your students know what the word abiotic means (for suggestions, there are many online labs that help students explore the difference between biotic and abiotic; some examples are here: http://bit.ly/SdWssY). If you did not do the vocabulary lesson, ask students to work together in pairs or small groups to define ecosystem and abiotic factors. Explain to

> **Check Student Understanding:** As the students are collecting data about the abiotic environment, ask them to brainstorm about why these abiotic factors might be important. Some students may not be able to distinguish between abiotic and biotic factors. Students may not recognize that an abiotic factor (e.g temperature) might affect different species differently depending on the species' traits. Talk to the students about what niche means and how these abiotic factors play into an organism's niche. Students more easily recognize that abiotic factors can affect organisms and less easily recognize that organisms can affect abiotic factors (e.g. submerged plants in a stream can increase dissolved oxygen concentration).

them that the data they are collecting are about the abiotic characteristics of the stream. Abiotic characteristics can affect living things. Ask the students to brainstorm how each factor might affect what lives in the stream. Later you will help the students see that abiotic factors affect organisms, but the organisms are also able to affect abiotic factors.

Assessment Ideas:

1. Exit ticket: Give an example of how one of the abiotic variables you measured might affect a particular species.
2. Exit ticket: Give an example of how a living organism might alter one of the abiotic variables you measured.
3. Exit Ticket: Explain how you think your results may be different between the leaf packs you place in the different parts of the stream.

Experimental Set-up Procedure

1. Obtain one mesh bag from your teacher.
2. Fill the mesh bag with 25 g or 2 cups of dry leaves.
3. Close the bag by tying a knot.
4. Attach a tag to the bag.
5. Label the bag by writing your group name or number and type of leaves on the tag with a permanent marker.
6. Go to the stream. Tie the bag to trees, rocks, or roots to ensure that it doesn't move during the course of the experiment.
7. You or your teacher will collect the bag in 3-4 weeks. When they are taken out of the stream, each bag should be placed in a separate Ziploc bag.

Stream Characteristics Data Sheet

Date				
	Pool #1	Riffle #1	Pool #2	Riffle #2
Water temperature				
Dissolved Oxygen				
Turbidity				
Stream Flow				
Other:				

Calculating Stream Flow

Measure a 1m segment of your stream to collect the following measurements:

Step 1: Stream segment width: Find the width of your stream: ______ m

Step 2: Stream segment velocity: Using your segment, drop an orange and record the speed at which the object travels the length of the segment. You should do this twice at the left, middle, and right side of the stream, and then average your measurements.

Left side (sec)	Middle (sec)	Right side (sec)	Average
Average of all three segments (time in seconds)			

Step 3: Stream depth. Stretch a tape measure across the stream at the mid-point of your stream segment. At 1 m intervals across the stream, measure the depth (in m) and record it in the table below. If you have a very wide stream, measure depth every 2 or 3m.

Distance (m)	Depth		Distance (m)	Depth
0	0		6	
1			7	
2			8	
3			9	
4			10	
5			11	

Sum of depths: ______ / number of samples taken = _________ average depth of stream

Step 4: Flow calculation
Now that you have all your measurements, simply plug in the numbers in the equation:

[1m (length) x _____ m (width) x _____ m (depth)] ÷ _____ (time secs) = _____ cubic meters/sec

Place this value into the chart on the previous page.

Lessons 6 and 7— What lives in leaf packs? Macroinvertebrate data collection

Instructional Goal

At the end of this lesson, SWKABAT:

a. Observe characteristics of stream macroinvertebrates
b. Recognize that macroinvertebrate diversity exists
c. Classify these organisms into fine groups (e.g. mayflies, dobsonflies) based on similarities and differences in morphology
d. Recognize that varying abiotic and biotic conditions differentially impact different types of organisms based on their particular abiotic and biotic requirements.
e. Explain how these differential impacts can cause a biological community to be diverse and for separate biological communities to be different.

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Using Mathematics & Computational Thinking
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Patterns
Structure & Function

Common Core Standards Addressed:

Mathematics:
Quantities- Reason quantitatively and use units to solve problems
Mathematical Practices- Reason abstractly and quantitatively
Attend to precision

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic E: Diversity

Materials

Optional Field Trip[3]:

- Waders or appropriate shoes
- Scissors to cut string attaching bags to rock, tree etc.
- Ziploc bags (1 for each student group, 2 for AHS)
- Buckets
- Battery powered bubbler (optional – only if you want to try and keep the organisms alive overnight)
- Stroud macroinvertebrate identification key (available online http://www.stroudcenter.org/education/MacroKeyPage1.shtm) or on the course website
- Leaf pack sorting sheets (waterproof; 1 per group, available from Connecticut Valley Biological Supply)
- Plastic spoons, tweezers, transfer pipets, or turkey basters and white trays for students to use while sorting
- Strainer (i.e., kitchen) or sieve and buckets for rinsing invertebrates from leaves

[3] If you don't do the set up in class, you will still need waders or appropriate shoes to collect the experiment yourself.

- Squirt bottles (optional)
- Petri dishes to hold organism groups while sorting (9 per group of students)
- Hand lenses (one or two for each pair or group of students) and/or dissecting microscopes
- Optional Safety equipment: latex gloves, goggles
- 70% ethanol solution – used to preserve animals (optional)
- Copies of **Macroinvertebrate Data Collection** worksheet (1 per group or per student, 2 for AHS)
- One classroom copy of **Stream Characteristics** data sheet, **Calculating Stream Flow Data Sheet**
- Projector to display Excel data sheet or create a chart/poster to collect class data

Advance Preparation

Prepare for outdoor collection trip, ensuring students' familiarity with water test kits. You do not have to take students outside to collect their packs if you need to save time. *However, it is strongly suggested that you take students outside, both to improve their motivation and to help them understand how the different experimental locations are different.* If students are not able to accompany you to the stream you may want to take pictures for students of stream and the packs in the stream. See Advance Preparation from lessons 4/5 to address safety concerns.

Download Excel workbook (Class template Les 5 and 7 – Exploring your data.xlsx) or make a poster to collect class data. Make student copies of **Macroinvertebrate Data Collection** worksheet and **Stream Characteristics Data Sheet**.

Lesson Procedure

1. You or the students should collect the leaf packs from the stream. While you are at the stream, make sure to record temperature, dissolved oxygen, and stream flow using the Stream Characteristics & Calculating Stream Flow data sheets **(especially if you did not do so when you set the bags out earlier)**. These data will help you confirm the earlier data from when the leaf packs were first set out. Collect data for each riffle or pool your students use. Decide if you are going to identify organisms in the field or in the classroom.

   A. **If you are going to ID in the classroom,** place each leaf pack in a separate Ziploc bag filled with some stream water and return to the classroom. If you want to keep the organisms alive overnight, make sure to keep each treatment bag in a separate bucket in a cooler or in the refrigerator with enough water to use an aquarium airstone or bubbler. Pay careful attention to keeping the treatment bags separate, so that your results are accurate.

   B. **If you are going to ID in the field,** have students observe how the leaves look once they are taken out of the leaf packs – observe color, shape, state of decay, etc. Students should carefully look for organisms on and around the leaves – see note below in "Learning Progression Look For" box.

   TEACHER'S NOTE - If you want to collect organisms one day and look at them the next, you can preserve the animals in a 70% ethanol solution, or you can keep them alive.

   - To keep the animals alive overnight, place them in a cooler or in the refrigerator with enough water; an air bubbler in the bucket will increase your chances that they will stay alive.
   - If your students don't have time to look at the organisms' feeding structures (mouthparts) using hand lenses, dissecting scopes, or as a class with a video microscope on the sorting-counting day you can preserve at least a representative sample of each type of organism for identification of the mouthparts in the classroom for Lesson 5.
   - If you have time at the stream, you can count how many of each type you have collected, and then keep one representative for classroom identification and analysis.
   - If you notice that there are many more organisms than you can possibly count, decide as a class to limit the counting time to a specified length – ie, count for 10 or 15 minutes and then stop. You want to make sure that you have some count data, as this will be necessary for graphing later on.

Pass out the **Macroinvertebrate Data Collection** worksheet so students have written instructions for how to explore the leaf packs and discussion questions. Ask students not to record data until they have finished sorting and identifying. Advanced HS groups will need two copies of page two of the data collection worksheet, since they are recording data for different kinds of leaf pack treatments.

2. Before students separate organisms from leaves, they should observe the leaves. Then have students separate the organisms from the leaves. There are two methods of separation:
   a. Pick through the leaves, removing organisms with tweezers, plastic spoon/fork or fingers.
   b. Using a strainer.

      i. Agitate the leaves in a bucket or tray of water to dislodge the invertebrates. Warm water works especially well if your invertebrates have been stored in a refrigerator overnight. The temperature difference helps them let go.
      ii. Remove the leaves from the water and place in a separate container.
      iii. Pour the bucket of water and invertebrates through a strainer, and into another bucket. The animals should be trapped on top of the strainer (either a science one like in the picture or a common kitchen strainer). A squirt bottle is helpful to dislodge the invertebrates from the strainer.
      iv. Rinse the invertebrates from the strainer into a tray or other container. If you notice animals that are still on the leaves, repeat the procedure.

Check Student Understanding: Ask students what happened to the leaves while they were in the stream? How does a leaf go from being "perfect" when it falls from the tree to "disappearing" when they pulled it out of the bags? Lower level students know about decomposers, but often don't invoke them to explain how a leaf changes over time. They also don't understand where the mass of a leaf goes- i.e. that it is eaten by microbes. Most students will simply say that the leaf 'disappears'. This is a connection to the carbon strand- remind students of conservation of matter.

3. Keep some leaves (a handful is fine) from the leaf packs for the microinvertebrate part of the unit- you will use them to observe microbial life living in the stream.
4. Ask students to place the macroinvertebrates into groups based on observable characteristics. This will assist them with classification skills, and foster their observation skills as they work to clarify the reasons they have grouped different organisms together.
5. Once the students have sorted the organisms, ask them to visit with another sampling team to see if they sorted the organisms in the same way. Ask students to make specific statements about **why** they sorted the way they did.
6. Give students the ID sheets to create more appropriate groups.
7. Have students sort the macroinvertebrates into Petri dishes using the identification sheets and keys. If student groups have more than one leaf pack type (advanced HS students) they need to sort and count each bag **separately**, one after another. You will need to introduce the term *macro-invertebrates* if you have not done so already. If you think your students will take too long to sort the organisms from their whole pack, you can have students count a subsample of the pack or just sort for a set amount of time (e.g. 5-10 minutes).

   As they are sorting, prompt small groups to think about what they are doing using the discussion questions on the handout.

Check Student Understanding: Students will group organisms based on morphology, but they often don't see the large differences within groups or the subtle ways in which organisms are different. Students often want to group different mayflies, for instance, into separate groups, or place dobsonflies in the group that includes isopods because they think the filaments on the abdomen are actually legs. Pointing out that there are hundreds of species of mayflies which take on very different forms (burrowers, swimmers, crawlers etc) will help students recognize diversity. If you are lucky enough to have a sample that has multiple types of one taxa with large differences in morphology such as mayflies, dragonflies, or caddisflies, spend some time with students highlighting the similarities and differences within an order. Instead of just telling students they are wrong when they sort their organisms into an incorrect group (such as the dobsonfly example), help them explore the ways in which they might be able to re-classify the organism.

As you walk around, a fun way to engage students is to have them observe the mouthparts of the different organisms. This will be focused on in a later lesson, but for now, point out to students the predators among the organisms (dragonflies, for example, have huge jaws that can be extended carefully with forceps) or organisms without visible mandibles (scrapers).

8. The discussion questions can be used either as discussion, or as written (and graded) questions depending on your group of students.
9. When they have sorted all of their organisms into the Petri dishes have students count the numbers of invertebrates in each Petri dish and record data on the **Macroinvertebrate Data Collection** worksheet. For the 2 non-insect Petri dishes (e.g. with leeches and crayfish) have students count the major types of each invertebrate. As mentioned earlier – if you have many more organisms than is feasible to count, decide on a timeframe for counting and count what you can in that timeframe (5 or 10 minutes).
10. Students should report their individual group data on the board so that all students can use the class data to understand the ecosystem. You might also use the Excel worksheet provided.
11. Guided by the worksheet students will describe qualitative and quantitative patterns among the different leaf packs, describe differences in the richness and evenness of different types of organisms.
12. Bring students together to talk about what they found. Add to the list of organisms living in the stream from Lesson 1. As a class, discuss how many different kinds of organisms they found and how they were able to tell when there were different kinds; emphasize careful observation of differences among organisms as a way of telling organisms apart. Have students share their speculation on whether they think these organisms all eat the same things and how they could explore that question if they wanted to.
13. Preserve a representative of each group of organisms in 70% ethanol for exploration of mouthparts in Lesson 6.

Assessment Ideas:

1. What traits or characteristics of the macroinvertebrates did you use to sort them into groups?
2. What traits or characteristics would you use to identify a mayfly?
3. What traits or characteristics would you use to tell the difference between a mayfly and a caddis fly? What traits or characteristics would you use to tell the difference between a dog and a cat?
4. In this unit, students only identify organisms to Order. Given the tool and skill constraints, they cannot identify the organisms at the species level. If you would like to talk about species diversity within Orders you might consider asking students to research the name and ecology of a specific local stream organisms using information from the library or internet.

Lesson 6/7: Macroinvertebrate Data Collection

(student worksheet)

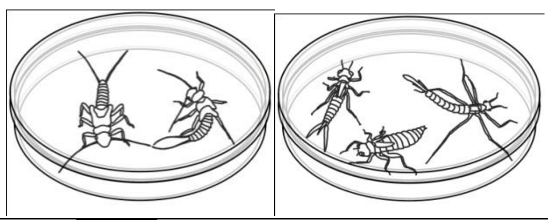
Names in group:	
Place in stream (riffle or pool):	Type of leaves:
Stream Name:	State:

1. First, before you empty your bags out, observe how the leaves look (is it green, brown, decaying, in clumps, etc.). Carefully explore in and around the leaves. Do you see any organisms? What parts of the leaf pack are the organisms in or on?

2. Empty the bag of leaf litter according to your teacher's instructions. Separate the animals you find into major groups using the key, sorting mat and Petri dishes provided.

3. Now, count the numbers of invertebrates in each Petri dish on your sorting mat and record your data in the table on the next page. Take notes about relative sizes and any other things you noticed about the invertebrates in your leaf pack.

Example



	Your results		Class Results					
Major Groups Common name (Scientific group name)	# Individuals you found		Pools - # of individuals	Pools – Total # of bags	Pools – Average # indiv./bag	Riffles – # of individuals	Riffles – Total # of bags	Riffles – Average # indiv./bag
Stoneflies (Order Plecoptera)	2		17	5	3.4	53	5	10.6
Dragonflies and Damselflies (Order Odonata)	3		4	5	0.8	27	5	5.4

Discussion Questions:

1. How can you tell when organisms are different kinds?

2. How are the organisms different from one another?

3. Do you think all of these organisms eat the same thing? Why or why not?

4. Are all the organisms in a Petri dish the same? Why or why not?

5. Collect your individual data, and then your class data, in the data table below - both the total number of individuals and the number of bags, so that you can calculate the average number of individuals per bag.

	Your results		Class Results					
Major Groups Common name (Scientific group name)	# Individuals you found		Pools - # of individuals	Pools – Total # of bags	Pools – Average # indiv./bag	Riffles – # of individuals	Riffles – Total # of bags	Riffles – Average # indiv./bag
Stoneflies (Order Plecoptera)								
Dragonflies and Damselflies (Order Odonata)								
Mayflies (Order Ephemeroptera)								
Water Beetles (Order Coleoptera)								
True Flies (Order Diptera)								
Crane Flies (Order Diptera, Family Tipulidae)								
Dobsonflies and Alderflies (Order Megaloptera)								
Caddisflies (Order Tricoptera)								
Net-spinner Caddisflies (Order Tricoptera, Family Hydropsychidae)								
Water mites (Order Acari)								
Scuds (Order Amphipoda)								
Sowbugs (Order Isopoda)								
Crayfish (Order Decapoda)								
Snails (ClassGastropoda)								
Clams and Mussels (Class Bivalvia)								
Leeches (SubclassHirudinea)								
Aquatic Earthworms (SubclassOligochaeta)								
Planaria (ClassTurbellaria)								

Look at your data from the chart, and answer the questions below.

1. Which organisms were the most common in the pools? In the riffles? What could be some reasons for the differences?

2. Why were you asked to find an average for the data from the different places in the stream separately?

3. Using your class data, how many taxonomic groups did your class find in each place?
   i. Leaf packs in **riffles** had _______ groups.
   ii. Leaf packs in **pools** had _______ groups.

4. Species richness tells us how many different species are in an ecosystem – in our experiment, we focused on groups of organisms instead of species. Based on the information in question #3, which location in the stream had the greatest richness of macro-invertebrate groups?

   Riffles **Pools**

5. *Evenness* tells us how evenly the different groups of organisms are **distributed** in an ecosystem, or the *relative abundance* of each group in an area. Look at the graph of your data. How "even" was the community you found in your packs? That is, did you have *similar numbers* of organisms in each of the different groups that you found or did you have many more in some groups than others? Give at least one example to support your answer.

6. Using the data your teacher provides, fill out the chart below to describe any differences in abiotic resources or conditions between the riffles or pools.

	Riffle	Pool
Amount of dissolved oxygen		
Turbidity		
Temperature of the water		
Water flow		
Other characteristics		

7. Imagine that you now have to estimate how many organisms live in the ENTIRE stream. Explain how you would go about finding the answer to this question. How confident are you that you could find a reasonable estimate? What would you like to know in order to be more confident in your answer?

8. Based on the information you currently have about your stream, how healthy do you think your stream ecosystem is? Explain your answer.

Lesson 6/7: Macroinvertebrate Data Collection

(Teacher Answer Key)

Discussion Questions:

1. How can you tell when organisms are different kinds?
   - How they look and act

2. How are the organisms different from one another?
   - Number of legs
   - Size
   - Color
   - Shape or body structure
   - Body covering

3. Do you think all of these organisms eat the same thing? Why or why not?
   - Unlikely since they all different and have different mouths; they live in different niches or the stream.

4. Are all the organisms in a Petri dish the same? Why or why not?
   - Unlikely because you have biodiversity!

5. Which organisms were the most common in the pools? In the riffles? What could be some reasons for the differences?
   - Depends on the results. Reasons for the differences could include: abiotic factors (stream flow, dissolved oxygen, temperature); biotic factors (predation, habitat preference); dispersal; sampling effort (some students may have been more careful than others); error (leaf packs could have washed away or been damaged).

6. Why were you asked to find an average for the data from the different places in the stream separately?
   - When you look at the averaged data for each location in the stream, you can see patterns more easily than with your own individual data. Averaging data gives us more confidence to make conclusions based on our work.

7. Using your class data, how many taxonomic groups did your class find in each place?
   iii. Leaf packs in riffles had _______ groups.
   iv. Leaf packs in pools had _______ groups.
   - Answers will vary depending on data.

8. Species richness tells us how many different species are in an ecosystem – in our experiment, we focused on groups of organisms instead of species. Based on the information in question #3, which location in the stream had the greatest richness of macro-invertebrate groups?

   Riffles Pools
   - Answers will vary depending on data.

9. *Evenness* tells us how evenly the different groups of organisms are distributed in an ecosystem, or the *relative abundance* of each group in an area. Look at your data. Which part of the stream – pool or riffle, had higher evenness? That is, did you have *similar numbers* of organisms in each of the different groups that you found or did you have many more in some groups than others? Give at least one example to support your answer.
   - Answers will vary. Students should identify which location in the stream was more even, and use evidence to support their answer.

9. **Using the data your teacher provides, fill out the chart below to describe any differences in abiotic resources or conditions between the riffles or pools.**

	Riffle	Pool
amount of dissolved oxygen	*Data will vary depending on your stream; most healthy streams should have a DO between 8-12 ppm*	*DO in pools should be lower than in riffles.*
Turbidity	*Again, data will vary. Depending on your method of sampling (secchi disk, test kit, or probe), your data will be different. For example, the average turbidity of the Hudson River is around 30 NTUs. A storm event with lots of sediment entering the stream could cause turbidity to spike; for example Hurricane Irene caused the Hudson River's turbidity to spike to almost 1,000 NTUs.*	*Turbidity should be lower in a pool.*
temperature of the water	*Data will vary. Older students can calculate the dissolved oxygen saturation, which takes into account the temperature of the water body and gives you a more accurate reading of the oxygen in the water.*	*There is often no difference between temperature in pools and riffles.*
Water flow	*Data will vary.*	*Water flow should be slower in a pool.*
Other characteristics		

10. **Imagine that you now have to estimate how many organisms live in the ENTIRE stream. Explain how you would go about finding the answer to this question. How confident are you that you could find a reasonable estimate? What would you like to know in order to be more confident in your answer?**
Students should say something about needing to know the size of the entire stream, versus the size of the stream that their samples were coming from. Estimating a population from a sample is very difficult, and requires lots of data in order for scientists to be comfortable that they have a reasonable estimate. Students may want to know more about results from other times of the year, whether the stream changes dramatically along its length, how much flow the stream receives, whether there are times of year that it is affected by pollutants, etc.

11. **Based on the information you currently have about your stream, how healthy do you think your stream ecosystem is? Explain your answer.**
Students may not have much information about this now, but they might hypothesize that if they found a lot of different organisms, their stream might be more healthy.

Lesson 8— Who Eats Whom?

Instructional Goal

At the end of this lesson, SWKABAT:

a. Explain how an organism's mouthparts affect how it obtains food
b. Explain how organisms with similar anatomy and preferences for feeding might compete for food
c. Construct a stream food web and label the direction of matter and energy flow between components
d. Explain how the feeding actions of an organism could affect the abiotic environment
e. Classify stream organisms into feeding groups and indicate these on their food web

Next Generation Science Standards Addressed

Science & Engineering Practices:
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Structure & Function
Energy & Matter

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic E: Diversity

Materials

- Prepared specimens from Lesson 5 (or live specimens if you kept them overnight)
- Hand lenses or dissecting scopes
- **Student Organism** cards, 1-16 only (1 set per pair of students) and **Teacher Organism cards made into magnets** (or post it notes)
- Food Web template (1 per pair of students, optional)
- List of stream organisms; student food webs from Lesson 3
- Filled out copies of **Macroinvertebrate Data Collection** worksheet (or have classroom data available)
- Copies of **Stream Biology Briefs** Reading
- Computer or overhead projector to display **Food Web** poster pdf and **Functional Feeding Group** ppt and videos (there are videos of each feeding group along with a video showing multiple types of mayflies).

Advance Preparation

Prepare copies of the **Organism** cards, either as magnets or for use as post-its on the board (or on a smartboard, etc). Laminating the cards makes them last much longer! Ideally, each group of students will have their own set. Remind students to bring their filled out copies of the **Macroinvertebrate Data Collection** worksheet or make sure to have classroom list available on a poster. Make copies of **Stream Biology Briefs** and the **Food Web** poster (optional scaffolding for students). Prepare overhead or download pdf of the **Food Web** poster. Prepare overhead printouts or download the **Functional Feeding Group** ppt presentation. There are links in the PPT to videos of feeding, so check that they work properly on your computer.

Lesson Procedure

1. Allow students to observe the preserved specimens using dissecting scopes or hand lenses. If you have a video microscope you can review the mouthparts as a class. Reviewing mouthparts will cause this lesson to be an **extra 10-15 minutes**.

2. Pass out **Who eats whom?** Worksheet. Show the **Functional Feeding Group PowerPoint** and discuss why organisms need food (i.e. matter for growth and reproduction and energy for life's processes) and how we can classify different organisms by their different feeding requirements. In this case, what kind of organisms or organic material do they need for food?

3. Present each major feeding group by showing the example pictures and videos and discussing how they feed. You should also discuss how different shaped mouthparts make different organisms suited to eat different things in different ways, i.e. shredding, scraping and collecting. There are notes in the PowerPoint to help in discussion. Have students answer questions 1 and 2 on the worksheet during the powerpoint.

> **Check Student Understanding**: Students may recognize predator-prey interactions, but not indirect interactions such as competition for resources. They also may not recognize how traits affect an organism's interactions. Talk to your students about how similar mouthparts may mean organisms have similar food requirement and thus may compete with each other even if they don't encounter one another.

4. The mayfly video provides an example of diversity within a group of organisms. There are more than 600 species of mayflies in North America, and not all of them are in the same functional feeding group. Showing students this video helps them think about the diversity within one of the larger groups they collected.

5. Students should record each organism group's feeding group on their **Who eats whom?** worksheet. If they don't remember from the video, you can have students use the **Stream Biology Briefs** reading individually, in groups, or as a class to find the feeding group for each type of organism found in their pack.

6. **Macroinvertebrate Cards activity:** Have the students pick out only the cards that were in their pack (or found by the whole class). Students should sort the cards by feeding group and construct a functional feeding group food web using the cards on their table. *If the packs have low diversity, have students use all of the cards or a subset of your choice.*

7. Many students are overwhelmed by building a food web if there are multiple groups of organisms of each feeding type (e.g. three types of collectors, 2 predators etc.) or because they are not familiar with decomposers. You may want to scaffold their food web construction by providing a copy of the **Food Web** template. They should draw the arrows to indicate matter-energy transfer themselves. Their web may still be incomplete as students might not add all producers or decomposers or vertebrates. These extensions will be added in Lesson 9.

   For advanced HS groups with two packs, you could have them either make two food webs or have half the class use their deciduous packs and have the other half use the coniferous packs.

> **Check Student Understanding**: Lower level students see feeding relationships in terms of life or death. You want to help your students see that feeding is about the transfer of matter and energy. Organisms need matter to grow and reproduce and energy to carry out the processes of life. Talk to your students about why they eat and how that is similar to what stream organisms eat.

8. Students should update the food webs they made in Lesson 2.

9. Students should answer the rest of the questions on the **Who eats whom?** Worksheet (except for the last question with the table). Update the class list of organisms: add a feeding group column.

10. Review the food web on the board (using the **food web poster** if needed) using the magnets (or post-it notes) and

> **Check Student Understanding**: Higher level students acknowledge that there is functional redundancy in communities (i.e. there is often more than one species that can perform a function) and higher level students also grasp the implications of functional redundancy (i.e. removing one species won't necessarily cause a food web to collapse). Talk to your students about functional redundancy – you may want to use the analogy of having several back-up quarterbacks on a football team.

lead a class discussion reviewing:

a. Why organisms need food (i.e. matter for growth and reproduction and energy for life's processes)

b. Where the different feeding groups of macro-invertebrates (i.e. predators and other consumers: scrapers, shredders, and collectors) get their food (i.e. each other, decomposers, or producers).

c. The answers to questions 8-11 on the **Who eats whom?** Worksheet.

11. Ask students to think about how the feeding actions of each group (e.g. removing prey organisms from the environment or breaking down organic material into smaller pieces) would affect abiotic factors in the stream. As a class, fill out the table in the final question of the worksheet describing these changes. The key is to think about what the food does when it is in the environment and then to speculate on what would happen when it is gone or broken down. This part is key to the unit- see the "Learning Progression Look For" at top right on next page..

12. You might choose to have students switch their food web with another group. The groups should point out 2 aspects of the other group's food web that they really like and 2 aspects that could be improved. We have found sharing food webs to be a great learning experience but it will add **an optional 10 minutes** to this lesson.

Check Student Understanding: Lower level students see that an organism is affected by its environment, but not that organisms affect their abiotic environment. Talk to your students about how individual organisms can modify the abiotic environment around them- for example, an increase in shredders would increase the turbidity of the stream. An increase in decomposers could reduce the oxygen levels (some students may have learned about eutrophication). Discuss with your students how small changes by many individuals can add up to big changes. For example, humans collectively are greatly increasing the amount of CO_2 in the earth's atmosphere. Another example is soil bacteria that make nitrogen available for plants. One bacteria doesn't do enough, but there are millions of bacteria in just a few tablespoons of soil have a large impact.

Assessment Ideas:

1. Exit ticket: Why do all organisms need food? Provide as many reasons as you can.
2. Exit ticket: Crane flies are shredders. How do they get their food? How do they change the abiotic environment as they get their food?
3. Show students various pictures of macroscopic organisms and have your class decide the role of the organism in the stream.
4. Show videos or pictures of different shredders, predators, collectors or scrapers and based on physical traits students may guess what role it plays in the stream environment. Add larger things if time permits like crayfish, snails, etc.

Lesson 8: Who eats Whom?

(student worksheet)

1. Why do organisms eat?

2. What do each of the following types of organisms eat?
   a. Predators:

   b. Scrapers:

   c. Shredders:

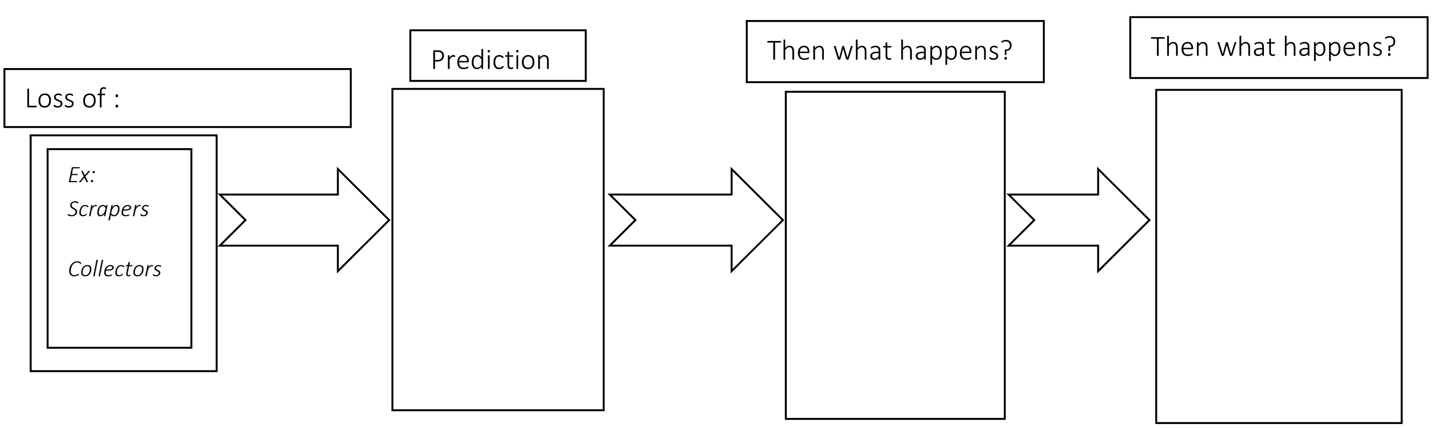
   d. Collectors:

3. Complete the "In the packs?" column in table below. Answer **yes** or **no** to whether it was found in your leaf packs. Look at the Macroinvertebrate cards and/or Stream Biology Briefs and determine how these organisms eat and complete the feeding group column.

Major Groups Common name (Scientific group name)	In the packs? Yes or No	Feeding Group Predator, Shredder, Collector, or Scraper
Stoneflies (Order Plecoptera)		
Dragonflies and Damselflies (Order Odonata)		
Mayflies (Order Ephemeroptera)		
Water Beetles (Order Coleoptera)		
True Flies (Order Diptera)		
Crane Flies(Order Diptera, Family Tipulidae)		
Dobsonflies and Alderflies (Order Megaloptera)		
Caddisflies (Order Tricoptera)		
Net-spinner Caddisflies(Order Tricoptera, Family		
Water mites (Order Acari)		
Scuds (Order Amphipoda)		
Sowbugs (Order Isopoda)		
Crayfish (Order Decapoda)		
Snails (Class Gastropoda)		
Clams and Mussels (Class Bivalvia)		
Leeches (Subclass Hirudinea)		
Aquatic Earthworms (Subclass Oligochaeta)		
Planaria (Class Turbellaria)		
Other		

5. Pick out the **Macroinvertebrate cards** of the organisms that were found. Sort these cards by feeding group (scrapers, collectors, etc).

6. Using the **Macroinvertebrate cards**, arrange them into a food web on your desk. Transfer all new organisms, their names and how they feed onto your original food web poster made back in **Lesson 2**.
7. What direction do the arrows go in your food web diagram? Why are they drawn that way?
8. How is the energy flowing? How is light energy transformed into chemical energy?
9. Where do we find stored chemical energy?
10. In which type of feeding group did you find the greatest number of organisms?
Why do you think that is?
11. Are there any feeding groups described in the Stream Invertebrate Biology Briefs that you did not find in your sample? What are some possible reasons for why that might be?
12. Pick one organism that you found in the stream (ex: mayflies). What feeding group is your organism in (shredder, scraper, etc)?
13. Use your food web drawing to predict what you think would happen to the other organisms found in the leaf pack if your chosen group of organisms did not exist in the stream. Use the boxes below to help organize your thoughts.



14. Complete the table below. Hint: The key is to think about what the food does when it is in the environment.

Feeding Group	What organism does this group eat? How does it get its food?	How will a decrease in that food affect the abiotic (nonliving) environment?
Scrapers		
Collectors		
Shredders		

Lesson 8: Who eats whom?

(Teacher Answer Key)

1. **Why do organisms eat?**
   - Provide cells with matter for growing and reproducing
   - So they have energy for living

2. **What do each of the following types of organisms eat?**
   a. **Predators:**
      - Other animals
   b. **Scrapers:**
      - Algae, bacteria, anything they can scrape off
   c. **Shredders:**
      - Leaves and algae, bacteria, and fungi which they remove from leaves as they break them into smaller pieces
   d. **Collectors:**
      - Small pieces of food and organic matter, like broken up leaves

3. Complete the "In the packs?" column in table below. Answer **yes** or **no** to whether it was found in your leaf packs.

4. Look at the Macroinvertebrate cards and/or Appendix A and determine how these organisms eat and complete the feeding group column.

Major Groups **Common name (Scientific group name)**	**In the packs?** Yes or No	**Feeding Group** Predator, Shredder, Collector, or Scraper
Stoneflies (Order Plecoptera)		*Mostly predators*
Dragonflies and Damselflies (Order Odonata)		*predators*
Mayflies (Order Ephemeroptera)		*Collectors*
Water Beetles (Order Coleoptera)		*Scrapers*
True Flies – includes midges (Order Diptera)		*Collectors*
Crane Flies(Order Diptera, Family Tipulidae)		*Shredders*
Dobsonflies and Alderflies (Order Megaloptera)		*Predators*
Caddisflies (Order Tricoptera)		*Shredders and predators*
Net-spinner Caddisflies(Order Tricoptera, Family		*Collectors*
Water mites (Order Acari)		*Parasites/predators*
Scuds (Order Amphipoda)		*Shredders*
Sowbugs (Order Isopoda)		*Collectors*
Crayfish (Order Decapoda)		*Predator and collectors*
Snails (Class Gastropoda)		*Scrapers*
Clams and Mussels (Class Bivalvia)		*Collectors-filter feeders*
Leeches (Subclass Hirudinea)		*Predators*
Aquatic Earthworms (Subclass Oligochaeta)		*Collectors*
Planaria (Class Turbellaria)		*Predators*
Other:		

5. Pick out the **Macroinvertebrate cards** of the organisms that were found. Sort these cards by feeding group (scrapers, collectors, etc).

6. Using the **Macroinvertebrate cards**, arrange them into a food web on your table. Transfer all new organisms, their names and how they feed onto your original food web poster made back in **Lesson 2**.
7. **What direction do the arrows go in your food web diagram? Why did you draw them that way?**
8. **How is the energy flowing? How does light energy transfer into chemical energy?**
9. **Where do we find stored chemical energy?**
    - Arrows should move up from producer to consumer (matter).
    - Arrows should also show energy moving in the same direction (energy).
    - Light is transferred into chemical energy by plants and photosynthesis.
    - Find stored chemical energy in the bonds making up sugar, proteins, carbohydrates and lipids (refer to chart in lesson 2).
10. **In which type of feeding group did you find the greatest number of organisms? Why do you think that is?**
- Answers will vary but the why could be because there was more food, better conditions (abiotic), predation, competition, etc.
11. **Are there any feeding groups described in the Stream Invertebrate Biology Briefs that you did not find in your sample? What are some possible reasons for why that might be?**
- Answers will vary and so will the reasons.
12. Pick one organism that you found in the stream (ex: mayflies). What feeding group is your organism in (shredder, scraper, etc)?
13. **Use your food web drawing to predict what you think would happen to the other organisms found in the leaf pack if your chosen group of organisms did not exist in the stream?**

Loss of :	Prediction	Then what happens?	Then what happens?
Scrapers	Would decrease the available oxygen in the stream by killing the algae	…then organisms that live in the stream that need higher amount of O2 would move or die	…then larger organisms that live in the stream would lose a food source …or lower O2 organisms rise due to less competition

10. Complete the table below. Hint: The key is to think about what the food does when it is in the environment.

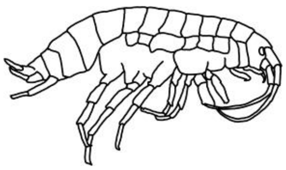
Feeding Group	What organism does this group eat? How does it get its food?	How will a decrease in that food affect the abiotic environment?
Scrapers	Algae. They scrape the algae off of surfaces.	Algae are producers that make their own food using photosynthesis. Producers release O2 when they make food. A decrease in algae will lead to a decrease in O2 in the water.
Collectors	Bits of organic matter and small organisms floating in the water. They take the floating bits out of the water	Bits of organic matter and small organisms floating in the water make the water cloudy turbid). A decrease in the bits in the water will lead to the water being clearer. This will let more sunlight into the water (more heat or more photosynthesis).
Shredders	Bacteria and fungi on leaf surfaces. They tear up leaves into small pieces.	Shredders tear up leaves into small pieces. This leads to an increase in sunlight. For example, in wetland ecosystems where this does not occur quickly, leaves pile up and hinder light availability. Bacteria and fungi are decomposers. Decomposers are messy eaters that leave a lot of nutrients in the water. A decrease in bacteria and fungi will decrease the amount of nutrients in the water

Stream Biology Briefs

(From Maryland DNR)

In aquatic ecosystems, scientists often categorize organisms by how they feed. This includes observation of the organisms in their habitat, and examining them under a microscope to investigate their morphology; the study of the form, structure and configuration of an organism. This includes aspects of the outward appearance (shape, structure, color, pattern) as well as the form and structure of the internal parts like bones and organs.

CLASSIFICATION BY FEEDING GROUP

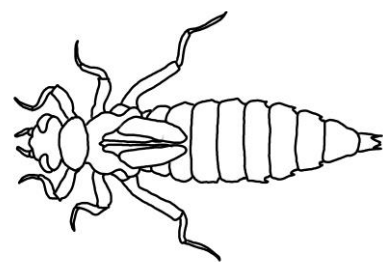


Shredders: These animals take detritus, such as leaves, and break it into smaller particles or "skeletonize" it. Microbes colonize the leaf litter first, followed by the larger invertebrates such as the cranefly, some caddisflies & stoneflies, and amphipods (at left). The crane fly breaks down the leaves from the trees and makes the energy and nutrients in the leaves available to other aquatic organisms.

Collectors (both gathering and filtering): Some organisms are filter-feeders, spinning nets to catch fine particles of detritus. Others feed on detritus at the bottom of streams and ponds. These animals include the net-spinning caddisfly, blackfly larvae, midge larvae, clams, and some mayflies. Net-spinner caddisflies construct a mesh net for filter feeding, but this net is usually destroyed during collection. Black fly larvae and midge larvae have "fans" on their heads to capture material floating in the water. Some scientists separate out the scavengers from this group, but we will include scavengers.

Scrapers: Scrapers include animals that have mouthparts they can use to graze on hard surfaces such as rocks. They have to be strong to hold onto the surface while they feed. Many of these animals have a hard shell (such as the snail or water penny) to protect them from the high energy of the water. The water penny scrapes diatoms from the surface of rocks and then eats the material as it moves, since it is sheltered from the current by the hard plates. These animals include most snails, the water penny beetle, and some mayflies.

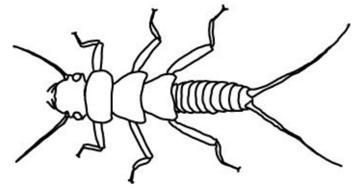
Predators: These animals have large mouthparts consisting of two opposing jaws which they use to kill other smaller invertebrates. Dragonflies (at right), damselflies, and the dobsonfly are part of this group. Dragonflies and damselflies have a large, extendable lower "lip" (labium) that can engulf very large prey, with mature dragonflies sometimes eating small fish. This lip covers the other mouthparts of the larvae, allowing it to capture large animals and tear pieces of their prey while still moving around on all six legs. Some scientists separate out parasites from this group, but we will include them here.



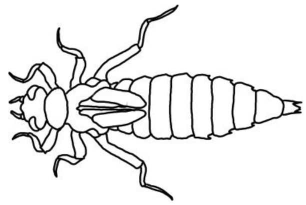
Decomposers: These organisms colonize leaf surfaces and use the leaves for food: microbes such as bacteria and fungi.

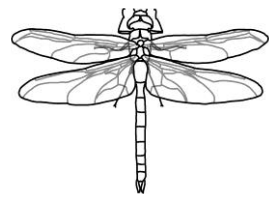
Producers: These organisms do photosynthesis. They make their own food, using sunlight to transform carbon dioxide and water into sugar plus oxygen. Producers include trees, diatoms, and algae.

Stoneflies (Order Plecoptera)- Most stonefly are predators; some are shredders. Mouthparts determine whether they are shredders or predators. Shredder mouthparts are directed downward and are shaped for cutting and grinding, while predator mouthparts project forward and are very sharp and pointed. Common prey are midges and black flies along with mayflies. Lives in water with 8-12 mg/L of dissolved oxygen.

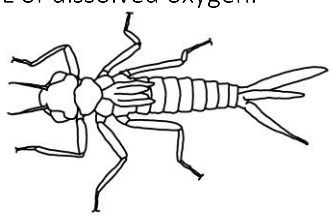


Dragonflies (Infraorder Anisoptera; order Odonata) – Predators of anything smaller-as young larvae they eat mostly zooplankton, and as they grow larger they will eat mayflies and even small fish. Lives in water with 4.1-7.9 mg/L of dissolved oxygen.

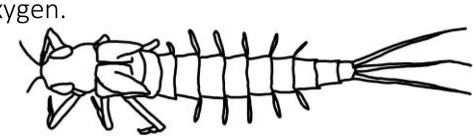




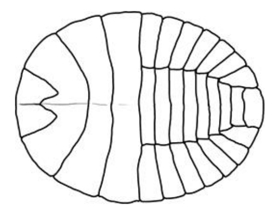
Damselflies (Suborder Zygoptera; order Odonata) – Aquatic nymphs hatch from eggs that are laid in the water. Many overwinter as nymphs, which crawl up on vegetation in the spring to emerge as adults. They are predators and live in water with 4.1-7.9 mg/L of dissolved oxygen.



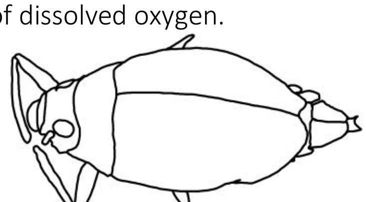
Mayflies (Order Ephemeroptera) – Overwinter as aquatic nymphs. Diet is mostly algae or detritus; mayflies are either collectors or scrapers (76% of the families are collectors, 19% are scrapers, and 5% are predators). Lives in water with 8-12 mg/L of dissolved oxygen.



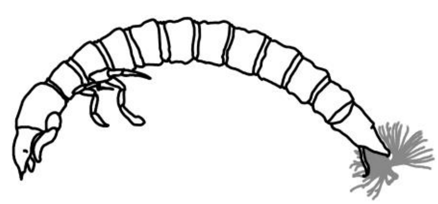
Water penny beetle (Order Coleoptera) – Flat shaped beetle that often curls up when disturbed, and has a strong grip to allow it to move across surfaces in highly turbid water. Water pennies are scrapers who graze on algae on rocks. Lives in water with 8-12 mg/L of dissolved oxygen.



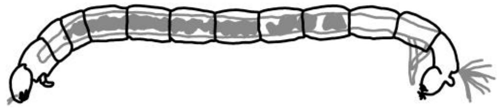
Whirligig Beetles (Order Coleoptera) - Beetles that swim on the surface or underwater and are primarily collectors. Lives in water with 8-12 mg/L of dissolved oxygen.



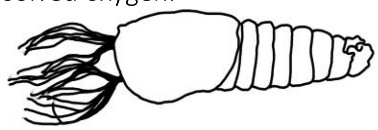
Riffle beetles (Order Coleoptera) – Small, torpedo-like larva with circular stripes or rings around the body, they are primarily collectors that eat diatoms and algae. Lives in water with 8-12 mg/L of dissolved oxygen.



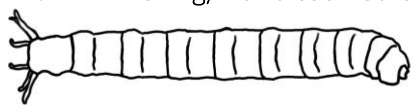
Midge larvae (Family Chironomidae, Order Diptera)- Collectors that filter organic components of sediment & algae. Lives in water with less than 4.0 mg/L of dissolved oxygen.



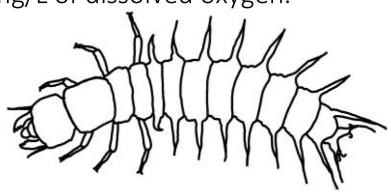
Blackfly larvae (Family Simuliidae, Order Diptera)- Collectors; they hold onto the substrate with tiny hooks and then extend a foldable "fan" into the stream, filtering particles of food (bacteria, detritus, algae) into the fan which is then scraped into its mouth every few seconds. Larvae are very small – between 3 and 12 mm long. Lives in water with less than 4.0 mg/L of dissolved oxygen.



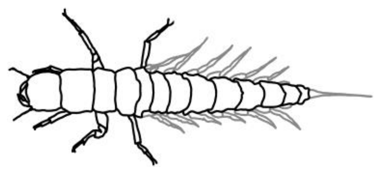
Crane Fly Larvae (Family Tipulidae, Order Diptera)- shredders; break down leaves from trees. Crane fly larvae often look like large worms or maggots, and can be up to 2" long (10-100mm). (Crane fly from genus *Hexatoma* are engulfer-predators.) Lives in water with 4.1-7.9 mg/L of dissolved oxygen.



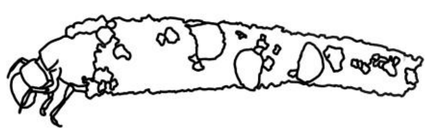
Dobsonfly larvae (also called Hellgrammite; Subfamily Corydalidae, Order Megaloptera)- Predators of any small invertebrate. Lives in water with 4.1-7.9 mg/L of dissolved oxygen.



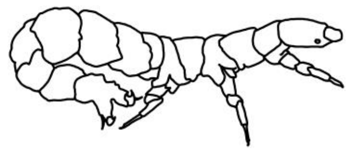
Alderflies (Order Megaloptera) – Aquatic larvae are active predators that feed on aquatic insects, worms, crustaceans, snails and clams. All are predators. Lives in water with 4.1-7.9 mg/L of dissolved oxygen.



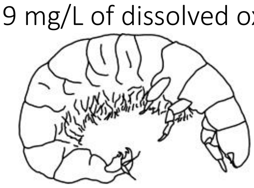
Caddisfly larvae- case makers (Order Trichoptera)- most caddisflies that construct cases of small stones are shredders of detritus and algae. Lives in water with 8-12 mg/L of dissolved oxygen.



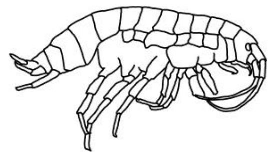
Free-living Caddisflies (Order Trichoptera)- are mostly predators of smaller invertebrates or scavengers. Lives in water with 8-12 mg/L of dissolved oxygen.



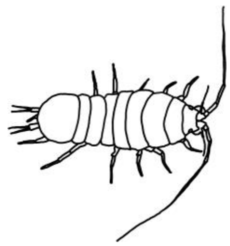
Net spinner Caddisfly (Order Trichoptera; Family Hydropsychidae) – Collectors who spin nets to catch fine particles of detritus. Lives in water with 4.1-7.9 mg/L of dissolved oxygen.



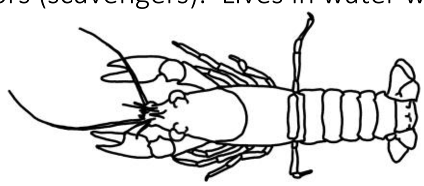
Scud (Order Amphipoda; also called sideswimmers and amphipods)- Shredders who eat mostly detritus, algae, bacteria, and any recently dead organisms. Lives in water with 4.1-7.9 mg/L of dissolved oxygen.



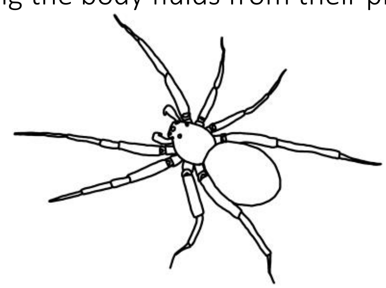
Sowbugs/Pill bugs (Order Isopoda) – Eat a variety of decaying organic matter. Most are collectors. Lives in water with 4.1-7.9 mg/L of dissolved oxygen.



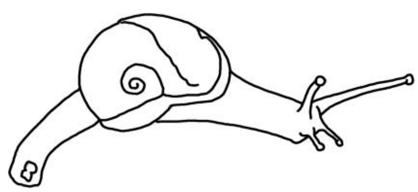
Crayfish (Order Decapoda)- omnivores, primary food is decaying vegetation but will eat anything they can subdue; they are predators and collectors (scavengers). Lives in water with 4.1-7.9 mg/L of dissolved oxygen.



Spiders (Class Arachnids) - Feed by sucking the body fluids from their prey; predators.

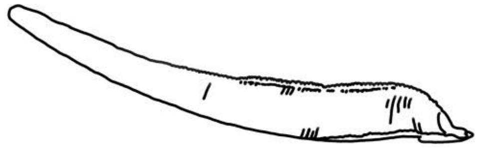


Snails (Class Gastropoda) – Snails scrape algae and other organic matter from ponds substrates. Most snails are scrapers. Gilled snails live in water with 8-12 mg/L of dissolved oxygen, lunged snails can live in water with less than 4 ml/L of dissolved oxygen.

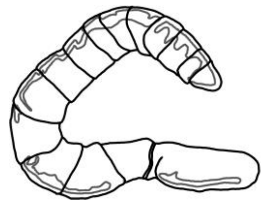


Clams and mussels (Class Bivalvia) – Clams & mussels are filter feeders that live on phytoplankton, zooplankton, detritus and bacteria. They are collectors. Lives in water with 4.1-7.9 mg/L of dissolved oxygen.

Leeches (Subclass Hirudinea) – Worm-like, soft-bodied organisms with not legs and suckers at either end of the body that attach to hosts and suck fluids from other animals. They are predators (or parasites). Lives in water with less than 4.0 mg/L of dissolved oxygen.

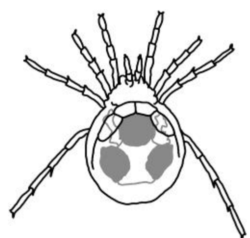


Aquatic Earthworms (Order Oligochaeta) – Most eat detritus, algae and bacteria; these are collectors. Lives in water with less than 4.0 mg/L of dissolved oxygen.



Planaria (Class Turbellaria)- Also called flatworms; predators of soft-bodied invertebrates.

Water mite (Subclass Acari) – These small, tick-like animals live on land and in water. They are parasites or predators of other organisms.



Small arthropods and other protists: mostly consumers (omnivores) that eat small arthropods, protists, bits of detritus, algae etc.

References:

Voshell, J.R. 2002. *A Guide to Common Freshwater Invertebrates of North America*. McDonald & Woodward Publishing Company, Virginia.

Thorp, J.H. & A.P. Covich. 2010. *Ecology and Classification of North American Freshwater Invertebrates*. Elsevier, Amsterdam.

Lesson 9— Exploring Your Data

Instructional Goal

At the end of this lesson, SWKABAT:

a. Explain how variability originates, and how both induced and real error are components of variability.
b. Select which set of samples has more variability.
c. Explain why identifying variability and its potential sources is important when analyzing data, and how different amounts of variability allow you to be more or less confident about a claim.
d. Make a claim, supported by appropriate evidence, to explain the differences in their leaf packs using evidence and reasoning about the components of the ecosystem.

Next Generation Science Standards Addressed

Science & Engineering Practices:

Analyzing & Interpreting Data
Using Mathematics & computational Thinking
Constructing Explanations
Engaging in Argument from Evidence
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:

HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:

Patterns
Systems & System Modela

Common Core Standards Addressed:

Mathematics:

Quantities- Reason quantitatively and use units to solve problems
Mathematical Practices- Reason abstractly and quantitatively
Attend to precision
Model with mathematics
Construct viable arguments and critique the reasoning of others

Materials

- Copies of student handout
- Plastic bags filled with two different colors of beans (enough bags for each pair of students to have one)
- 10 leaves from the same tree (or 10 pine needles, pine cones, blades of grass, etc)
- Computer or overhead projector.
- Beans Example Template (Excel datasheet)
- Biodiv 2012 TE Les 5 and 7 Class Template - Exploring your data.xlsx (Excel datasheet). There is also a filled out spreadsheet with example data for your reference or if your class data collections don't work out.

Advance Preparation

Prepare a bag for each pair (or group) of students that has two different colors of dried beans (any two colors will work). You want to have enough beans in the bag so that students need to take the beans out of the bags and carefully count them. We suggest bags of 20-30 beans per color. Each bag needs to have the same amount of beans- but don't tell the students this! You will limit the amount of time it takes them to count the beans, and providing a distraction while they are counting can also be helpful. We suggest giving students 30 seconds to count if you use 20-30 beans per color. This reminds students how easy it is to make mistakes when you aren't paying close attention! For a fun introduction to this idea, consider watching the "Gorilla in the Room" video: http://www.youtube.com/watch?v=m_8nJZ_VUKY . This video shows two teams of students (team white vs team black) passing basketballs. Students are asked to count how many times the white team passes their ball. Most students will completely miss the gorilla that walks into the middle of the basketball court during the 1-minute exercise.

Lesson Procedure

1. Students should group their results based on feeding type (which they discovered in Lesson 6) and complete the first chart on the worksheet (**My group's data**).
2. Using this information, students should make a graph of their group's pool or riffle data. Depending on your students, you can have them use the space in the worksheet to make the graphs, their own graph paper, or use Excel. This will allow the students to begin thinking about variability between their invertebrate feeding groups.
3. Share the graph results. Ask students: Why do you think there were differences between the number of organisms from each feeding group found in their group's bag? Spend some time on the answers – students may offer ideas about dispersal, food availability, competition, habitat preference, etc. Students may also think about other types of error, such as human error.
4. Students should now turn to another group and share their results. Did they find the same results? For example, did both groups have more shredders than anything else? Did they have the same number of predators? Ask students to brainstorm some ideas about why their results might be different – start a list on the board. Ideas might include differences between the bags or location of the samples, but could also relate to sampling effort, size, accuracy of counting the results, etc.
5. To introduce these ideas, give each pair (or group) of students a bag of beans. Give students a defined amount of time (less time if you have fewer beans) and ask them to count all of the beans in the bags. Don't allow students to recount their beans. The students should write their results up on the board.
6. Compare and discuss the students' results – are they the same? Do some counts differ? Why? What are some reasons for the differences – could it be due to human error, or actual differences between the bags?
7. Next, provide students with the natural objects – leaves, pine needles, etc. They should have enough of the objects so that when they compare them, they are similar but not exactly the same. Ask students to measure the diameter of the leaves or the lengths of the pine needles, and record the results. Students should share their results. Ask: Why are there differences between the leaves? Are these differences due to the leaves, or to human error?
8. Place this chart up on the board, and fill in with student help (students have a copy of this chart in their packet). Ask students to think about potential error with their macroinvertebrate counts. Some examples are included below.

Real *– what might be some sources of variability that are due to the ecosystem?*	***Induced (experimental)*** *– variability due to human error, sampling error, tool error*

• *Sampling during different times of year might provide different results* • *Different invertebrates might have preferences for different types of leaves* • *Temperature or water flow might affect which organisms are in the stream, or which organisms where able to stay attached to the leaves* • *Our bags might have been made of a type of material that invertebrates don't like*	• *We could have counted wrong* • *We might not have sampled enough* • *The bags we used might have had a mesh size that is too small to let in some invertebrates* • *Our bags may not have been submerged for long enough* • *Our bags might have been filled with too many leaves*

9. Show students the "Beans Example Template" that gives an example of the bean data – this spreadsheet will show you an example of the activity. First, you can see the bean counts individually (as a scatter plot), the averaged bean counts (bar graph), and a bar graph with error bars. Ask students to explain the benefits and drawbacks of the different types of graphs. Students should recognize that error bars allows them to have some information about the range of the data in the sample, similar to a scatter plot, but with the additional benefit of knowing the average of the set of data.

10. Students should share their macroinvertebrate results (there is a chart for all the class data, separated into feeding groups) with the class, creating a class data set that shows scrapers, predators, shredders, and collectors.

11. Students should graph their class results by feeding group. A template is provided in their packets, and an Excel template is also provided for your use. The "Class Template Lesson 7" will allow you to demonstrate both the difference between graphing an average versus all of the samples in a dataset, and the use of error bars to explore the variability between groups.

12. TEACHER'S NOTE – Sample size, replication, and the knowledge that nature is variable are important issues in scientific studies. Sample size (also known as sampling effort) will dictate whether you get just the most common organisms or if you pick up some of the rare ones. Generally, we need to do replicate samples to get a sense of the variability (here you would calculate both averages & standard deviations) between samples. Low variability (small standard deviations) gives you confidence to make predictions from your data. Depending on your students you may wish for them to calculate standard deviations. Excel will also calculate standard deviations using the =STDEV() function.

13. Once students have explored the ideas of variability, they should review their data on the abiotic conditions of the stream and think about whether these data can help them explain any of the differences they found in the leaf packs.

<u>Exit Ticket:</u>

Look at the graph that your teacher has created of all of your class data, with the error bars. How is this graph the same, and how is it different, from the one you made of the averages? Explain.

Lesson 9 - Exploring Your Data

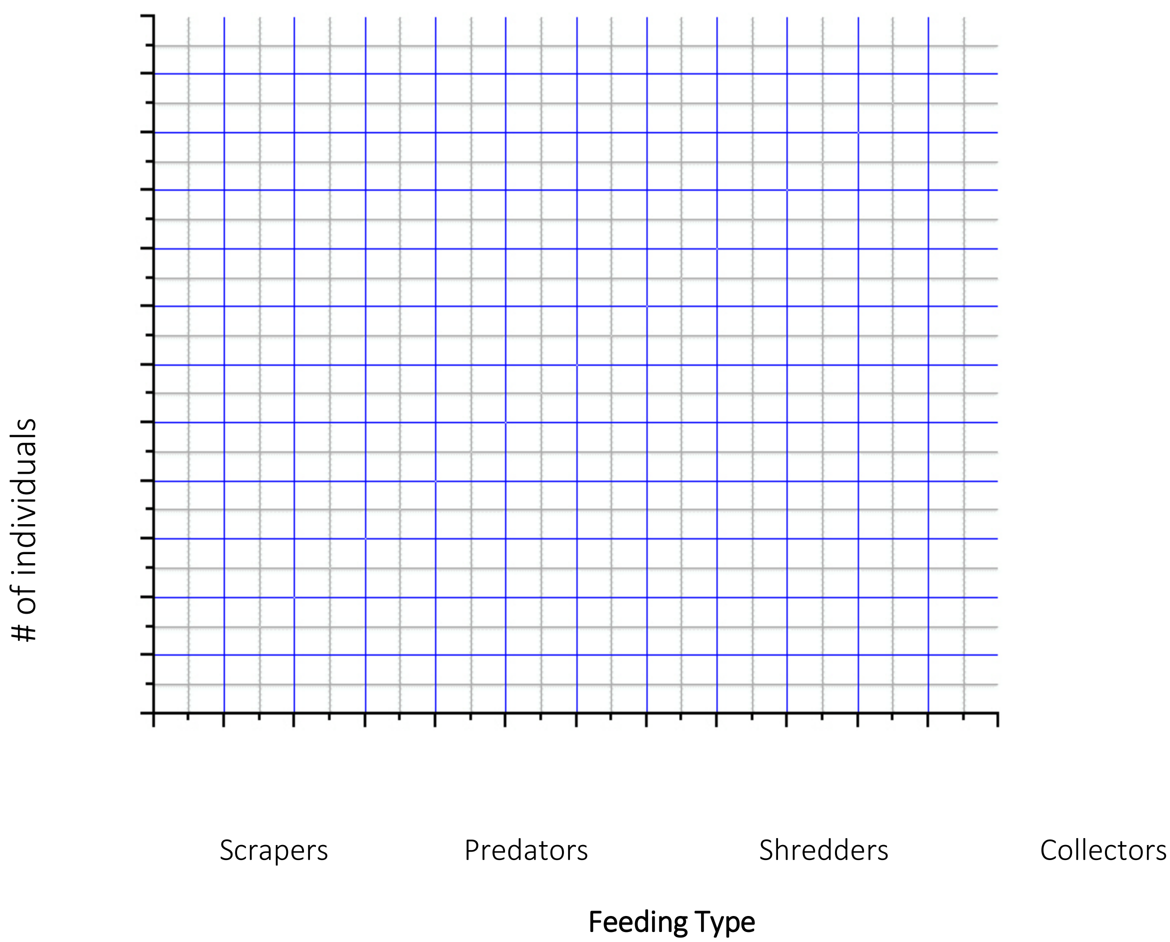
(student worksheet)

Name: ___________________________

My group's data: Record the summary data in the table below from your leaf pack. If your group investigated more than one leaf pack, use other spaces. Otherwise, leave that blank. You'll fill this in with your class data later. (If you only have one leaf pack, you don't need to worry about the "average" column.)

Feeding Type	# Individuals in Pool #1	# Individuals in Pool #2	*Average*	# Individuals in Riffle #1	# Individuals in Riffle #2	*Average*
Scrapers						
Predators						
Shredders						
Collectors						

1. Make a graph of just the pool or just the riffle data. You want to compare the differences between the bags to see how variable the groups were. You can use the graph template below, your own graph paper, or the Excel workbook for graphing. Remember to label your graph correctly.



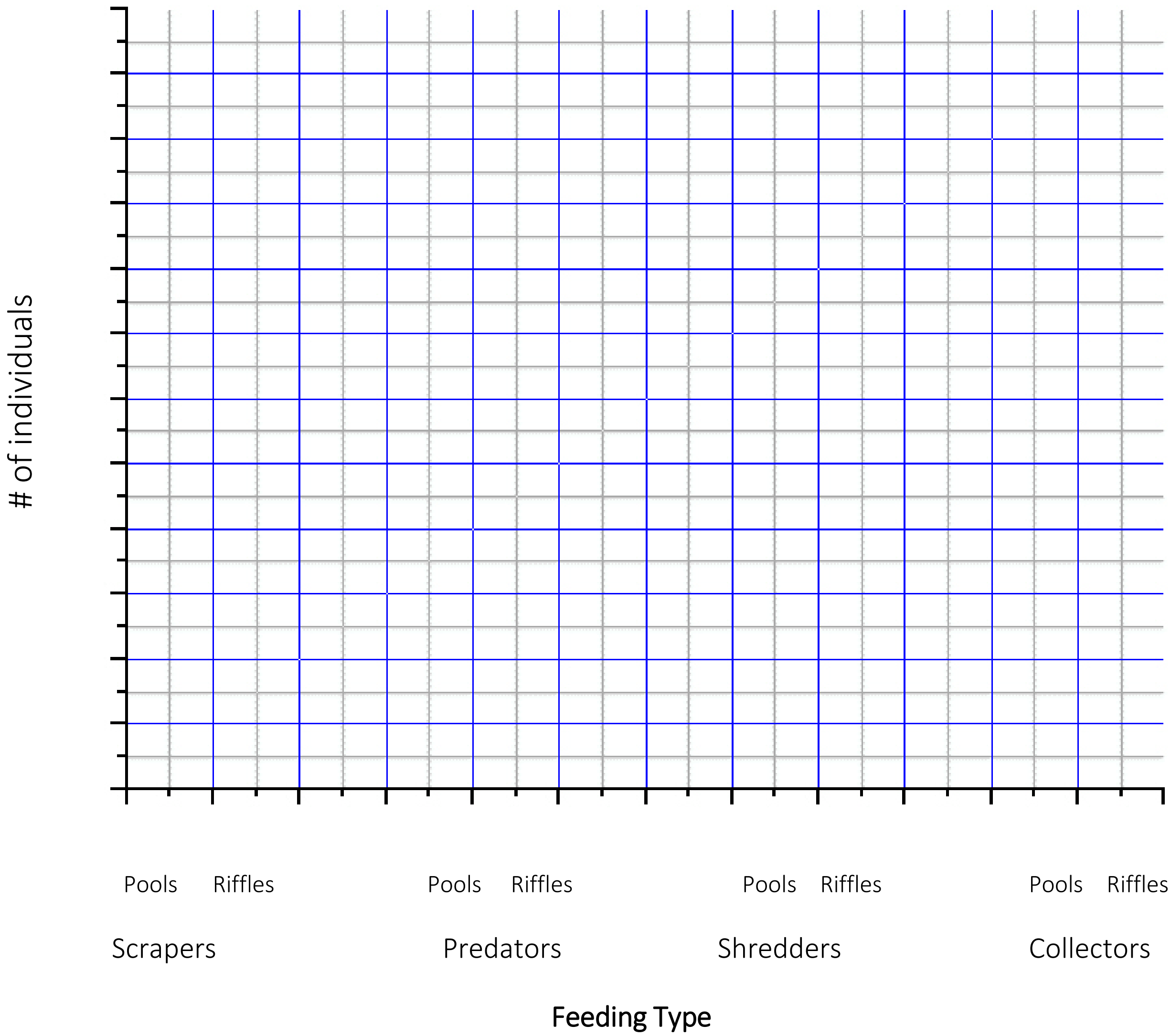
2. List the potential sources of variability in your investigation.

Induced (experimental) *– variability due to human error, sampling error, tool error*	***Real*** *– what might be some sources of variability that are due to the ecosystem?*

Your class data: Record the class data below, making sure to keep pool and riffle data separate.

Pool				
Group Name	Total # Scrapers	Total # Predators	Total # Shredders	Total # Collectors
John & Mary	*8*	*3*	*1*	*1*
Totals				
Class Data Average				
Riffles				
Group Name	Total # Scrapers	Total # Predators	Total # Shredders	Total # Collectors
Totals				
Class Data Average				

Now, make a graph of your class data, showing the average number of organisms in each group for the bags left in the riffles and bags left in the pools. You can use this template, the Excel template, or your own graph paper.



3. Are there any patterns that you notice between organisms that are found in pools vs riffles?

4. Look at the individual data that you used to create your averages for the graph. Which feeding group has the largest amount of variability? Does this variability make you more or less confident about your average? Why?

5. What are you missing when you see a graph of averages, instead of a graph of all of your data?

6. How confident are you in using your class data to predict what the invertebrate community of a stream 20 miles away will look like? Think about the sources of variability that you explored when doing the bean counting activity. Explain your reasoning.

7. Which groups of organisms are likely to be found in pools? In riffles? Support your claim using evidence from your class experiment and explain the reasons why this claim makes sense. Remember to think about the abiotic data.

Lesson 9 - Exploring Your Data
(teacher answer key)

2. List the potential sources of variability in your investigation.

Induced (experimental) *– variability due to human error, sampling error, tool error*	***Real*** *– what might be some sources of variability that are due to the ecosystem?*
• *We could have counted wrong* • *We might not have sampled enough* • *The bags we used might have had a mesh size that is too small to let in some invertebrates* • *Our bags may not have been submerged for long enough* • *Our bags might have been filled with too many leaves*	• *Sampling during different times of year might provide different results* • *Different invertebrates might have preferences for different types of leaves* • *Temperature or water flow might affect which organisms are in the stream, or which organisms where able to stay attached to the leaves* • *Our bags might have been made of a type of material that invertebrates don't like*

3. Are there any patterns that you notice between organisms that are found in pools vs riffles?
Answers will vary. Students should find organisms with higher oxygen requirements (stoneflies, caddisflies, mayflies), in riffles but not in pools.

4. Look at the individual data that you used to create your averages for the graph. Which feeding group has the largest amount of variability? Does this variability make you more or less confident about your average? Why?
Answers will vary. Students should mention that the more variability they have in a sample, the less confident they are about the average. Higher variability means that there is a greater probability that more data will provide a different result, or that there are many additional, unaccounted for variables.

5. What are you missing when you see a graph of averages, instead of a graph of all of your data?
If you see a graph of averages, instead of all of the data, you do not see the individual data points and you miss the variability.

6. How confident are you in using your class data to predict what the invertebrate community of a stream 20 miles away will look like? Think about the sources of variability that you explored when doing the bean counting activity. Explain your reasoning. **Student answers may vary. They may be very confident if they did not have much variability within the bean counting example; however, most students should not be confident because of the potential error, both induced and real.**

7. Which groups of organisms are likely to be found in pools? In riffles? Support your claim using evidence from your class experiment. Remember to think about the abiotic data. **Student answers will vary based on their evidence; students should back up their answers with evidence.**

Lessons 10 and 11— What lives in leaf packs? Let's look closer (Two day lesson)

Instructional Goal

At the end of this lesson, SWKABAT:

a. Observe microscopic life
b. Recognize that diversity of microscopic life exists
c. Group microscopic life based on feeding group
d. Know that decomposers are organisms that live in the stream and break down dead things
e. Explain that decomposers get food to obtain matter and energy, just like other consumers do
f. Explain that when decomposers get their food they don't take up everything from the environment that they digest, so some minerals and other useful molecules are left in the environment to be taken by other organisms

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Scale, Proportion, and Quantity
Structure & function

Maryland Environmental Literacy Standards Addressed

Standard 3: Flow of Matter & Energy Topic A: Conservation of Matter Within Earth Systems
Standard 4: Populations, Communities, & Ecosystems Topic E: Diversity

Materials

- **Decomposer** PowerPoint presentation (Biodiv 2012 TE Les 8 Decomposers.pptx) and projector to display it
- Copies of "What Lives in Leaf Packs? Let's look closer" chart
- Stream organism poster from Lesson 1
- To explore microscopic life, at least one of the following is needed:

  Option A: Exploration using video compound microscope or Compound microscopes (1 per pair or small group)
    - Copies of **Life in a Drop of Water** key (obtain this document from your research contact)
    - Slides (regular or depression) and cover slips
    - Pipettes
    - Water samples from stream with one or two leaves in each jar sample (one or two per leaf type) to feed microbes.
    - Demoslides
    - Alcohol or Protoslo to slow down microbial movement

  Option B: Virtual Exploration
    - "Life in a Drop of Water" full video at: http://streaming.discoveryeducation.com/ if you have a subscription or some clips free at: http://vimeo.com/222273, http://vimeo.com/246258 (http://vimeo.com/2721563, (unable to download to CD, use links to access videos)
    - Computer classroom, have students explore "The smallest page on the web" http://www.microscopy-uk.org.uk/mag/wimsmall/smal3.html

- Other videos are available in the resources section – look for videos titled "Lesson 8: Decomposers"

- To explore bacteria and/or fungi in the water samples, one of the following is required:
  Option A: Bacteria culture activity
  - Pond water
  - Slide and cover slip
  - Microscope

  Option B: Jell-O Culture activity
  - 1-2 3 oz boxes of flavored Jell-O or clear Gelatin
  - Bowl
  - Spoon
  - Boiling water
  - Measuring cup
  - For each pair of students: 3 Petri dishes or clear containers with flat bottoms
  - Hand lenses, optional
  - Decomposing leaves from the leaf pack

Advance Preparation

Make copies of **What lives in leaf packs? Let's look closer** chart and the **Life in a Drop of Water** key. Download **Decomposers** ppt presentation. If you are using microscopes of any kind you will need to save water samples from Lesson 3; store samples with one or two leaves in each jar sample (one jar or two jars per leaf type) and prepare materials for students.

Jell-O Culture activity: Make Jell-O by combining one cup boiling water with the packet of Jell-O, then add a cup of cold water to the mixture. Pour into the Petri dishes, filling them about half way. Cover immediately. Ideally, allow the Jell-O to set in a refrigerator.

Lesson Procedure

1. Start by asking students what type of organism was missing from the food web they constructed in Lesson 3. Tell them today they will be taking a closer look at some other organisms that lived in their leaf packs.
2. Give groups of students a sample of leaves; ask them to look closely at the leaves and make observations about them. They may be several days old at this point, but it should still be hard for students to see anything 'alive' on the leaves (unless they didn't remove all organisms carefully).
3. Hand out the "What lives in leaf packs? Let's look closer" chart for students to keep track of data. Remember to add your class data to your master organism list of stream organisms.
4. Exploring microscopic life-

   Option A: Exploring microscopic life in person.
   Using the video scope and/or individual microscopes, have students observe and identify different types of microorganisms found in their leaf packs (using the **Life in a Drop of Water** key). Record the organisms the class observes by updating the classroom list. Students will not be using these data in a quantitative way so there is no need to count organisms or be very precise in identification. The goal here is for students to understand there is a huge diversity of life they cannot "see".

   *Having students create their own slides and investigate microscopic organisms using individual microscopes will increase the length of this lesson by at least **20 minutes**.*

> **Check Student Understanding**: Ask students: What happened to the leaves while they were in the stream? How does a leaf go from being "perfect" when it falls from the tree to "disappearing"? Students know about decomposers, but often don't invoke them to explain how a leaf changes over time. They also don't understand where the mass of a leaf goes- i.e. that it is eaten by microbes. Most students will simply say that the leaf 'disappears'. This is a connection to the carbon strand- remind students of principle of conservation of matter.

WET MOUNT INSTRUCTIONS: Scrape the surface of a few leaves into a small amount (25 ml or less) water. Observe both this water and water that collected in the bottom of the zip loc bags for microscopic organisms. Place a few drops of the water on a slide and put a cover slip on top. If possible, include some decaying leaves or bits of plant matter, as they will prevent the small organisms from being squashed. Look at the slide under your microscope starting at low power. Look near the decaying leaves , and try to find living organisms -- if the protists or small animals are moving they probably are alive.

After observing the organisms swimming around in the water, you may want to use Protoslo or a drop of alcohol to slow down the protists so that you can see them better. Put one tiny drop of Protoslo on a clean slide. Then, place a drop of pond water on top of the Protoslo and mix gently with a toothpick. Place a cover slip over the solution. Examine the slide under low power first to find moving objects. Then, increase to medium and high power.

Option B: Exploring microscopic life virtually. If you don't have a video scope you may consider showing a few minutes of the "Life in a Drop of Water" video or "The smallest page on the web" to give students an idea what lives in aquatic systems.

5. Discuss the feeding roles of the various organisms. Small arthropods and other protists are mostly consumers (omnivores) that eat small arthropods, protists, bits of detritus, algae etc.; Protists with chloroplasts (euglena, algae) are producers.

6. Exploring bacteria and/or fungi in water –

   Option A: Bacteria Culture Activity: Place a cover slip on the surface of pond water. After one night whole colonies of bacteria will grow on the underside of the cover slip. Carefully place the cover slip on a slide (an extra drop of water may be added), and observe the growth with the 40x or 100x objective.

   Option B: Jello Culture Activity: When the Jello is ready, have students add small bits of leaves to the top of the Jello. Leave the dishes in an undisturbed area of the classroom. Within 4-7 days students will see the fungal hyphae (and some bacteria colonies if they are lucky) growing out to eat the already digested simple sugars in Jell-O (plus the more complex proteins). If you'd like to turn this into more of an "experiment", you can have students culture different items to help them understand that microbes live in different densities on different items (rocks, penny, piece of paper etc). Keep at least some of the Jello dishes empty to ensure a control.

7. After students are done observing with microscopes or watching the video tell them you are going to show them pictures taken with an even stronger microscope so they can see even smaller organisms that live on leaves in the water. Show the **Decomposer** ppt presentation and discuss the role of these organisms in decomposing leaves. There are notes in the notes section of the ppt to help guide discussion. Update the organism list started in Lesson 1 with these microscopic organisms.

   The big take-home messages with respect to microorganisms are these:

   1. Microorganisms are everywhere and they are present in numbers so large we can't even comprehend them.

> **Check Student Understanding**: Ask students to make observations of their Jello dishes each day, writing down which Petri dishes had growth and which didn't. Ask students to explain why there was a lot of growth in the dishes that had the leaves from the stream. Ask students to predict where microbes might live, besides the items that were tested in this activity. Helping students understand the diversity of life is important, as well as helping them understand the connections between microbes and the broader food web.

2. Bacteria and fungi are evolutionarily and morphologically different, but perform many of the same metabolic functions. They are the true decomposers—they release nutrients and carbon back into the environment from dead organic material, so that other organisms can use those compounds again (e.g. plants).

Students can usually name "bacteria" and "fungi" as examples of microorganisms. It is important to stress that there are many more "good" or harmless bacteria than there are "bad" or pathogenic ones. You may also want to highlight the major differences between bacteria and fungi. Bacteria are in their own domain of life, whereas fungi are in the same domain we are—Eukarya. Thus, humans are more closely related to fungi than they are to bacteria. Bacteria are single-celled organisms, whereas most fungi are multicellular. Bacteria do not have a nucleus in their cells, but fungi do. What they do have in common is that their genetic information is contained and transferred in DNA.

> **Check Student Understanding**: Students typically do not recognize (1) the existence of microorganisms (both decomposers and other microscopic organisms) and (2) the role those organisms, decomposers in particular, play in ecosystems. Students tend to think of organisms such as earthworms or small invertebrates as decomposers – this lesson helps clarify that idea to include the broader suite of microorganisms. When it comes to nutrients like nitrogen, it is sufficient to think of decomposers as "messy eaters." This will help students understand how microbes affect the abiotic components of the ecosystem.

The majority of true decomposition (i.e. the conversion of dead organic material back into inorganic components like CO_2 and ammonium/nitrate) is 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 (through cellular respiration) and to build biomass. Cellular respiration results in CO_2 production, completing the carbon cycle and putting the C from detritus back into the atmosphere where plants can use it for photosynthesis.

In some cases, the compounds released by the enzymes don't get back to the bacteria or fungi that made the enzymes, and instead can get taken up by other organisms, like plants or photosynthetic protists. However, plants and algae (generally, there are exceptions) can't take up organic compounds from soil or water, so it is safe to say that most organic molecules are going to be processed by a bacterium or fungus sometime during decomposition.

So, why do bacteria and fungi release nitrogen into the environment instead of having evolved a more efficient feeding mechanism that will not "waste it"? Microorganisms need carbon and nitrogen in particular ratios (typically about 20:1); if the compounds they are eating differ from that ratio, they can either release excess N (because they don't have enough C to go with it; called mineralization) or compete with plants for N in the environment (because they don't have enough N to go with their C; called immobilization). Some microorganisms can use nitrogen compounds instead of oxygen for cellular respiration (called denitrification), which converts the N back into a gaseous form that goes back into the atmosphere, completing the N cycle).

This may be more complicated than you want for your students. For most students, it is probably a good step forward that they understand that bacteria and fungi are responsible for decomposition and that these processes are chemical in nature and take place outside the cell. However, like all other broad groups of organisms, there are differences in "food preference" between bacteria and fungi. Generally, bacteria prefer easier-to-degrade compounds like sugars whereas fungi are better at decomposing complex compounds like wood. You may want to push your students to extend some of their conclusions about "different organisms have different biotic and abiotic requirements" to bacteria and fungi. *Students could learn that decomposer organisms, bacteria and fungi, have specific biotic (easy and difficult to digest organic matter) and abiotic requirements (different bacteria and fungi require difference amounts of dissolved oxygen).*

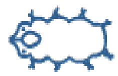
There are several challenges with teaching students about microorganisms and decomposition. (1) In their natural environment (in water, on leaf surfaces or in soil), microorganisms are not visible even with most school laboratory microscopes. Environmental scanning electron microscopes can take good, still pictures of microorganisms, but they still aren't very dynamic. One exception is white rot fungi, which you can grow by keeping some straw or wood moist in a jar with some soil (and maybe a bit of nitrogen fertilizer). (2) For the most part, microbial ecologists study microorganisms indirectly (i.e. we **never** look at them)—we extract DNA, we measure their activity (e.g. CO_2 or N_2O production) or we measure their ability to metabolize a compound by measuring how much of the compound disappears over time. There are lots of interesting ways to look at microbial activity, but they all require understanding indirect measurements and what they mean (difficult for students). (3) It is practically impossible to generalize about microorganisms. There are microorganisms that can do just about every kind of metabolism, and not just in extreme foreign places like hydrothermal vents. ENERGY: In an aquatic ecosystem, there will be some organisms that get their energy from carbon compounds (like us), and others that get their energy from nitrogen compounds (nitrifying bacteria convert ammonium to nitrate to capture energy). MATTER: Some will get their carbon from organic compounds (like us) and others will get their carbon from CO_2. As we mentioned earlier, there are many microorganisms that can use compounds other than oxygen as electron acceptors in respiration—some use nitrate whereas others can even use CO_2 (methanogens). Thus, you can see that microorganisms are a huge (and interesting) topic all on their own.

Assessment Ideas:

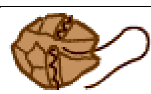
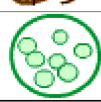
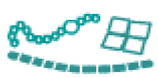
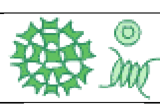
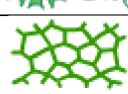
1. Exit ticket: Are all microscopic organisms in the same Kingdom?
2. Exit ticket: Why do bacteria and fungi need food? What do bacteria and fungi eat? How do bacteria and fungi impact the abiotic environment as they get their food? Why do you think those things impact your leaf pack community even though you didn't see them?

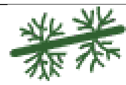
Life in a Drop of Water: Freshwater Microbes and small Arthropods

Arthropods (invertebrate animals with jointed appendages and exoskeletons)

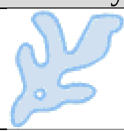
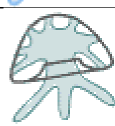
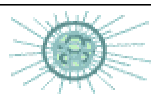
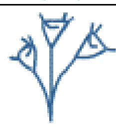
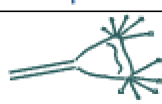
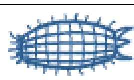
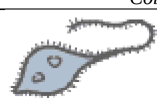
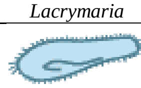
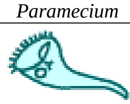
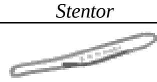
Organism Group	General Body Plan	Characteristics	Feeding Group
Ostracods (types of crustaceans)		bean-like shell <2 mm	Consumer
Copepods (types of crustaceans)		long antennae, tiny eyespot 0.5 - 3 mm	Consumer
Daphnia ("water fleas")		antennae, large compound eye 0.3 - several mm	Consumer
Water bears (Tardigrades)		8 stumpy legs body <1 mm	Consumer
Water mites		8 legs, round body 0.5 - 5 mm	Consumer
Mosquito larvae (e.g. fly)		Long, slender body, often moves in S-shaped curves 1 - 20 mm	Consumer

Protists - algae are types of protists (All algae do photosynthesis).

Organism Group	General Body Plan	Characteristics	Feeding Group
Flagellated forms (flagella may not be visible)			
Euglenoids		green, flagella (whip-like cilia), free-swimming, red eye spot, body is flexible <0.4 mm	Producers (but can be a consumer if kept in the dark)
Dinoflagellates		brown, 2 flagella, (1 in girdle), free-swimming, tough armour <0.4 mm	Producers
Volvox (type of Green Algae)		Special colonies of cells	Producers
Non-flagellated forms			
Blue-green algae (cyanobacteria)		blue-green, often slow locomotion, used to be considered algae but more related to bacteria cells<0.05 mm colonies can be many mm	Producers
Diatoms		usually brownish, silica cell wall in two parts, solitary or colonial, some have a slow gliding motion <0.5 mm	Producers
Desmids		green, no flagella, mainly solitary, some colonial, various shapes, two semi-cells which are mirror images <0.5 mm	Producers
Green algae (Chlorophyta)		Green, may or may not move, not attached to a surface	Producers
Water net		a sock-like colony, green algae	Producers

Organism Group	General Body Plan	Characteristics	Feeding Group
Filamentous forms			
Pond scum (Gamophyta: conjugating green algae)		non-branching, green, chains of cells with distinctly shaped cell contents cell with <0.1 mm. length: centimeters	Producers
Other non-branching forms			Producers
Branching forms			Producers
Red algae (Rhodophyta)		mainly marine, but some freshwater forms, not always red	Producers

Other Protists

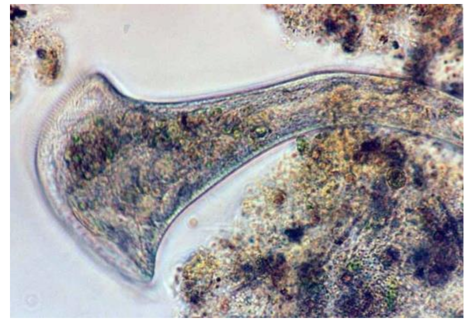
Organism Group	General Body Plan	Characteristics	Feeding Group
Amoeba		move with pseudopods 0.02 - 5 mm	Consumer
Shelled amoeba		amoeba with a shell e.g. of sand grains 0.1 - 0.4 mm	Consumer
Heliozoans 'Sun animalcules'		immobile, spherical with radiating hair-like pseudopods 0.01 - 1 mm	Consumer
Ciliates - Peritrichs		cylindrical or bell-shaped bodies, undulating membrane of cilia, some stalked, often colonial and attached to animals or plants bell: <0.25mm	Consumer
Ciliates - Suctoria		on water plants and other animals, adult ciliates have lost cilia, sticky tentacles capture prey <0.7 mm	Consumer
Other ciliates	 *Coleps*	various, mostly free living forms	Consumer
	 *Lacrymaria*	cell usually of a fixed shape but can be contractile, or extending neck, cilia of various forms, fixed mouth 0.01 - 4 mm	Consumer
	 *Paramecium*		Consumer
	 *Stentor*		Consumer
	 *Spirostomum*		Consumer

Drawings and information from:
Pond Life Identification Kit: a simple guide to small and microscopic pond life. Wim van Egmond and Dave Walker. Micscape Magazine, November 2000. http://www.microscopy-uk.org.uk/mag/indexmag.html

Lessons 10 and 11: What lives in leaf packs? Let's look closer

(student worksheet)

By now, you will have found many invertebrates living in your leaves from your stream. It's time to look closer, and find out what else lives in and around the leaves that is alive!



A cup of water can contain a million microorganisms! The living things in a drop of water are an intricate part of the ecosystem, acting as producers, consumers, and decomposers, and sometimes these microscopic organisms can have more than one job. Euglena, for example, which are a type of protozoa, have chloroplasts that allow them to photosynthesize. If, however, you keep the organisms in the dark, they lose their chloroplasts and then begin to eat organic matter. The amazing organisms that live in water include many forms of life- you can find animals, protists, fungi, and bacteria. The difficult part is identifying what the organisms are, since you can't use simple things like "color" to help you. For example, some species of stentor (see picture above), which are protists, are filter feeders that **look** green. They have cilia along the edge of the "trumpet" that allow them to sweep food particles inside them. They host symbiotic algae provide them with food, while the algae converts stentor's waste products into useful nutrients. These algae are what make stentor look green. **Below are common producers, consumers, and decomposers that you might find in your sample:**

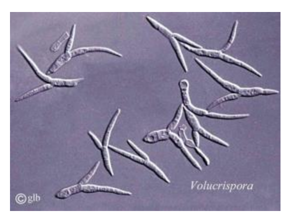
Producers:





Producers include organisms like the green algae volvox, desmids, and diatoms (left to right). All have the ability to photosynthesize. Some protozoa (like the euglena, fourth from left) are able to photosynthesize. Many bacteria, such as anabaena (far right), are producers, and can also take nitrogen gas from the air and turn it into usable nitrogen for living things (this is called nitrogen fixation). Bacteria that can photosynthesize are called cyanobacteria.

Decomposers:



Decomposers include fungi (left) and bacteria (right) that digest their food outside of their bodies. They don't have mouths.

Consumers:



Consumers include organisms like rotifers (left) and protozoa like the amoeba (middle) that eat by taking food into their mouths (or mouth-like structures). Note that some protozoa contain chloroplasts and can thus photosynthesize. Flagellated ciliates such as the paranema at right are scavengers and predators.

Keep track of the microorganisms that you see on your slides. Use the information above and the key to help you (from Life in a Drop of Water).

What did you find?	What major feeding group does it belong to? Producer Decomposer Consumer	Why do you think it belongs to that group?
Ex: Algae	*Producer*	*Because it has chloroplasts and makes its own food*

Now add these microscopic organisms you found to your group food web poster for this project.

1. Which decomposers did you see:

2. How do bacteria and fungi get their food?

3. How do bacteria and fungi impact the abiotic environment as they get their food?

Lessons 10 and 11: What lives in leaf packs? Let's look closer

(Teacher Answer Key)

1. Which decomposers did you see:
   - Answers will vary
2. How do bacteria and fungi get their food?
   - Bacteria and fungi get food by excreting enzymes that digest the food material outside of their body; the smaller molecule is then absorbed through their cell membrane.
3. How do bacteria and fungi impact the abiotic environment as they get their food?
   - They are "messy" eaters and have no use for nutrient minerals (N2 has a low energy bond) so nitrogen molecules are left behind to mix in with the water.
   - These nutrients like nitrogen, are then absorbed by other organisms, thereby being recycled.

Lesson 12: Classifying: What size is it?

Instructional Goal

Students will know the relative sizes of microscopic and macroscopic organisms identified in the leaf pack, and be able to describe the relative size and composition of matter and organisms found in a stream environment: is it made of atoms *and/or* molecules *and/or* a single cell *and/or* multiple cells.

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Using Mathematics & Computational Thinking
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS1: From Mlecules to Organisms: Structures and Processes
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Scale, Proportion, and Quantity
Energy & Matter

Common Core Standards Addressed:

Mathematics:
The Real Number System- Extend the properties of exponents
Mathematical Practices- Reason abstractly and quantitatively
Attend to precision

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic E: Diversity

Materials

Organism, inorganic, and organic cards, all (1 set per pair of students), and **magnets**
Small **Powers of Ten** poster (1 per pair of students)
Copies of **What size is it?** Worksheet
Computer or overhead projector to display **Powers of Ten** poster pdf

Advance Preparation

Prepare overhead or download pdf of the **Powers of Ten** poster. Partial key: water molecule 10^{-9}, dissolved inorganic matter like nitrogen, phosphorus and dissolved oxygen 10^{-9}, algae 10^{-5} to 10^{-4}, fish 10^{0}, oak trees 10^{1}…

Lesson Procedure

1. Begin the lesson by orientating students to the **Powers of Ten** poster by sorting familiar objects—pencil, eraser, dog, car etc.
2. Pass out the **What size is it?** Worksheet and have students use it to determine the size of all the organisms they have identified in their leaf packs plus the extra things (larger organisms, organic and inorganic matter) using the organism and other cards. List the cards you want them to sort on the board.
3. After they determine the size of the items they should fill out the rest of the chart: is the thing living or non-living, what is their reasoning (e.g. Can it reproduce? Can it find or make its own food?), is the item made of atoms *and/or* molecules *and/or* a single cell *and/or* multiple cells?

4. When students are done with the chart, use the projected poster and magnets to have a couple of students demonstrate how they classified their cards. Have the students discuss any differences in their classification methods. Be sure to draw students' attention to how small bacteria and fungi are and review the consequences that being small has on how they eat (i.e. external digestion, which leads to them leaving mineral nutrients in water—or soil).
5. If students understand elements, and you want to tell them where you can find certain elements inside living single and multi-celled organisms, the following is a good start:
    - Nitrogen atoms are commonly found in proteins and DNA.
    - Phosphorus is found in DNA.
    - Oxygen is necessary inside all living organisms to get energy from food through the process of cellular respiration and is part of the chemical formula of carbohydrates, proteins, fats and DNA.
    - Carbon is part of the chemical formula of carbohydrates, proteins, fats and DNA.
    - Hydrogen is part of the chemical formula of carbohydrates, proteins, fats, and DNA.

What size is it?

Using your **Macroinvertebrate Data Collection** worksheet copy the names of some of the organisms you identified in your leaf pack. Using the **Powers of Ten** chart and the Organism Cards, decide what size each of these organisms are. Then record the size in the chart below and decide if each item is living or non-living, and what each thing is made of.

Name of Organism	Size	Is it Living or Non-living?	What is it made of? atoms *and/or* molecules *and/or* a single cell *and/or* multiple cells
Microorganisms			
1 2 3 4 5 6			
Macroinvertebrates			
1 2 3 4 5 6 7 8 9			
Other organisms			
1 2 3 4			
Matter in water			
Nitrogen molecules Phosphorus molecules Oxygen molecules Organic matter			
Water molecules			

1. What is a mature Oak tree made of? Start with the visual parts of the tree that you can see and finish with the smallest particles you can trace. E.g. leaf, leaf cells, organelles-chloroplasts, nucleus, molecules-carbs, fats, atoms-CHNO

2. Is there Carbon in an Oak tree? Nitrogen? Oxygen? Phosphorus? How do we know?

Lesson 13— How are organisms related?

Instructional Goal

At the end of this lesson, SWKABAT:

a. Explain that organisms are classified into nested, broad groups (e.g. Kingdom, phylum) based on similarities and differences in morphology
b. Place organisms in a biological classification based on morphological characteristics
c. State the traits of an organism if told where the organism fits in the biological classification at the kingdom and phylum (for animals) level
d. Explain related groups have some related traits (i.e. all animals groups have common traits)
e. Know that group relatedness is based on evidence of evolutionary common ancestry (optional)
f. Explain the importance of diversity within a similar group of organisms
g. List abiotic factors relevant to stream ecosystem
h. Explain the implications and limitations of functional redundancy (i.e. sometimes there is more than one species capable of carrying out a function so removing one species may not eliminate an ecosystem function, however, sometimes species with overlapping functions have different biotic or abiotic requirements)

Next Generation Science Standards Addressed

Science & Engineering Practices:
Constructing Explanations
Engaging in Argument from Evidence

Disciplinary Core Ideas:
HSLS4: Biological Evolution: Unity & Diversity

Cross-Cutting Concepts:
Patterns
Structure & function

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic E: Diversity

Materials

- **Student organism cards (macro and micro, numbers 1-28)**, 1 set per pair or group of students, and **Teacher organism magnets** (or post it notes), you can also use the abiotic cards if you want the students to be able to tell the difference between living and non-living things
- **Classification poster** (1 per pair or group of students), this is made by taping the two 11” x 17” pieces of paper together
- Copies of **How are organisms related?** worksheet
- Class list of organisms found in the stream
- Computer or overhead projector to display the **Biological Classification** ppt

Advance Preparation

Prepare overhead or download ppt . Cut out organism cards that you are adding (most should be ready from Lesson 6) and tape the two halves of the posters together.

Lesson Procedure

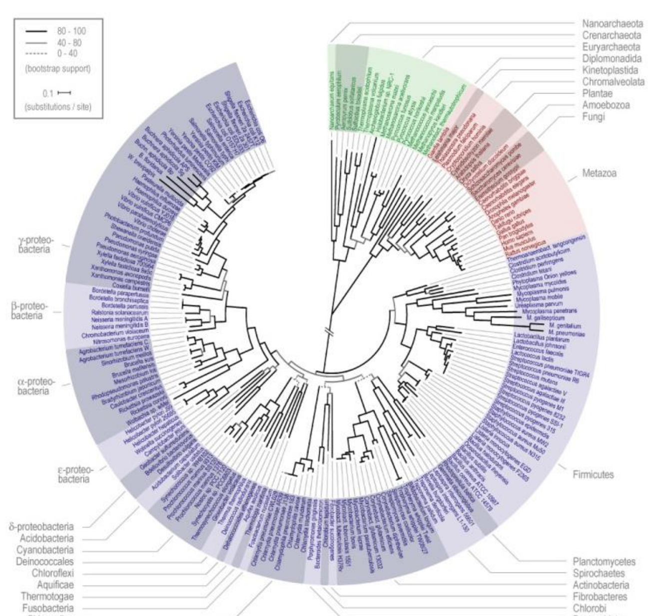
1. Start the lesson with a formative pre-assessment: Put the Classification poster up in the front of the classroom. Give each group of students 1-3 organism magnets or post-it notes until all living things are taken. Students need to discuss where their card belongs on the Classification poster and be able to back up their answer. One at time have student representatives place their cards on the poster and then the class decides if placement is correct or not. Ask them to name the physical traits used for placement.
2. Use the results of the formative assessment to determine how much you need to teach of points 3-5 before students do the worksheet.
3. Project the **Biological Classification** ppt. Using mammals (mouse and rat, ape and chimpanzee), show students how you can classify by Domain, Kingdom, Phylum, Class. Domain Eukarya>Kingdom Animalia>Phylum Chordata>Class Mammalia. Demonstrate that mammals can be subdivided even further (Order Rodentia and Order Primates).
4. Talk with students about how groups at every level of classification have common traits: Eukaryotes have nuclei, Animals eat food and have nerves and muscles (mostly), Chordates have notochord than becomes backbone, Mammals all have hair and nurse their young. For each rodents and primates you can talk about similar body plans and feeding habits.

Check Student Understanding: Lower level students recognize that groups of related organisms share familiar external morphological traits. Help students understand that groups at all levels (e.g. Kingdoms, Order) share external and internal morphological traits and behavioral traits.

5. Now do the same for examples from the leaf pack (mayflies and crane flies). Domain Eukarya>Kingdom Animalia>Phylum Arthropoda> Class Insecta). Talk with students about how groups at every level of classification have common traits. Eukaryotes have nuclei, Animals eat food and have nerves and muscles (mostly), Arthropods have exoskeleton and jointed legs, Insects all have 6 legs and many have wings.
6. Hand out **How are organisms related?** worksheet. Orient students to the classification poster by having them name example members of each kingdom: Animalia, Plantae, Fungi, Protista, Archaea, Bacteria. Explain that groups are arranged on the web in terms of their relatedness, and that the branching pattern shows evolutionary relatedness. The animals phylogeny of the Classification poster was constructed using molecular evidence. Another competing animal phylogeny is constructed using only morphological traits. Now repeat classification of mammal and leaf pack organism examples using the classification poster. To save time you can use the Classification poster instead of the ppt for steps 3-5.

TEACHER NOTE: Students will probably not be familiar with Archaea so you will probably have to introduce them if you want to include them in your teaching. You can edit the worksheet and materials to remove Archaea if you'd prefer. If you include Archaea, it might be helpful to explain to students that although Archaea and Bacteria look similar on the outside, they are very different with respect to their genes, what they eat, and other characteristics. Talking about how Archaea are often found in extreme environments (e.g. high salinity, low pH) is a good introduction.

The phylogeny depicted on the classification poster is drawn to make it an effective teaching tool while students are sorting organisms that are mostly animals. However, a phylogeny that represents the known diversity of life would be much different with animals taking up a small space and bacteria the greatest amount of space. The figure here is from adapted from a 2006 article in Science (go to http://www.bork.embl.de/tree_of_life/ for an interactive version). Blue represents the Domain Bacteria, green Domain Archaea, and Red Domain Eukaryota, which includes plants, animals, fungi, and protists. We do not necessarily suggest you share this phylogeny with students but include it to represent a truer diversity of life.



7. As a class, review all of the organisms students found in their packs by looking at the classroom list (both macro and micro organisms). Challenge students to add parts of the broader community that they didn't sample, but think are in the stream, to the class list.
8. Students now classify organisms similar to those on their list using the organism cards. There are cards for a sampling of microorganisms and other macroscopic life. Students should use the pictures on the cards, their observations from Lesson 5 and information on the poster to classify (place in the appropriate spot on the poster) the organisms on the classification poster.
9. Students should then fill out the table and answer questions 1-4 on the worksheet. Review their answers with them, and emphasize using traits associated with groups.

Check Student Understanding: Lower level students understand that organisms can be "adapted" to fit their environment but they cannot often be specific about what in the environment is affecting the organism OR what trait of the organism allows or doesn't allow it to survive in a given environment. With the mayfly diversity example, help students connect the traits of individual types of mayflies with their abiotic environment.

Assessment Ideas:

1. Questions 2-4 on the worksheet are good assessments of the students learning about groups and relatedness and can be used as exit tickets or bell ringers.
2. Parts of the table are also appropriate for exit tickets or bell ringers.

Lesson 13: How are organisms related?

(student worksheet)

Use the **Classification Poster** to classify the organisms on the cards provided to you by your teacher. The cards have organisms that are commonly found in streams. Put each card in the appropriate place on the poster. Use the traits of the organisms drawn or written on the cards to help you sort correctly. Fill in the chart below:

Kingdom	Phylum	Name of Organisms
Archaea		
Bacteria		
Protists		
Plants		
Fungi		
Animals	Arthropods	
	Annelids	
	Nematodes	
	Platyhelminthes	
	Molluscs	
	Chordates	

1. What abiotic (non-living) cards are left in your card pile?

2. Name three ways the animals in the Phylum Arthropoda are the same (e.g., number of body parts).

3. Name two ways the animals in the Phylum Arthropoda are different from each other.

4. a. Name several organisms that you know live in the stream but were not found in our leaf packs.

   b. What factors kept these organisms from entering the leaf packs?

   c. How do these organisms that were not in the leaf packs impact the stream community?

Lesson 13: How are organisms related?

(Teacher Answer Key)

Use the Classification poster and all Macro Invertebrate cards (oak tree, trout etc.) and put all living organisms into correct kingdoms. The some cards are organisms that were found in the stream, others are not. Put each card near the appropriate place on the Classification poster. Use the traits of the organism to help you sort correctly. Fill in the chart below.

Kingdom	Phylum	Name of Organisms
Archaea		
Bacteria		**Pseudomonas, Anabaena**
Protists		**Paramecium, Amoeba, Diatoms , Green algae (Algae are classified as protists but some people include anything with green chloroplasts in the plant kingdom)**
Plants		**White Pine Tree, Oak Tree, Oak Leaf,**
Fungi		**Hyaline Mitosporic Fungi,**
Animals	Arthropods	**Stoneflies, Dragonflies & Damselflies, Mayflies, Water Beetles, True Flies, Craneflies, Dobsonflies & Alderflies, Caddisflies, Scuds, Sowbugs, Crayfish,**
	Annelids	**Leeches, Earthworms,**
	Nematodes	
	Platyhelminthes	**Planaria,**
	Mollusks	**Snails, Clams & Mussels,**
	Chordates	**Salamander, Trout**

1. What abiotic (non-living) cards are left in your card pile?
   Water molecule, Nitrate, Oxygen, Phosphate

2. Name three ways the animals in the Phylum Arthropoda are the same (how they feed, number of body parts)?**Possible answers: Same Kingdom, invertebrates, consumers, all have jointed appendages , similar body plans, exoskeletons, all reproduce sexually,**

3. Name two ways the animals in the Phylum Arthropoda are different from each other?
   Possible answers: different number of legs, different number of body segments, different appendages (claws), different feeding groups, different mouth parts,

4. a. Name several organisms that you know live in the stream but were not found in our leaf packs.

Various answers

b. What factors kept these organisms from entering the leaf packs?

- Couldn't get into the leaf pack (too big)
- Too small to stay in the leaf pack (simply "floated through");
- Needed different abiotic conditions/resources;
- Not enough food available in the leaf packs, predators in the leaf packs, seasonal differences (wrong time of year for some organisms as they are hibernating, etc.);

c. How do these organisms that were not in the leaf packs impact the stream community?

- Decomposers help break down to make nutrients available;
- Trees on edge of stream make stream
- Shady vs sunny;
- Large predators eat organisms in or out of leaf packs; producers (not usually found in
- leaf packs) are the basis of the food webs; competitors could deplete resources

Lesson 14— Disturbance and Dispersal

Instructional Goal

At the end of this lesson, SWKABAT

a. List abiotic factors relevant to stream ecosystem
b. Explain how an organism's traits (i.e. dissolved oxygen needs) influence how it interacts with specific parts of the abiotic environment
c. Group stream organisms in multiple ways using multiple traits: dispersal potential, dissolved oxygen needs, size
d. Explain how traits of various stream organisms affect their ability to disperse from one habitat to another

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics
HSL3: Heredity: Inheritance and Variation in Triats

Cross-Cutting Concepts:
Structure & Function

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic B: Population Dynamics; Topic E: Diversity

Materials

Student cards, all (1 set per pair of students), and **Teacher cards made as magnets** (or post-it notes)
Copies of **Disturbance and Dispersal** Worksheet
Copies of **Biotic/Abiotic Interaction** tool

Advance Preparation

Print copies of the **Disturbance and Dispersal** Worksheet

Lesson Procedure

This lesson may take more than one class period, depending on how familiar your students are with abiotic factors.

1. Pass out **Disturbance and Dispersal** Worksheet. Tell the students that they already grouped organisms based on their feeding type and grouped them based on their relatedness. Add that there are still other ways to group organisms based on their similarities and they are going to practice grouping organisms in some of those other ways. Instruct students to work independently or in groups on questions 1-3 of the worksheet. Discuss the students' answers.
2. Now remind students about how different organisms also have different abiotic resource and condition needs. In this case we will focus on requirements for dissolved oxygen. Review dissolved oxygen; you may want to use the lesson in the Appendix B suggested during lesson 2. Discuss what it means to need less oxygen: traits allow organism to live when there

> **Check Student Understanding**: Mid-level students will see that there is functional redundancy among organisms but may oversimplify the idea because they only look at one function of an organism. For example, species X may be a scraper, may be a food source for species Y, and may tolerate really low dissolved oxygen. If the students only focus on the scraping function of species X, they may misunderstand or oversimplify the consequences of losing species X from the system.

are less oxygen molecules in the water; the organism's cells don't use as much oxygen.

3. Students should use the **Stream Biology Briefs** reading individually, in groups, or as a class to find the dissolved oxygen needs for each type of organism and fill out the table for question 4. **NOTE: Net-spinner caddisflies are grouped with the other cards for simplicity – however, they have a lower dissolved oxygen tolerance than the other caddisflies.**
4. Ask students: Do all organisms in a feeding group have the same dissolved oxygen needs? If not, what implications does this have for functional redundancy?
5. Update the class list of organisms: add a dissolved oxygen needs column.
6. Now work with students to use the Biotic/Abiotic Interactions Reasoning Tool to predict what will happen to the stream ecosystem with disturbance.
    a. Project and discuss a stream food web (there is one provided below or you can use a students'). This tool will work well with any food web.
    b. Discuss community characteristics/health of environment/the biodiversity/how robust is the food web and **fill in the top of the tool (describe the starting biotic and abiotic environment).**
        i. Is there a high abundance of organisms?
        ii. Are there many different types of organisms? (A Great Lakes food web doesn't have many different types of organisms.)
        iii. What is the non-living environment like?
            1. Help students think of the solid materials found in the stream (both living and non-living), the liquids and gases and place them correctly under the abioitic or biotic category.
            2. Help them think at the atomic molecular level (nitrogen, phosphorus and sulfur molecules) if they haven't included these things already.
    c. **Fill in the "Describe the disturbance" box in the middle.** Example: A power plant is built along a stream and is releasing much warmer water into the stream than before.
    d. Hypothesize with students the resulting direct consequences that warmer water will hold for the stream's abiotic and biotic characteristics. **Fill in the first arrow bottom side of the tool.** Example: *Abiotic*: Less oxygen in the stream water. *Mechanism for change*: Warm water holds less oxygen.
    e. Let students hypothesize further indirect changes resulting from the disturbance; help students understand that a disturbance continues to impact ecosystems in many ways and may have different consequences. It may also be useful to think with students about the magnitude of the change that takes place within a community; if a population changes size, it can have a dramatic impact even if it isn't removed from the local area.
7. Have students complete the Biotic/Abiotic Interactions Tool for an example of their choice or assign this as homework.
8. After students have completed the rest of the questions on the worksheet, discuss which organisms would be able to disperse between streams A & B. Ask students to share the reasons why they think the organisms will or won't be able successful at dispersing between the streams.

Assessment Ideas:

1. How will changes in oxygen affect a food web? Have students make the stream food web using the organism cards. Now imagine the power plant problem or similar, what would happen to the food web? Ask them to demonstrate that with the cards. How are the food webs different?
2. What trait of a mayfly might allow it to disperse long distances? Why is dispersal important for determining what you might find living in an area?
3. Name three abiotic resources or conditions in the stream.

4. Assessment for next day. Have the students come in and use their interactions tool to write out a short paragraph about the power plant problem OR hand out a new blank interactions tool and have students fill it in before moving on to the next lesson that deals with more disturbance problems.

Lesson 14: Disturbance and Dispersal

(student worksheet)

1. The cards you have are things that are often found in leaf packs. Sort the cards into three piles: living (biotic) things that are macroscopic, living (biotic) things that are microscopic, and non-living (abiotic) things. Then record the names of the things in the chart below.

Is it a living thing? (Biotic)		Is it a non-living thing? (Abiotic)
Macroscopic	Microscopic	

2. How did you decide what to put in the
    a. biotic columns?

    b. abiotic column?

    c. macroscopic column?

    d. microscopic column?

3. When you include both the biotic and abiotic components in an area what are you describing? (circle one)

    species population community ecosystem biome biosphere

4. Abiotic resources and conditions can affect which organisms can live in an area. What traits an organism has determines what abiotic resources the organism needs. For example, the leaves of tomatoes have the trait of needing a lot of sun light in order to make food. This means tomato plants have to live in sunny, not shady, areas of your garden. Other plants have the trait that they only need a little bit of sun light in order to make food. These plants can live in the shady parts of your yard. Another example is of this is how macroinvertebrates can be grouped according to how much dissolved oxygen they need to survive. Some groups need a lot of oxygen in the water (8-12 mg/L) and some groups only need a little (<4 mg/L).

   Organize your macroinvertebrate cards into three groups: high (8-12mg/L), medium (4.1-7.9 mg/L) and low (>4mg/L) oxygen groups. **Note: We've added the caddisflies, since you only have one card for them but they actually have different oxygen tolerance levels.**

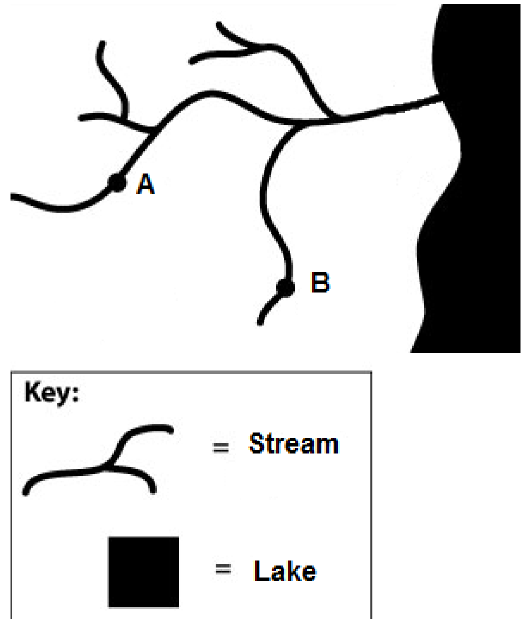
   List your answers in the chart below:

High oxygen	In your leafpack? Y/N	Medium oxygen	In your leafpack? Y/N	Low oxygen	In your leafpack? Y/N
Caddisflies		Net-spinner caddisflies			

5. **Example of Disturbance:** Imagine a Power plant is built along your stream and starts dumping hot water into the stream. Warm water holds less oxygen so the dissolved oxygen amount in the stream will decrease. If the dissolved oxygen decreases to 5 mg/L what might happen to the living and non-living things in the water? Your teacher will show you how to use the Biotic/Abiotic Interactions Reasoning Tool to reason through what is happening to the stream environment due to water warming.

6. After completing the power plant example, use the Biotic/Abiotic Interactions Reasoning Tool to reason through another example of biological disturbance that has or is happening in your area or that you have heard about in the news.

7. **Example of Dispersal:** Many factors determine what organisms can live in an area: sunlight, nutrients, available food. Consider the drawing on the right. The streams labeled A and B are five miles apart. The land in between is mostly corn fields with some roads and houses.

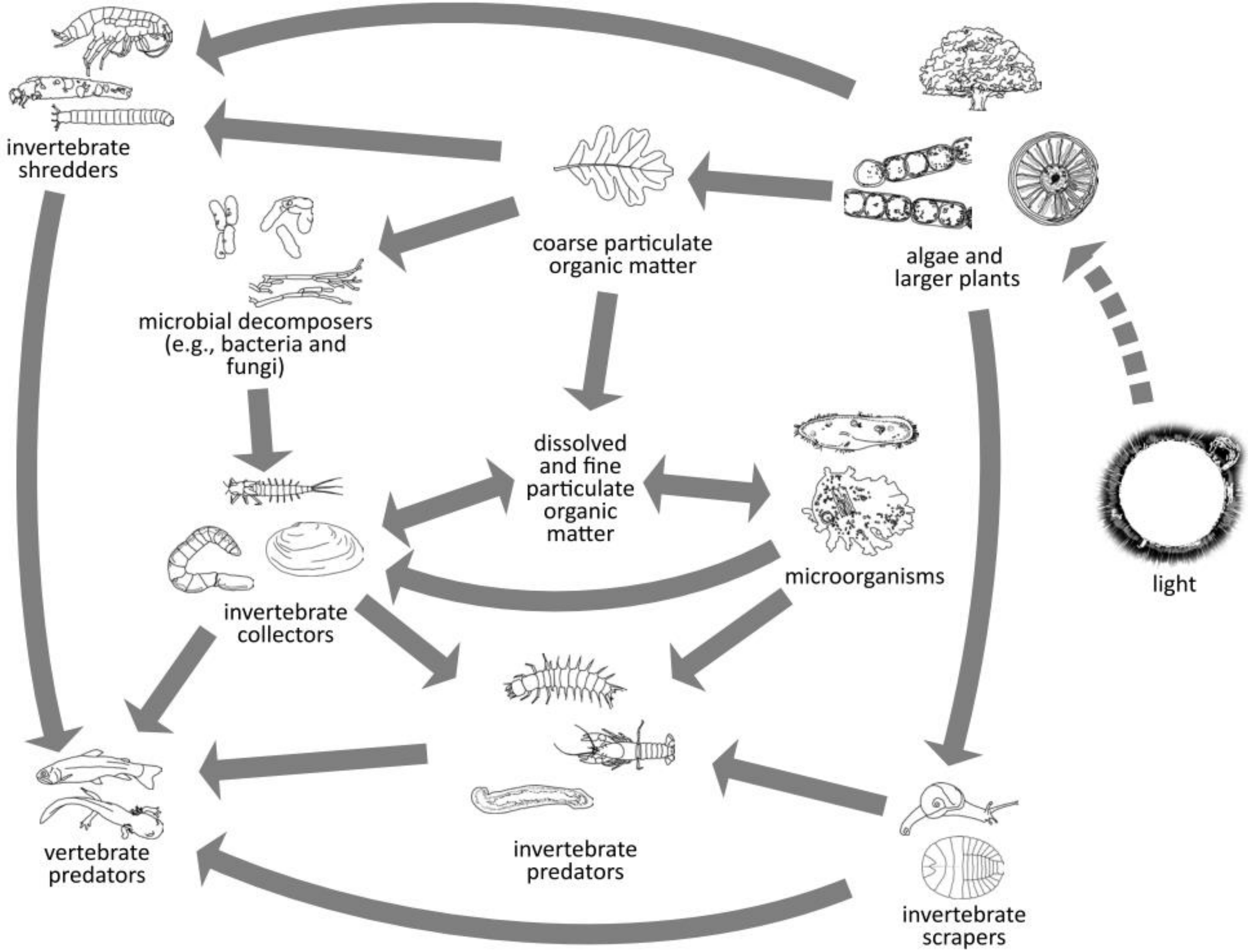


Randomly pick 5 organism cards from the deck of macro cards and fill out the table below. Which of these organisms do you think could move from stream A to stream B?

Name of organism	Would it be able to get from stream A to stream B? How?	What traits of the organism did you use when making your decision?

8. Think about the results from your leaf packs. Besides the abiotic conditions you measured when you went to the stream, what else could have influenced the diversity of the organisms you found in the two types of leaf packs?

Other Abiotic Resources or Conditions	
Biotic Interactions:	
Dispersal	
Other	


invertebrate
shredders
coarse particulate
organic matter
algae and
larger plants
microbial decomposers
(e.g., bacteria and
fungi)
dissolved
and fine
particulate
organic
matter
microorganisms
light
invertebrate
collectors
vertebrate
predators
invertebrate
predators
invertebrate
scrapers

Biotic/Abiotic Interactions Reasoning Tool

Describe environment before the disturbance	**Abiotic:**	**Biotic:**

Describe the disturbance: .

Hypothesize the changes to the ecosystem

Abiotic/Biotic:	**Abiotic/Biotic:**	**Abiotic/Biotic:**	**Abiotic/Biotic:**
Mechanism for Change:	**Mechanism for Change:**	**Mechanism for Change:**	**Mechanism for Change:**

Lesson 14: Disturbance and Dispersal

(Teacher Answer Key)

1. Now sort all Macroinvertebrate cards into three piles: macroscopic living things, microscopic living things, and non-living, abiotic items. Record the names of things in the chart below.

Is it a living thing? (Biotic)		Is it a non-living thing? (Abiotic)
Macroscopic	Microscopic	
Stoneflies	Planaria	Water molecule
Dragonflies & Damselflies	Pond Scum (algae)	Nitrate
Mayflies	Paramecium	Oxygen
Water Beetles	Amoeba	Phosphate
True Flies	Pseudomonas	
Craneflies	Hyaline Mitosporic Fungi	
Dobsonflies & Alderflies	Anabaena	
Caddisflies	Diatom	
Scuds		
Sowbugs		
Crayfish		
Snails		
Clams & Mussels		
Leeches		
Earthworms		
White Pine Tree		
Oak tree		
Oak leaf		
Salamander		
Trout		

2. How did you decide what to put in the
   a. Biotic columns?
      Alive, moving, feeding, etc.
   b. Abiotic column?
      Not living, not moving or feeding, chemicals
   c. Macroscopic column?
      Large enough to see without magnification
   d. Microscopic column?
      Need magnification to see
3. When you include both the biotic and abiotic components in an area what are you describing? (circle one-you may refer back to your vocabulary list if needed)
   species population community <u>ecosystem</u> biome biosphere

4. Abiotic resources and conditions can affect which organisms can live in an area. What traits an organism has determines what abiotic resources the organism needs. For example, the leaves of tomatoes have the trait of needing a lot of sun light in order to make food. This means tomato plants have to live in sunny, not shady, areas of your garden. Other plants have the trait that they only need a little bit of sun light in order to make food. These plants can live in the shady parts of your yard. Another example is Macroinvertebrates, they can be grouped according to how much

dissolved oxygen they need to survive. Some groups need a lot of oxygen in the water (8-12 mg/L) and some groups only need a little (<4 mg/L).

Organize your macroinvertebrate cards into three groups: high (8-12mg/L), medium (4.1-7.9 mg/L) and low (>4mg/L) oxygen groups. **Note: We've added the caddisflies, since you only have one card for them but they actually have different oxygen tolerance levels.**

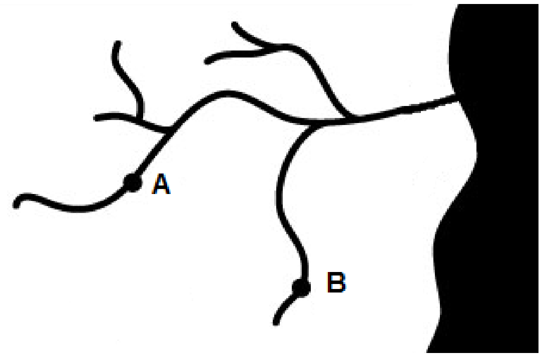
List your answers in the chart below:

High oxygen	In your leafpack? Y/N	Medium oxygen	In your leafpack? Y/N	Low oxygen	In your leafpack? Y/N
Stoneflies Mayflies Water beetles Caddisflies		Dragonflies and damselflies Crane flies Dobsonflies and alderflies Scuds Sowbugs Caddisflies – net spinners Crayfish Clams and mussels		True flies Leeches Snails Aquatic earthworms	

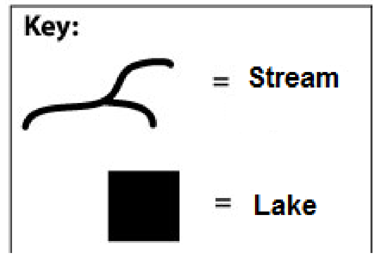
5. **Example of Disturbance:** Imagine a Power plant is built along your stream and starts dumping hot water into the stream. Warm water holds less oxygen so the dissolved oxygen amount in the stream will decrease. If the dissolved oxygen decreases to 5 mg/L what might happen to the living and non-living things in the water? Use the Biotic/Abiotic Interactions tool to reason through what is happening to the stream environment due to water warming.

   After completing the power plant activity, can you reason through a new example of biological disturbance that has or is happening in your area or in the news? Take this example through the previous steps.

6. **Example of Dispersal:** Many factors determine what organisms can live in an area: sunlight, nutrients, available food. Consider the drawing on the right. The streams labeled A and B are five miles apart. The land in between is mostly corn fields with some roads and houses.



Randomly pick 5 organism cards from the deck and fill out the table below. Which of these organisms do you think could move from stream A to stream B?



Name of organism	Would it be able to get from stream A to stream B? Yes or No	Describe How	What traits of the organism did you use when making your decision? Is there another part of the organisms life cycle that might make the movement easier?
1. Leech	Yes	Leeches are parasite so attach to other organisms that might be able to travel over land or upstream	Traits: parasite, attach to another organism (hitchhike) Life cycle: No
2. Snail	Not likely	Move very slow; not likely to go over land; not hitchhikers	Traits: No Life cycle: Maybe, Some snails lay eggs that can float down stream, other snails give live birth
3. Dobsonfly	Yes	If larva grows to adult can fly to another area	Traits: Adults have wings Life cycle: Adults have wings and can fly

5. Besides the abiotic factors you measured, what else could have influenced the diversity of the organisms you found in the two types of leaf packs? Think back to the discussions the class has had about other types of factors that influence an organism.

Other Abiotic Resources or Conditions	For example, if the part of the stream with pools was shadier than the part with riffles then more algae might be found in the leaf packs in the riffles.
Biotic Interactions:	The types of other organisms present. A group is less likely to be found if its predators or competitors are there and more likely to be found if its food source and other organisms that they depend upon to survive are there.
Dispersal	How far leaf bags were from where the organisms were living at the time. If too far, then they could not have migrated/dispersed from their original habitat to our bags. If the holes in the leaf bags were too small, some larger organisms couldn't get in.
Other	For different leaf types: If the leaf packs were placed near one another in the same stream then the most likely cause of the difference would be related to the types of leaves themselves. One type of leaf might have been a better food source and/or a safer refuge for the species. Also, the type of leaf that wasn't preferred could have had substances in it that were toxic or not tasty for that species (e.g., pine needles vs deciduous).

Lesson 15— Who eats whom? Revisited

Instructional Goal

At the end of this lesson, SWKABAT

a. Describe the roles of major feeding group types of organisms in a freshwater stream (i.e. producers, consumers-predators, shredders, collectors, scrapers, decomposers)
b. Explain how the feeding activities of each feeding group could affect the stream's abiotic environment (i.e. water clarity, DO, and minerals) and predict how these abiotic impacts might impact other biota
c. Explain the implications and limitations of functional redundancy (i.e. sometimes there is more than one species capable of carrying out a function so removing one species may not eliminate an ecosystem function, however, sometimes species with overlapping functions have different biotic or abiotic requirements)
d. Recognize that varying abiotic and biotic conditions differentially impact different types of organisms based on their particular abiotic and biotic requirements.
e. Explain how these differential impacts can cause a biological community to be diverse and for separate biological communities to be different.

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Structure & Function

Common Core Standards Addressed:

Mathematics:
Interpreting Functions- Interpret functions that arise in applications in terms of the context

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic B: Population Dynamics; Topic C: Community & Ecosystem Dynamics

Materials

- **Organism cards (macro and micro, numbers 1-28)**, 1 set per pair or group of students, and **magnets** (or post it notes)—(Optional for this lesson)
- **Who eats whom? Revisited** worksheet (1 per student)
- **Lesson 6 and 11 Food Web** template (1 per pair of students, optional for students who need more scaffolding)
- Stream ecosystem food webs from Lesson 3
- Copies of **Stream Biology Briefs** Reading and **Life in a Drop of Water** key (optional for this lesson)
- Computer or overhead projector to display **Food Web** poster pdf

Advance Preparation

Have the class list of organisms poster available for students. Remind students to bring or collect from students their **Stream ecosystem food webs** from Lesson 3; they might also need their **Stream Biology Briefs** and the **Life in the Drop of Water** Key for IDing feeding groups. Make copies of **Les 6 and 11 Food Web** template, if needed, and

Who eats whom? Revisited worksheet. You might consider decreasing or increasing the number of filled out boxes in the table on the worksheet if your students need less or more support. Prepare overhead or download pdf of the **Food Web** poster.

Lesson Procedure

1. Have students refamiliarize themselves with the stream food web they diagramed in Lesson 3 and then add to their food web other organisms they didn't have on before (both microorganisms and the larger organisms that live in a stream but weren't found in the pack). Young or inexperienced students may have a hard time building a food web and you may want to scaffold their food web construction by providing a copy of the Les 6 and 11 **Food Web** template.
2. As students are working, be sure they have identified specific kinds of decomposers (bacteria and fungi) and producers (trees that live on the river bank and drop their leaves, algae) rather than simply "decomposers" or "producers". Students may especially need some help remembering what protists and other microorganisms eat (as producers, consumers, collectors, or decomposers—ask them to refer to the **Life in a Drop of Water** key). Asking students to use the **Organism** cards may help them use specific

> **Check Student Understanding**: Lower level students tend to see only macroscopic organisms and we want students to notice microscopic organisms too because they play very important functional roles in ecosystems. Also, lower level students tend to group organisms into very broad groups. Help students acknowledge that there are different species of bacteria and fungi, just like there are different species of mammals.

kinds of organisms.

3. Have students answer questions 1 and 2 on the **Who eats whom? revisited** Worksheet
4. Lead a class discussion on why organisms need food (i.e. matter for growth and reproduction and energy for life's processes), where major feeding group types of microscopic organisms and larger organisms (i.e. producers, decomposers, consumers-predators and other consumers) get their food, and why there might be more than one organism type in each feeding group. Students should also discuss the potential implications of multiple organisms of each feeding type: competition for resources and functional redundancy.

Optional Class Discussion to help students understand redundancy in food webs:

a. Draw or project a food web on the board.
b. Ask students to point out a shredder on their food web and remove that shredder.
c. Ask students whether there are other shredders on their food web.
d. Ask a student to redraw the arrows on the food web so that the arrows that once went to the shredder go somewhere else.
e. Ask a student to explain their reasoning for how they redrew the lines.
f. Ask the students to raise their hands or move to opposite sides of the room to vote whether or not they think the absence of the shredder will make a big difference to the food web.
g. Ask one student from each group to explain their reasoning.

> **Check Student Understanding**: Higher level students acknowledge that there is functional redundancy in communities (i.e. there is often more than one species that can perform a function) and they know the implications of functional redundancy. One implication is that organisms that eat the same food items will compete. Another is that removing one species won't necessarily cause a food web to collapse). Talk to your students about functional redundancy – you may want to use the analogy of having several back-up quarterbacks on a football team.

5. Now have students answer the accompanying questions on the **Who Eats Whom? Revisited** Worksheet either in groups or as a class in discussion.
6. Biotic-Abiotic Interactions Practice. You may want to provide students with more copies of the Interactions Reasoning Tool. Draw or project a food web on the board and brainstorm with the students about how one organism could affect the abiotic environment in a way that will influence another organism. If the students don't come up with some ideas, here are some you could use
    a. Removing algae may reduce dissolved oxygen and that could in turn negatively affect the fish and macroinvertebrates that have high DO requirements.
    b. Decomposers release mineral nutrients into the water and aquatic plants use those mineral nutrients to grow. If there is a decrease in decomposers, there will be a decrease in mineral nutrients and a decrease in plant growth.

    The students will do this linking of biotic-abiotic-biotic factors on their own or with your guidance when they do questions 5-11 in the worksheet.

> **Check Student Understanding**: Lower level students may recognize that the abiotic environment affects organisms, but students must also recognize that organisms can also affect their abiotic environment. We want students to be able to explain how organism A affects its abiotic environment and how that effect could in turn affect organisms B and C. Indirect effects of one organism on another are particularly hard for students to understand.

Assessment Ideas:

1. Use **Who Eats Whom? revisited** worksheet as an assessment (questions 6, 7, and 8 are scenario-based questions that will help you see whether students have grasped the idea that organisms can change their abiotic environment in ways that then affect other organisms.
2. Pick one or a few of the rows in the Table from the table below. Ask students to explain how the change in the abiotic factor could affect one or more specific organisms in the food web.

Feeding Group	What organism does this group eat? How does it get its food?	How will a decrease in that feeding group affect the abiotic environment?	How will the change to the abiotic environment affect another organism?
Decomposers	Dead organisms.	Bacteria and fungi are decomposers. Decomposers are messy eaters that leave a lot of mineral nutrients in the water. A decrease in bacteria and fungi will decrease the amount of mineral nutrients in the water.	
Scrapers	Algae. They scrape the algae off of surfaces.	Fewer scrapers mean more algae. Algae are producers that make their own food using photosynthesis. Producers release oxygen when they make food. A decrease in algae will lead to a decrease in oxygen in the water.	

Collectors	Bits of organic matter and small organisms floating in the water. They take the floating bits out of the water.	Bits of organic matter and small organisms floating in the water make the water cloudy. A decrease in the bits in the water will lead to the water being clearer. This will let more sunlight into the water.	
Shredders	Bacteria and fungi on leaf surfaces. They tear up leaves into small pieces.	Shredders tear up leaves into small pieces. This leads to an increase in sunlight. For example, in wetland ecosystems where this does not occur quickly, leaves pile up and hinder light availability. Bacteria and fungi are decomposers. Decomposers are messy eaters that leave a lot of nutrients in the water. A decrease in bacteria and fungi will decrease the amount of nutrients in the water	
Producers	Makes their own food using sunlight, CO_2 and water and produce O_2 and food.	When producers make food they increase the amount of oxygen in the water.	

Lesson 15: Who eats whom? Revisited

(Student worksheet)

1. How do each of the following types of organisms get food?
   a. Producers:

   b. Decomposers:

   c. Consumers:

2. Check your food web diagram. Make sure you indicate the way each of the organisms in your food web gets their food.

3. How does light energy get transferred through your food web and what does it get transformed into?

4. A. Is there more than one type of microscopic consumer in your pack?

   B. Why do you think that is?

   C. Why is there not just one best type of microscopic consumer?

5. What would happen to the abiotic environment if collectors disappeared from the stream?

6. What would happen to the biotic environment if collectors disappeared from the stream?

7. What would happen to the abiotic and biotic environment if there were three types of collectors and one of them disappeared from the stream?

8. Imagine over time that small trees on the banks of your stream grew into really big trees.
   a. How would the growth of the trees affect the amount of sunlight that hits the stream?

   b. Pick an organism from the food web you drew earlier and explain how the change in sunlight hitting the stream would affect that organism.

   c. How would the change in sunlight affect an organism that is directly connected to your organism in the food web?

9. Imagine that a new mollusk was introduced to the stream. Mollusks are filter feeders and consume a lot of plankton as well as use up oxygen in the stream for cell respiration.
   a. How would the growth of the mollusk population affect the amount of oxygen in the stream?

How would the growth of the mollusk population affect things that need to eat plankton to live?

b. Pick an organism from the food web your group has made and explain whether or not the change in oxygen would affect it. How would the change in the amount of plankton affect it?

c. How would the change in oxygen or amount of plankton affect an organism that is directly connected to what you picked in b (Pick an organism from those in the food web that are surrounding the organism you picked for b)?

10. If all shredders in the stream went extinct and dead leaves were no longer ripped apart, what would happen to the bacteria that feed upon shredded dead leaves?

11. You have just learned how an organism can change its abiotic environment in a way that also affects the other members of biological community. Think about changes to a biological community in another ecosystem (forest, ocean, etc) that would change the abiotic environment and therefore affect the biological community. Write out two different examples below.

Lesson 15: Who eats whom? Student Assessment Worksheet

(Teacher Answer Key)

1. How does each of the following types of organisms get food?
   a. Producers: **Producers make their own food through the photosynthesis process.**
   b. Decomposers: **Decomposers (or saprotrophs) are organisms that eat by digesting dead organisms outside of their bodies, and in doing so carry out the natural process of decomposition.**
   c. Consumers: **Consumers obtain their food by eating plants or other living organisms.**

2. Check your food web diagram. Did you diagram the way each of the organisms in your food web gets their food? Did you mention how energy moves in this system?
   Students should make sure all organisms are connected in their food webs.
   The arrows in the food web should show the direction of the energy.

3. How does light energy get transferred through your newest food web and what does it get transferred into?
   Light energy is used by the producers (green plants) to create glucose. It is now stored chemical energy. Then, when other living organisms eat, whether plants or animals, that stored chemical energy is transferred to the consumer.

4. A. Is there more than one type of microscopic consumer living in the stream?
   Yes.

   B. Why do you think that is?
   There are many different conditions and areas for microscopic organisms to live in. Many different organisms would be supported by the stream environment.

   C. Why is there not just one best type of microscopic consumer?
   The stream will support many different types. If there were only one type of microscopic organism there might not be enough food and other resources to support just that one consumer. Having different consumers allows them to find their own "niche" and to live in different parts of the stream under different conditions.

5. What would happen to the abiotic environment if collectors disappeared from the stream?
   The water would get cloudier and less sunlight would get into the water. Less algae would grow which might cause less dissolved oxygen.

6. What would happen to the biotic environment if collectors disappeared from the stream?
   There would probably be fewer algae (due to cloudy water) and more of the little organisms collectors eat.

7. What would happen to the abiotic and biotic environment if there were 3 types of collectors and one of them disappeared from the stream?
   It would depend on the other two types of collectors and if they can live in all the places that the one that disappeared lived. If they can live in the same habitat (same dissolved oxygen, other conditions) then the other two collectors would become more abundant and there may not be changes in the abiotic environment. If they cannot live in the same habitats, then there might be an increase in the cloudiness in those habitats

8. Imagine over time that small trees on the banks of your stream grew into really big trees.

a. How would the growth of the trees affect the amount of sunlight that hits the stream?
   - **The growth of the trees would slowly block more and more sunlight from reaching the stream itself. So, there would be less algae which would impact the algae-eating organisms.**

b. Pick an organism from the food web above and explain how the change in sunlight hitting the stream would affect that organism.
   - **Producer: Less sunlight could affect the photosynthesis**
   - **Consumer: Less sunlight could mean less plants, or at least less robust plants to feed on for the herbivores, which would in turn affect the carnivores/omnivores and also the decomposer/scavengers.**
   - **Decomposers: There would be less matter for the decomposers to break down.**

c. How would the change in sunlight affect an organism that is directly connected to your organism in the food web?
   - **For a connected organism, it could mean that the conditions will change: less food, less/more dissolved oxygen, more of another type of species that might survive better in shadier conditions.**

9. Imagine that a new mollusk was introduced to the stream. Mollusks are filter feeders and consume a lot of plankton as well as use up oxygen in the stream for cell respiration.
   a. How would the growth of the mollusk population affect the amount of oxygen in the stream? How would it affect the things that need to eat plankton to live?
      - **As the mollusk population grew, the dissolved oxygen could be lowered. If the mollusks were eating the plankton as their primary food source that would give other filter feeds possibly less plankton to eat.**

   b. Pick an organism from the food web your group has made and explain how the change in oxygen would or would not affect it? How about the amount of plankton?
      - **Various answers, depending upon the chosen organism. If the organism is one that needs high dissolved oxygen, then its survival could be in question due to the mollusks taking in more oxygen.**
      - **If the organism is one that feeds on plankton (another filter feeder or low level consumer), then its food source could be less due to the feeding by the mollusks.**

   c. How would the change in oxygen or amount of plankton affect an organism that is directly connected to what you picked in b (those that are surrounding the organism you picked for b in the food web diagram)?
      - **Various answers, depending upon the organism chosen in b. A connected organism could be affected, too, by the amount of dissolved oxygen being less and to their food source being affected by the mollusk population. Since there could be less plankton that would have a ripple effect in the food web of the stream causing less of some organisms (directly eating the plankton) and causing more of other species.**

10. What if all shredders in the stream went extinct and dead leaves were no longer ripped apart. What would happen to the bacteria that feed upon shredded dead leaves?
    - **It would be harder for bacteria to eat the un-shredded leaves, so their population would go down.**

What would happen to the amount of carbon that gets released from bacteria consuming them? Remember: what % of dry mass of leaves is made of carbon atoms ______

- **There would be a lot of dead leaf build-up in the stream. Less bacteria would mean less carbon atoms being released by the bacteria through cell respiration.**

4. You have just learned how an organism can change its abiotic environment in a way that also affects the other members of biological community. Can you think of any changes to a biological community in another ecosystem (forest, ocean, etc) that would change the abiotic environment and therefore affect the biological community? Write out two different examples below.
    - **Many responses possible: volcanic activity, over-fishing, oil spills, heavy storms, run-off from farming, factories, etc. Most examples will be related to human effects, natural disasters, weather.**

Lessons 16 and 17: What affects what lives in leaf packs? (Two day lesson)

Instructional Goal

Students will be able to calculate group averages, create and interpret tables and identify characteristics of groups based on the calculated group averages. Students will know that abiotic and biotic conditions differentially impact different types of organisms because organisms have particular abiotic and biotic requirements. They will be able to explain how these differential impacts can cause a biological community to be diverse and for separate biological communities to be different from one another.

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Using Mathematics & Computational Thinking
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Scale, Proportion, and Quantity
Systems & System Models

Common Core Standards Addressed:

Mathematics:
Quantities- Reason quantitatively and use units to solve problems
Mathematical Practices- Reason abstractly and quantitatively
Attend to precision
Model with mathematics

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic B: Population Dynamics; Topic C: Community & Ecosystem Dynamics

Materials

Graph template if you want students to graph data by hand or Excel template and projector
Copies of **What affects what lives in leaf packs?** Worksheet
Filled out copies **Macroinvertebrate Data Collection** worksheet
Predictions and experimental design poster from Lesson 2

Advance Preparation

Remind students to bring, or collect from students, their filled out copies of the **Macroinvertebrate Data Collection** worksheet. Find student prediction and experimental design poster/notes from Lesson 2. Find predictions and experimental design poster from Lesson 2. Make copies of the **What factors affect what lives in leaf packs?** Worksheet and graphing template

Lesson Procedure

1. Students should now calculate the average number of individuals for each group of organisms for each type of leaves using class data. They should then graph the averages in a bar graph as shown in the Excel template. If

students are graphing the data by hand it may be helpful to provide graphing paper. Having students group bars by functional feeding group will make it easier for them to interpret their graphs. Depending on the amount of time you have and the level of your students, you can present the averages and/or graphs to the class using the Excel template for graphs on the projector or by running off copies. It is best if students are able to look closely at the graphs so, if students are not graphing themselves, print a classroom set of the graphs. Having student calculate their own averages and create their own graphs may add at **least 20-30 minutes** to this lesson. If you are having students compare more than two leaf packs (e.g. AHS different leaf types comparison, comparing your classes leaf packs with other in your area or with schools across the country) and are low on time, you may have students graph some of the data and present them with graphs of the rest of it.

You will need to provide students with the measured abiotic stream data for them to complete question 8.

TEACHER'S NOTE – Sample size, replication, and the knowledge that nature is variable are important issues in scientific studies. Sample size (also known as sampling effort) will dictate whether you get just the most common organisms or if you pick up some of the rare ones. Generally, we need to do replicate samples to get a sense of the variability (here you would calculate both averages & standard deviations) between samples. Low variability (small standard deviations) gives you confidence to make predictions from your data. Depending on your students you may wish for them to calculate standard deviations. Excel will also calculate standard deviations using the =STDEV() function.

A perhaps more approachable way for your students to explore the variation within the same type of leaf packs (the replicates) is to use histograms for the total number of organisms found in each bag (or for each (or a limited number) of types of the organisms found). Create a bar graph with Number of individuals on the y-axis and Number of bags with that number of individuals on the x-axis.

2. Hand out the **What factors affects what lives in leaf packs?** Worksheet. Guided by the worksheet students will describe qualitative and quantitative patterns among the different leaf packs, describe differences in the richness and evenness of different types of organisms and functional/feeding groups, and describe differences in measured stream characteristics. Discuss the patterns in the data (described in step 2 above) with students after they have answered questions 1-7 on the worksheet to prepare them to answer questions 8+.

3. Write on the board or the poster:

very similar ---very different

Ask students to vote by putting an X on this continuum in response to the following question: *Did we find* ***very similar*** *or* ***very different*** *organisms in the leaf packs we are comparing?* Let students talk briefly about these qualitative results. For the students who predicted something else, did they learn something? For the students who predicted correctly, do they still have the same reasoning?

This discussion is to prepare students to work in small groups or pairs to interpret the data from the leaf packs using questions 8+. If you chose to add other comparisons (e.g. AHS different leaf types comparison, comparing your classes leaf packs with other in your area or with schools across the country), you will need to have students repeat questions 1-2 and 8-11 on the worksheet for each comparison. You might consider breaking the class into small groups, each of which only concentrates on one comparison.

4. Allow students to work through questions 8-10. Depending on your students you might choose to cover questions 11-16 in a discussion format.

EXTENDED TEACHER'S NOTES FOR QUESTIONS 8-16: As in lesson 1, when comparing communities in packs of different leaf types or different locations, students should think about the following three determinants of diversity. Now that they have data they can talk specifically about some biotic (type of food organisms) and abiotic (amount of dissolved oxygen) factors. Competition for food by organisms of the same feeding type is a biotic interaction students should recognize.

a. **Dispersal - Can the organism get there?** (e.g., direct organism movement, water, wind) Organisms can't live in a specific time or location if they can't get there; we call this "dispersal," the ability to travel to a new habitat. Is it likely that there are barriers to migration or dispersal that prevent the organisms of interest from being located at one of the two locations? (e.g. dams, nearby streams that adult stages of insects can fly in from). There may be corridors of habitats connecting two places an organism can use.

b. **Abiotic resources and conditions - Can the organism survive and reproduce given these abiotic resources and conditions?** (e.g. light, water, oxygen, nitrogen, phosphorus, temperature, pesticide pollution, etc.) Abiotic resources and conditions influence whether organisms are able to survive and reproduce in a specific time or location. In addition, organisms influence the abiotic environment around them. Is it likely that there are differences in the abiotic resources between the two locations?

c. **Biotic resources and conditions - can the organism survive and reproduce given the range of biotic resources and interactions**? (Does it have food, does something eat it, what are the competitors, mutualists, habitat forming organisms, diseases, etc.) Biotic resources and interactions also influence how successful organisms are in a specific time or location. Are the surrounding organisms different between the two communities that might influence the success of the organism of interest? (e.g., new competition, lack of prey).

Discuss why there are (potentially) multiple types of each functional group in the leaf packs (questions 12-14), making sure students understand that each type of organism can have slightly different abiotic and biotic requirements. Organisms can be grouped by the function they perform in a system (e.g. shredder). The term functional diversity refers to the number of different functions being performed in a system. Students often think that removing any species from a system would cause a major problem. This isn't always the case though, if there are lots of species that can perform the same function in the system. Sometimes, there may be only 1 or 2 species that are able to perform a certain function and sometimes there will be lots of species capable of performing a certain function. When there are lots of species performing a function, we call this functional redundancy. Talk with your students about functional diversity and functional redundancy. Ask them what would happen to the system if you removed all individuals of a single species from a functional group that had low redundancy? How would the result be different if the group had high redundancy? A useful analogy might be to talk about a high school football team. If there were 5 guys who could all play quarterback well, the team wouldn't suffer if one of those guys transferred to a different school. But, if there was only 1 guy who could QB, then the team would have some losing games if that student moved away.

What affects what lives in leaf packs?

1. Calculate the average number of individuals in each macroinvertebrate group using the data collected in the whole class. Do this separately for the leaf packs in the riffles and in the pool. Why are you averaging the data from the different places in the stream separately? The place in stream (and leaf type for AHS) is the variable in our experiment and we want to be able to compare the differences between the two places.

2. Create a bar graph comparing the number of individuals in each group from the two types of packs, riffles and pool, using the graphing handout provided by your teacher.

3. Using the averages from your class data, how many groups did your class find in:
   a. Leaf packs in riffles had ________ groups.
   b. Leaf packs in pools had ________ groups.
   c. *Richness* tells *us how many different groups* of organisms are in an ecosystem. Based on this information, which leaf packs had the greatest richness of macroinvertebrate groups?

Riffles **Pools**

4. Look at the following example:

Tree Type	Habitat A (No. of ind.)	Habitat B (No. of ind.)
Pines	220	900
Oaks	300	50
Maples	380	50

Using the example table, what is the **richness** in each habitat? A: B:
Richness in each habitat is 3 because there are 3 taxonomic groups.

5. *Evenness* tells us how evenly the different groups of organisms are **distributed** in an ecosystem, or the *relative abundance* of each group in an area. Using the example table, which habitat has greater **evenness**? Evenness is greater in Habitat A because the # of individuals of each group is about the same. In Habitat B, there are many more pines than oaks or maples.

6. Look the graphs of your data. How "even" were the communities you found in your packs? That is, did you have similar numbers of organisms in each of the different groups that you found or did you have many more in some groups than others?

7. Do you think it matters if a community is **more even** or **less even**?
Why?
This is a very hard question for students. You may want to use it as a discussion question instead of asking them to do it in small groups. If a community is less even, there is a good chance that functional redundancy will be low. Thus taking one species out of the system could make a big difference to the functioning of the system. If a species that performs a key function is removed and there is not another species to take its place (i.e. fill the niche), then the system will be very altered.

8. Using the data your teacher provides, describe any differences in abiotic resources or conditions between the riffles or pools in-

   -the amount of dissolved oxygen:

   -the pH of the water:

   -the temperature of the water:

   Other characteristics:

9. Using the graphs you made in question 2, describe any major differences in the groups of invertebrates you found in leafs packs in the riffles and pools.

10. Why might the groups that you found in the leaf packs be different? You may want to use your answer to question number 8 and your **Macroinvertebrate Data Collection** table to help you answer this question.

Each group of organisms had a range of resources and conditions (e.g. temperature, turbidity, stream velocity, dissolved oxygen, amount of sunlight) it can tolerate. The orders that could tolerate the stream conditions would be more plentiful than the orders that couldn't tolerate the conditions. Students should use the measured differences in dissolved oxygen and what they know about the needs of the different orders to provide evidence for their statements.

11. Besides the abiotic factors you measured, what else could have influenced the diversity of the organisms you found in the two types of leaf packs?

- Other Abiotic Resources or Conditions. This extends to the non-invertebrate organisms as well. For example, if the part of the stream with pools was shadier than the part with riffles, more algae might be found in the leaf packs in the riffles.
- Biotic Interactions: The types of other organisms present could influence what invertebrates we found. An order is less likely to be found if its predators or competitors are there and more likely to be found if its food source and its mutualists are there.
- Dispersal: How far our leaf bags were from source populations for organisms is important. If our leaf bags were too far away from other organisms, then they could not have migrated/dispersed from their original habitat to our bags. If the holes in our leaf bags were too small, some larger organisms couldn't get in.
- AHS For different leaf types: If the leaf packs were placed near one another in the same stream, then the most likely cause of the difference would be a factor related to the types of leaves themselves.

One type of leaf might have been a better food source and/or a safer refuge for the species. Also, the type of leaf that wasn't preferred could have had substances in it that were toxic or unpalatable (i.e. not tasty) for that species.

12. Are there the same of feeding groups in both types of leaf packs?

13. Are the members of each feeding group exactly the same in both types of leaf packs?

Why do you think that is?

14. There were probably multiple kinds of collectors or predators living in your leaf packs. Why do you think there are multiple kinds of collectors or predators instead of one best collector?

The collector or predator species/orders probably differ from one another in many ways even though they are all collectors or predators. The different collector or predator species/orders may prefer/tolerate different abiotic conditions (e.g. Stonefly larvae prefer high amounts of oxygen while dragonfly larvae prefer lower amounts), may be different in terms of how well they collect certain types of leaf matter or kill certain organisms (e.g. bigger or smaller leaf pieces or animals), or may be different in terms of how they escape certain types of predators (e.g. caddisflies have carry around camouflage and midges don't). Because the environment might always be changing in some biotic and/or abiotic ways or be different in different (but close by) places, one collector or predator species/order isn't every numerous enough for long enough to outcompete the other species.

15. A thought experiment: If you took a bunch of invertebrates from a stream in New York and put them in a stream in California, what do you think would happen? Explain why. Give as many reasons as you can.

This question is KEY to this unit: Organisms have particular abiotic and biotic requirements. If you change location (e.g. NY to CA), some things change (e.g. temperature of the water during the winter, the food available), and some needs of an organism ***might*** *not be met and then they* ***might*** *not be able to survive and reproduce*. There are lots of possible answers for this, but you want to make sure that students pay attention to possible abiotic and biotic differences between the locations. You might also want to change this question to two locations that make more sense to your students (e.g. stream in the Upper Peninsula v. Los Angeles). New York is likely colder in the winter than California. New York also has longer days in the summer because it is further from the equator. The invertebrates may thrive because their predators, diseases, or competitors aren't in the new habitat. The invertebrates could die because there isn't enough food for them or because the abiotic conditions are outside the range of their tolerance.

16. What additional information would you need to know to feel more confident in your answer?

I would need to know what certain important abiotic conditions (e.g. stream temperatures throughout the year) in the California stream are and how they compare to what the invertebrate species can tolerate. I would need to know if there are predators, competitors, or diseases that are likely to kill the invertebrates that get transplanted. I would need to know if there will be food for the invertebrate in the California stream. I would need to know if the invertebrate species has mutualists upon which it depends and if those would be in the California stream.

Lesson 18— Comparing the stream to what is familiar

Instructional Goal

At the end of this lesson, SWKABAT

a. Construct a food web for an ecosystem and label feeding groups and direction of matter and energy flow in the web
b. Recognize the diversity of microscopic life and macroscopic life exists in all ecosystems
c. Group familiar organisms in multiple ways using multiple traits: feeding group, phylogeny

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Energy & Matter

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic A: Cycling of Matter & Energy; Topic E: Diversity

Materials

- Poster paper for students to draw food webs on
- Copies of **Comparing the stream to what is familiar** Worksheet

Advance Preparation

Collect students' diagrams of their familiar ecosystems in Lesson 1 for distribution to groups. Make copies of the **Comparing the stream to what is familiar** Worksheet

Lesson Procedure

1. Ask students to work together in pairs or small groups and make a food web for a familiar ecosystem. Can they add more organisms (e.g. bacteria, fungi, or other microorganisms; multiple types of insects or other macroinvertebrates like snails or earthworms) or details about relationships now that they have studied the stream ecosystem? Have students fill out the tables in Q4.
2. In the **Comparing the stream to what is familiar** Worksheet, students will identify similarities and differences between the familiar and stream ecosystems with regards to both relatedness and feeding types and other things they may think of (Q5-6) and think about biotic-abiotic interactions (Q7-9).

> **Check Student Understanding**: Students' ability to describe redundancy in natural systems is limited. Redundancy, the idea that multiple organisms can share similar biotic (e.g. feed on similar organisms) requirements is often a new one to them when thinking in the food web context. Hopefully their experiences with the leaf packs will expand this awareness, but watch for this in their discussion of their original food webs.

3. Lead a classroom discussion around the charts and questions. Focus the discussion on comparing the biota (i.e. feeding types, classification, interactions) in each ecosystem, similarities and differences in the abiotic environment, and the dispersal capabilities of the organisms in the food web. If you have time, you may choose to have several groups with different contexts present their familiar ecosystems to the class (biotic, abiotic, and dispersal) and compare and contrast them, finding similar feedings patterns, in addition to the stream.

   Although they've examined these requirements in detail for the stream community using their leaf packs, they should now be able to apply these ideas to any ecosystem, even those for which they don't know all of the details. One key conceptual link for students to make between the streams and the (likely) terrestrial ecosystems that they originally described is in the way that new energy is introduced into the system. For most ecosystems, solar energy captured during photosynthesis and stored as chemical energy in producers is the energy source for all of the other organisms 'higher' in the food web. In an ecosystem built on decomposition, such as the leaf packs, the fresh inputs of energy are in the form of chemical energy in the detritus (leaves, stems, dead bodies of animals, etc) of that system, which is then passed up through a food web that in other ways is almost exactly like the more familiar ones.

Assessment Ideas:

1. Focus on questions 4-9 as formative or summative assessments to probe student ability to transfer ideas from the lessons back to familiar food webs.

Lesson 18: Comparing the stream to what is familiar

1. What ecosystem are you most familiar with (Deciduous, Kelp, Tropical, Redwood, Alpine, Coniferous, etc)?

2. What makes it an ecosystem?

3. Make a food web for the ecosystem you chose in question one. Think back on the previous lessons to help you add more organisms or details about relationships based on what you learned about the stream ecosystem.

4. In the tables below, name example(s) of each type of organism that live in the forest you drew. Add organisms from the list below to your new food web if not already included.

Feeding Type	
Producer	
Consumer that is a predator	
Consumer that is not a predator	
Decomposer	

Kingdom			
Plant	1.	2.	3.
Animal	1.	2.	3.
Fungi			
Protist			
Bacteria			

5. What are three similarities between your familiar forest ecosystem and the stream ecosystem?
   1.
   2.
   3.

6. What is one difference between these two ecosystems?

7. Think of one change in the biological community of your forest ecosystem that would change the abiotic environment. Describe it:

8. How would these changes affect the biological community?

9. **Group Challenge for Extra Credit:** List and explain as many different examples as you can of changes that could occur to your forest (natural, man-made or invading) that would affect the biological community.

Lesson 18: Comparing the stream to what is familiar

(Teacher answer key)

1. What type of forest are you most familiar with (Tropical, Temperate, Redwood, Alpine Coniferous, etc.) List organisms you would find living there.
   Answers will vary
2. What makes it an ecosystem? Refer back to your vocabulary list.
   - **What makes it an ecosystem is that it is a community of living and non-living things that interact in that forested area.**

3. Make a food web on poster paper from your list in question one. Can you add more organisms or details about relationships now that you have studied the stream ecosystem?
4. In the tables below, name example(s) of each type of organism that live in the forest you drew. Add organisms from the list below to your new food web if not already included.

Feeding Type	
Producer	
Consumer that is a predator	
Consumer that is not a predator	
Decomposer	

Kingdom	
Plants	1. 2. 3.
Animals	1. 2. 3.
Fungi	**Students should be able to name at least on fungi in general terms like mushrooms, morels etc..**
Protist	**Students may not know specific names of these, but should include "Protists" in their web.**
Bacteria	**Students may not know specific names of these, but should include "Bacteria" in their web.**

5. What are 3 similarities between your familiar forest and the stream ecosystem?
Answers will vary.

6. What is one difference between these two ecosystems?
Answers will vary

7. Think of one change in the biological community of your forest that would change the abiotic environment? Describe it:
Students could describe a tree fall increasing sunlight addition, more animals coming and urinating or defecating adding nutrients to an area. An increase in deer could decrease shrubs and increase light in the understory.

8. Would these changes affect the biological community? How exactly?
Changing sunlight or nutrients could increase plant growth in the understory.

9. **Group Challenge for Extra Credit:** List and explain as many different examples as you can of changes that could occur to your forest (natural, man-made or invading) that would affect the biological community.

Lesson 19— Biodiversity & Your Stream

Instructional Goal

At the end of this lesson, SWKABAT:

a. Explain how dispersal, biotic factors, and abiotic factors can account for what they found in their leaf packs.
b. Calculate the diversity index of their stream ecosystem
c. Compare their stream's biodiversity to that of other streams.
d. Explain how biodiversity can be used to assess ecosystem health.

NOTE: ***This is the culminating lesson to see if students integrate the three determinants of local biodiversity (biotic, abiotic, and dispersal).*** The later part of this lesson, with calculating indices, might be too advanced for your students. If you don't want to calculate indices, focus on steps 1-4 below and use the exit ticket assessments have a class discussion about

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Using Mathematical & Computational Thinking
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Scale, Proportion, and Quantity
Systems & System Models

Common Core Standards Addressed:

Mathematics:
Quantities- Reason quantitatively and use units to solve problems
Mathematical Practices- Reason abstractly and quantitatively
Attend to precision

English Language Arts Standards- Science & Technical Subjects
Integration of Knowledge & Ideas- CCSS.ELA-Literacy.RST.11-12.8
Range of Reading & Level of Text Complexity- CCSS.ELA-Literacy.RST.11-12.10

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic B: Population Dynamics; Topic C: Community & Ecosystem Dynamics; Topic E: Diversity

Standard 5: Humans & Natural Resources Topic A: Human Impact on Natural Resources

Materials

- Copies of Biodiversity & Your Stream Worksheet

- Class data sheet with the number and type of macro-invertebrates collected in Lesson 2
- Predictions and experimental design poster from Lesson 1
- Excel template
- Projector
- Individual student whiteboards

Advance Preparation

Find student prediction and experimental design poster/notes from Lesson 1. Make copies of the **Biodiversity & Your Stream** worksheet.

Lesson Procedure

1. Write on the board or the poster:

   very similar --very different

   Ask students to vote by putting an X on this continuum in response to the following question: *Did we find **very similar** or **very different** organisms in the leaf packs we are comparing?* Let students talk briefly about these qualitative results.

2. Ask students what they think might influence *why* they found differences in their bags – focus students on the ecosystem itself, instead of induced error.

3. As in lesson 1, when comparing communities in packs of different leaf types or different locations, students should think about the following three determinants of diversity. Now that they have data they can talk specifically about some biotic (type of food organisms) and abiotic (amount of dissolved oxygen) factors. Competition for food by organisms of the same feeding type is a biotic interaction students should recognize.

   a. **Dispersal - Can the organism get there?** (e.g., direct organism movement, water, wind) Organisms can't live in a specific time or location if they can't get there; we call this "dispersal," the ability to travel to a new habitat. Is it likely that there are barriers to migration or dispersal that prevent the organisms of interest from being located at one of the two locations? (e.g. dams, nearby streams that adult stages of insects can fly in from). There may be corridors of habitats connecting two places an organism can use.

   b. **Abiotic resources and conditions - Can the organism survive and reproduce given these abiotic resources and conditions?** (e.g. light, water, oxygen, nitrogen, phosphorus, temperature, pesticide pollution, etc.) Abiotic resources and conditions influence whether organisms are able to survive and reproduce in a specific time or location. In addition, organisms influence the abiotic environment around them. Is it likely that there are differences in the abiotic resources between the two locations?

   c. **Biotic resources and conditions - can the organism survive and reproduce given the range of biotic resources and interactions**? (Does it have food, does something eat it, what are the competitors, mutualists, habitat forming organisms, diseases, etc.) Biotic resources and interactions also influence how successful organisms are in a specific time or location. Are the surrounding organisms different between the two communities that might influence the success of the organism of interest? (e.g., new competition, lack of prey).

> **Check Student Understanding:** Upper level reasoning always involves being able to think of these three determinants (biotic, abiotic, dispersal) as interacting constantly in all ecological situations and are part of what governs diversity. Although we need to isolate them as much as possible to conduct experiments, each determinant can lead to changes in the others. As your students discuss these, try to guide them into making this realization explicit, if they don't do so themselves.

Discuss why there are (potentially) multiple types of each functional group in the leaf packs (questions 10-12), making sure students understand that each type of organism can have slightly different abiotic and biotic requirements.

Check Student Understanding: ***Functional diversity*** refers to the number of different functions being performed in a system. Lower level students think that removing any species from a system would cause a major problem. This isn't always the case though, if there are lots of species that can perform the same function in the system. Sometimes, there may be only 1 or 2 species that are able to perform a certain function and sometimes there will be lots of species capable of performing a certain function. When there are lots of species performing a function, we call this ***functional redundancy***. Talk with your students about functional diversity and functional redundancy. Ask them what would happen to the system if you removed all individuals of a single species from a functional group that had low redundancy? How would the result be different if the group had high redundancy? A useful analogy might be to talk about a high school football team. If there were 5 guys who could all play quarterback well, the team wouldn't suffer if one of those guys transferred to a different school. But, if there was only 1 guy who could QB, then the team would have some losing games if that student moved away. At the most advanced level, students should recognize that organisms serve more than one function. If one of the 5 back-up QBs moved away, the football team wouldn't suffer. But, what if that back-up QB was also the only tenor in the Glee Club?

4. Show the results from your class stream study using the Excel template. Students should refer to their calculations of richness and evenness from Lesson 5.
5. Decide whether you want to look at the results in aggregate – ie for the whole stream, or separately for pools and riffles. Now that students have summarized the possible reasons why they got the results they did, they are ready to think about what the diversity of their ecosystem means for ecosystem health. There are two options for calculating the Shannon diversity index:
    a. Calculating with a calculator – use the provided handout in Appendix G to walk students through the process of calculating the Shannon Index for their results.
    b. Using an online applet to find the Shannon index – Go to http://www.changbioscience.com/genetics/shannon.html and input your data. A Shannon Diversity Index value will be provided to you.
6. Remind students that you do not actually have species data, but group data.
7. Depending on your samples, you may have a very low Shannon index. Talk with the students about possible reasons, and what this might indicate about your stream and/or your experiment. Remind students of the need to do replicates, study a system over longer time periods, etc.
8. The Shannon Index incorporates both richness and evenness. To highlight this with your students, project the following table at the front of the classroom:

Community	Number of species	Diversity Rank	Shannon Diversity Index
Marshes	15		

Tropical woodlands	21		
Deserts	6		
Mixed forests	30		

Using the whiteboards, ask students to rank the ecosystems from #1 to #4, with #1 being the most diverse. Then, show students the Shannon Diversity values associated with each community. Were students correct in their predictions? Why or why not? What do you think was different between the ecosystems, besides species richness, that contributed to the differences in the Shannon Diversity values? Remind students that a diversity index takes into account not just richness, but also evenness. Since you don't have the abundance information here, you don't have enough information to say anything about the diversity.

Community	Number of species	Diversity Rank	Shannon Diversity Index
Marshes	15		1.79
Tropical woodlands	21		5.23
Deserts	6		3.25
Mixed forests	30		3.92

9. Students will now look at a graph of data from streams in Wisconsin that relates watershed imperviousness with the Shannon Diversity index. Ask students to a) explain the graph and b) relate the graph to their own data.
10. In order to relate the stream data to water quality, students will now calculate a water quality index (based on the Hilsenhoff Biotic Index, a common stream index that originated in Wisconsin and is commonly used throughout the United States). Although this water quality index is intended for educational purposes, it can give students another measure of why diversity in a stream is important – it gives us an idea of who lives in the stream, why, and what that might imply for overall ecosystem health.
11. Finally, students compare their water quality index with some values from rural and urban streams in Kentucky, and discuss whether there might be ways of improving their stream's ecosystem health.
12. If you think your students can handle the reading level, for homework, students should read "In Bat Deaths" and answer the associated questions to review the ideas about the importance of biodiversity. Other possibilities are to use excerpts for a class reading and discussion. Suggested reading questions are included.

Assessment

This is the culminating lesson to see if students integrate the three determinants of local biodiversity (biotic, abiotic, and dispersal). Some ideas for exit ticket questions:

1. There were probably multiple kinds of collectors or predators living in your leaf packs. Why do you think there are multiple kinds of collectors or predators instead of one best collector?
2. A thought experiment: If you took a bunch of invertebrates from a stream in New York and put them in a stream in California, what do you think would happen? Explain why. Give as many reasons as you can.
3. What additional information would you need to know to feel more confident in your answer?

4. A local watershed group comes to you asking for help. They have a stream in a local forest they would like to protect from development. No one has surveyed the stream, but it is very similar to the one you studied. The watershed group would like to know if you can tell them what kinds of organisms might live in their stream, and whether their stream could have high levels of biodiversity. What would you tell them? How confident are you about your answer? Explain.

Lesson 19: Biodiversity & Your Stream

(Student worksheet)

Diversity is measured by two main components: species richness (the number of species present), species evenness (how relatively abundant each of the species are). Additionally, species composition (which particular species are present) is often measured. Scientists often use indices to help them compare different ecosystems. It gives them a reference point to help them understand the new ecosystem they are studying, and combines the above metrics into one number that is easier to compare across ecosystems.

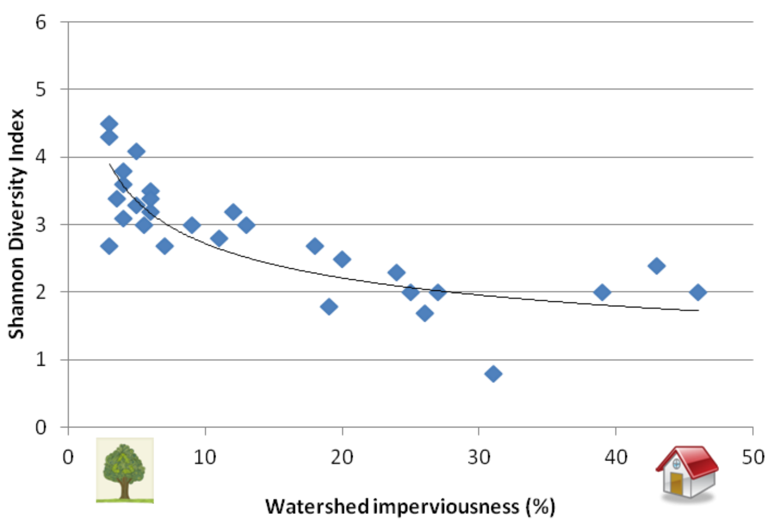
Quantifying Diversity

There are a number of diversity indices which can be used to summarize the diversity in a community – they look at both richness *and* evenness. We will use the Shannon Diversity Index (H'), which is commonly used by environmental scientists. It is often used when we wish to study a random sample from a larger community. As the value of the index increases there is more "order", or diversity, in the community. High values of H would be representative of more diverse communities. A community with only one species would have an H value of 0. If the species are evenly distributed then the H value would be high. The H value allows us to know both the number of species and how the abundance of the species is distributed in the community. *Concerns:* Shannon's index is particularly sensitive to the number of rare species in a community. The more replicates you have, the more you can reduce the chance that your diversity value is being affected by a small number of rare species.

1. Calculate the Shannon diversity index for the summary data of your samples. You can use either the biodiversity workbook provided (Excel) or the online applet. Shannon Diversity Index for ou

2. How confident are you that your diversity index is accurate? For instance, think about the types of things you could do better or change about your study in order to be more confident about your index value.

3. Look at the data below. These data are based on a study of 43 streams in southeastern Wisconsin (Stepenuck et al., 2002). The scientists evaluated streams in places where the watershed did not have a lot of impervious surfaces (forests), and places where there were more impervious surfaces (towns and cities). You can see the range of streams sampled below.



a. What does this graph tell you about the relationship between watershed imperviousness and the Shannon Diversity index?

b. If you were told that a building a new shopping mall would increase the impervious surface from 5% to 25% in a watershed, what would you predict would happen to the diversity of invertebrates based on the graph?

c. What do you think might change about a stream ecosystem as you move from a forest to a city?

d. Where does your stream data fit into this graph? Did you find similar, or different results? Explain.

4. In stream ecosystems, scientists often use other types of metrics to tell them more about the community. For example, some scientists use the information about the kinds of invertebrates that were collected to tell them about the water quality of the stream. Use the handout provided by your teacher (called Water Quality Index) to calculate the water quality index of your stream.
   a. What is the water quality "score" for your stream? ________
   b. Why do you think you got the water quality score that you did? In other words, what might influence the health of your stream ecosystem?

   c. Look at the data below, from a study of streams in Kentucky.

Type of stream	Water Quality Index (winter average)
Rural	4.8
Urban	7.3

Data modified from Johnson, R. et al. 2012. Within-year temporal variation and life-cycle seasonality affect stream macroinvertebrate community structure and biotic metrics. Ecological Indicators, 13:206-214.

Which stream type has better water quality? _____________

   d. What are some ways that you could improve the water quality index of the stream you studied?

5. Your town would like to develop an area near a river into a shopping mall. Would you support this development? Why or why not?

Water Quality Index

Directions: Input all of your data into column #1; if you have multiple samples, use the average for this chart. Multiply column #1 by column #2 to get the values for column #3.

Type	1 Total # collected	2 Pollution Tolerance Value	3 Total Tolerance Value
Stoneflies		1	
Dragonflies & Damselflies		5.5	
Mayflies		3.6	
Water beetles		4.6	
True flies		6	
Cranefly		4.0	
Dobsonflies & Alderflies		3.5	
Caddisflies: other		2.8	
Caddisflies: Common netspinners (no case)		5	
Water mites		unknown	
Springtails		unknown	
Scuds		6	
Aquatic pillbugs (sowbugs)		8	
Crayfish		5	
Snails		7	
Clams & mussels		8	
Leeches		8	
Aquatic worms		8	
Planaria & nematodes		unknown	

Totals Column #1: __________ Column #3: _________

Data for this chart are from the Stroud Water Research Center's Leaf Pack Network.

Divide: totals from column #3/totals from column #1= ________

This will give you a water quality number "score". Use the values below to understand more about your ecosystem.

Biotic Index	Water Quality	Degree of Organic Pollution
<3.75	Excellent	Unlikely
3.76-4.25	Very Good	
4.26-5.00	Good	Some pollution likely
5.01- 5.75	Fair	
5.76- 6.5	Fairly poor	Substantial pollution likely
6.51- 7.25	Poor	
7.26- 10	Very Poor	Severe pollution likely

1. Do you feel that the water quality rating your stream received is accurate? Why or why not?

2. You have other abiotic information about your stream – dissolved oxygen data. In most streams, "normal" dissolved oxygen levels are between 8-12 mg/L . Do your dissolved oxygen data support the water quality rating you found? Why or why not?

3. If you went back to your stream in two months and found many more mayflies and stoneflies than you did now, what would that tell you about the health of your stream? What else would you like to know before you felt confident about deciding on the health of your stream?

Lesson 19: Biodiversity & Your Stream

(Teacher answer key)

Diversity is measured by two main components: species richness (the number of species present), species evenness (how relatively abundant each of the species are). Additionally, species composition (which particular species are present) is often measured. Scientists often use indices to help them compare different ecosystems. It gives them a reference point to help them understand the new ecosystem they are studying, and combines the above metrics into one number that is easier to compare across ecosystems.

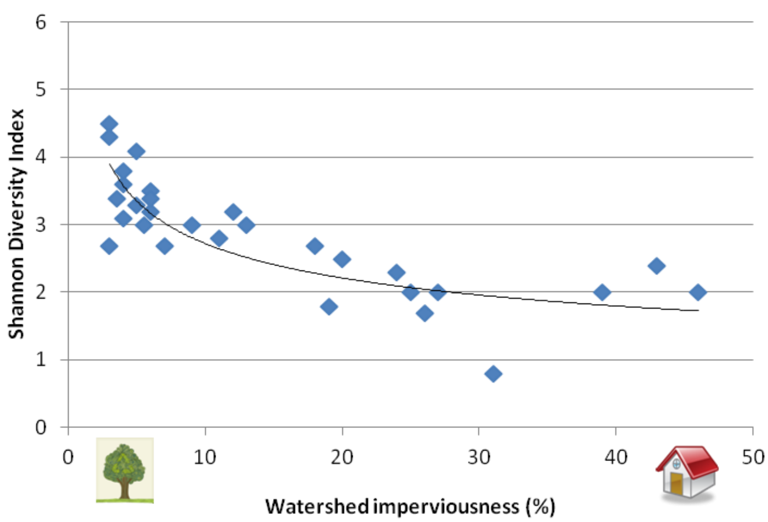
Quantifying Diversity

There are a number of diversity indices which can be used to summarize the diversity in a community – they look at both richness *and* evenness. We will use the Shannon Diversity Index (H'), which is commonly used by environmental scientists. It is often used when we wish to study a random sample from a larger community. As the value of the index increases there is more "order", or diversity, in the community. High values of H would be representative of more diverse communities. A community with only one species would have an H value of 0. If the species are evenly distributed then the H value would be high. The H value allows us to know both the number of species and how the abundance of the species is distributed in the community. *Concerns:* Shannon's index is particularly sensitive to the number of rare species in a community. The more replicates you have, the more you can reduce the chance that your diversity value is being affected by a small number of rare species.

1. Calculate the Shannon diversity index for the summary data of your samples. You can use either the biodiversity workbook provided (Excel) or the online applet. Shannon Diversity Index for ou

2. How confident are you that your diversity index is accurate? For instance, think about the types of things you could do better or change about your study in order to be more confident about your index value. **Students should suggest increasing the number of replicates, the scope of the study, the numbers of times the stream was sampled over the course of a year, etc.**

3. Look at the data below. These data are based on a study of invertebrate diversity in 43 streams in southeastern Wisconsin (Stepenuck et al., 2002). The scientists evaluated streams in places where the watershed did not have a lot of impervious surfaces (forests), and places where there were more impervious surfaces (towns and cities). You can see the range of streams sampled below.



a. What does this graph tell you about the relationship between watershed imperviousness and the Shannon Diversity index? **This graph shows you that as imperviousness increases, the diversity of invertebrates in Wisconsin streams decreases.**

b. If you were told that a building a new shopping mall would increase the impervious surface from 5% to 25% in a watershed, what would happen to the diversity of invertebrates, based on the graph? **The diversity of invertebrates would decrease.**

c. What do you think might change about a stream ecosystem as you move from a forest to a city? **A stream might become more polluted, there might be runoff from roads or homes, there are fewer permeable surfaces to absorb rain and slow down runoff during storms, leading to flooding.**

d. Where does your stream data fit into this graph? Did you find similar, or different results? Explain. **Student answers will vary based on the Shannon Diversity value calculated.**

4. In stream ecosystems, scientists often use other types of metrics to tell them more about the community. For example, some scientists use the information about the kinds of invertebrates that were collected to tell them about the water quality of the stream. Use the handout provided by your teacher (called Water Quality Index) to calculate the water quality index of your stream.
    a. What is the water quality "score" for your stream? _________
    b. Why do you think you got the water quality score that you did? In other words, what might influence the health of your stream ecosystem? **Students could think about land use, sources of pollutants, invasive species.**

    c. Look at the data below, from a study of streams in Kentucky.

Type of stream	Water Quality Index (winter average)
Rural	4.8
Urban	7.3

Data modified from Johnson, R. et al. 2012. Within-year temporal variation and life-cycle seasonality affect stream macroinvertebrate community structure and biotic metrics. Ecological Indicators, 13:206-214.

Which stream type has better water quality? **The rural stream.**

d. What are some ways that you could improve the water quality index of the stream you studied? **Students may suggest planting trees, reducing the input of pollutants, restoring natural stream channels, reducing impervious surfaces.**

5. Your town would like to develop an area near a river into a shopping mall. Would you support this development? Why or why not? **Students should ask for more information about the stream, its community, and the surrounding land use.**

The New York Times
Green
A Blog About Energy and the Environment

January 19, 2012

In Bat Deaths, a Catastrophe in the Making?

By Joanna M. Foster

A “biodiversity crisis”: that’s how some conservationists describe new numbers released this week by the federal Fish and Wildlife Service on so-called white-nose syndrome (at right, a bat infected with the fungus). According to the agency, 5.7 million to 6.7 million bats have died from the fungal ailment in eastern North America since an epidemic first broke out in upstate New York in 2006.

The new numbers are striking, and far higher than the previous bat mortality estimate of one million released in 2009, yet it is hard to put the number into perspective because researchers lack baseline data for many bat species populations from before the disease started demolishing colonies.

“We knew numbers for endangered species like the Indiana bat,” said Ann Froschauer, who coordinates communications releases on the bat disease for the Fish and Wildlife Service. “But we never made it a priority to count something like little brown bats, because, well, they were everywhere. It didn’t seem possible that they would be in danger of extinction in just a couple years.”

What is known is that when the fungus gets into a cave or mine where bats are hibernating, 70 to 90 percent of the bats die. In some cases, the mortality rate is 100 percent.

Over the past three years, the disease has spread from 88 sites in nine states in 2009 to at least 200 sites in 16 states today. Jeremy Coleman, the lead white-nose syndrome coordinator for the Fish and Wildlife Service, said that officials can’t keep up with new site infections and are now working on the assumption that all caves and mines are infected in areas where the ailment has existed for several years.

There are 45 species of bats in North America, 26 of which are hibernating species potentially susceptible to the fungus. While the disease has infected only six species so far, some researchers worry that it could wipe out as many as 20 bat species in the next few years.

Molly Matteson, a conservationist for the Center for Biological Diversity, an environmental group, says that’s a big deal — not just for the environment but for people as well. Researchers have estimated that bats save farmers at least $3.7 billion a year by keeping down crop pests.

Ms. Froschauer emphasized that each bat species fulfills a specific ecological purpose. “I think people tend to put bats in a bucket and think of them as one species,” she said. “But they are a hugely diverse group of mammals, and each species has a very special ecological niche that can’t be filled by a different bat species.”

“Different species eat different things, hunt in different locations and fit into the ecological puzzle in a unique way,” she said. “Losing one bat species would be huge — losing 20 would be catastrophic.”

Some conservationists take a bit of hope from recent reports that resistance to the fungus is growing in the bat population in parts of the Northeast.

“I’d love to believe that,” said Dr. Coleman of the Fish and Wildlife Service. “I hate always being the guy with the bad news.”

“But just because some bats are surviving doesn’t mean that we will have viable populations in the future,” he said. “These new numbers make it quite clear that this is still a crisis and a growing one.”

Reading questions:

1. What pathogen causes white nose disease? Why does it kill the bats?
2. Research the ecosystem of the little brown bat, and then draw a food web for the bat.
3. If you removed a bats from the food web what might happen to other species that are part of the food web? Explain your answer.
4. What might happen to abiotic components of the ecosystem?
5. Why do researchers think that this disease will be catastrophic?

Lessons 20-24: Design an inquiry experiment with defended hypothesis

Instructional Goal

Students' knowledge about abiotic and biotic influences on a stream community will be assessed. Students will be able to design an investigation of abiotic or biotic influences on a stream community, make predictions on the outcome, and defend their predictions.

Next Generation Science Standards Addressed

Science & Engineering Practices:
Asking Questions
Planning & Carrying Out Investigations
Analyzing & Interpreting Data
Using Mathematics & Computational Thinking
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Cause and Effect

Common Core Standards Addressed:

Mathematics:

Quantities- Reason quantitatively and use units to solve problems
Mathematical Practices- Reason abstractly and quantitatively
Attend to precision
Construct viable arguments and critique the reasoning of others
Model with mathematics

Maryland Environmental Literacy Standards Addressed

Standard 1: Environmental Issues Topic A: Environmental Issue Investigation

Lesson Procedure

Now is the time for your students to show you what they know, and to practice career-related skills related to the content they have learned.
Students should work in pairs or small groups to come up with an inquiry question based on their experiences with the leaf packs. They should then design an experiment:

- What question are they interested in?
- What is their hypothesis?
- Why do they predict that?
- How will changing or manipulating or comparing different X (es) affect Y?
- What do they have to measure to answer that question?
- What treatments will they set up? How will they do it?
- Do they need to control for any dispersal, abiotic, or biotic factors in the environment?

Take advantage of this opportunity for students to practice technical writing by having them formally write up their results in a report.

Lesson 25— Reign of the Rock Snot

Instructional Goal

At the end of this lesson, SWKABAT:
explore the basic principles of population growth
examine the factors responsible for Didymo population trends
assess damage to the environment imposed by Didymo population increases.

Next Generation Science Standards Addressed

Science & Engineering Practices:
Analyzing & Interpreting Data
Using Mathematics & Computational thinking
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics

Cross-Cutting Concepts:
Patterns
Cause & effect
Systems & system models

Common Core Standards Addressed:

Mathematics:
Quantities- Reason quantitatively and use units to solve problems
Mathematical Practices- Reason abstractly and quantitatively
Attend to precision
Construct viable arguments and critique the reasoning of others
Model with mathematics

Maryland Environmental Literacy Standards Addressed

Standard 7: Environment & Society Topic A: Environmental Quality
Standard 4: Populations, Communities, & Ecosystems Topic B: Population Dynamics
Standard 5: Humans & Natural Resources Topic B: Human Impact on Natural Resources

Materials

- copies of the *It's Gooey. It's Gross. It Kills.* article (http://www.treehugger.com/corporate-responsibility/its-gooey-its-gross-it-kills-beware-rock-snot-is-invading-new-york.html)
- interactive Google Earth map of the Gunpowder watershed in MD/Didymo testing stations (https://maps.google.com/maps/ms?hl=en&ie=UTF8&msa=0&msid=102249127972796766811.00045a8cff906ac644985&ll=39.560847,-76.659301&spn=0.11752,0.096286&t=h&source=embed)
- copies of Gunpowder River Didymo Abundance Data from MD DNR (July 2008 to June 20123)
- copies of *Reign of the Rock Snot—Student Worksheet (1 per student)*
- graph paper

Advance Preparation

Make copies of the **It's Gooey. It's Gross, It Kills.** article, the **Gunpowder River Didymo Abundance data sheet**, and the **Reign of the Rock Snot** student worksheet.

Teacher Background:

As its common name suggests, Didymo may look like snot, but it's not. *Didymosphenia geminata*, Didymo for short, is a microscopic freshwater diatom that secretes a fibrous stalk which it uses to attach itself to rocks and plants in aquatic systems. During blooms, the stalks grow to form mats up to 20 cm thick which can completely cover the stream bottom. This diatom may look slimy, but its silica cell walls make it feel more like wet wool. Didymo, unlike other diatoms, grows a yellow-brown or grayish-white, muco-polysaccharide shoot that extends up to 2 feet long, thus earning the unflattering nicknames of "rock snot" and "boulder booger".

Nuisance Didymo "blooms" are often mistaken for raw sewage spills because trailing stalks look like wet toilet paper in the water. Although Didymo mats may look slimy, they actually feel gritty and somewhat fibrous (like wet wool). Individual stalks can break off, drift downstream, get snagged on woody debris, and persist for up to two months. From an environmental perspective, the thick mats formed during blooms can completely cover substrate, trap sediment, and potentially disrupt food webs. These extensive mats are a threat to biodiversity because they can smother benthic macroinvertebrates, native diatoms, and aquatic plants, thereby reducing food and habitat for fish.

The first report of Didymo in the northeastern U.S. came from the northern reaches of the Connecticut River and the White River in Vermont in June 2007. In October 2007, Didymo was discovered in New York and Pennsylvania. About five years later, in May 2012, was first discovered in Virginia in 2006 and in West Virginia in 2008. In Maryland, the Department of Natural Resources has been collecting data on increasing Didymo abundance at several locations along the Gunpowder River since 2008. In 2009, DNR staff also began conducting annual surveys of macroinvertebrate and trout populations in the Gunpowder. Environmental scientists have also been evaluating factors such as depth, water temperature, velocity, and turbidity that may affect the seasonal occurrence of Didymo blooms. These data are currently being analyzed to assess whether evidence of larger-scale ecological changes can be conclusively linked to the presence of Didymo. Currently, Didymo has been found in eighteen U.S. states and three Canadian provinces.

The field of population ecology evaluates organisms from the point of view of the size and structure of their populations. Population ecologists study the interaction of organisms with their environments by measuring properties of populations (rather than the behavior of individual organisms), including size, density, dispersion, growth, or limits on growth. In this activity, students will explore basic principles of population ecology relating to the spread of an invasive species, as well as graph and interpret real data to assess Didymo abundance and impact to the environment.

Lesson Procedure

1. Introduce the idea of "invasive" species to the class. Invite the students to make guesses about what it means for an organism to "invade" an environment, asking students for examples of invasive species they may have heard about.

2. Define "native" species and ask the students how adaptations for an invasive species might be different from a native species (examples could include more feathers, bigger mouth, larger body size, camouflage…etc.). Explain that invasive aquatic species are considered invaders because of special adaptations they have that allow them to survive better than native species in their environment.
3. Tell your students that Didymo is an example of an invasive aquatic species. Show this photo of Didymo to the class: http://des.nh.gov/organization/divisions/water/wmb/exoticspecies/didymo/graphics/didymo2.jpg. Explain that Didymo is sometimes called "rock snot" or "boulder booger". Invite the students to brainstorm ideas as to why they think Didymo earned these nicknames.
4. Divide students into groups--hand out copies of and ask the students to read this article: http://www.treehugger.com/corporate-responsibility/its-gooey-its-gross-it-kills-beware-rock-snot-is-invading-new-york.html.
5. If time allows, have the students research Didymo and its habitat using their internet devices. Discuss what features of Didymo or its habitat allow it to thrive and invade aquatic areas—invite students to write their ideas on the board.
6. Explain that, as a result of optimal conditions, Didymo can (1) completely cover substrate, (2) smother aquatic plants, insects, and mollusks to effectively reduce fish habitat and food, and (3) outcompete native species of algae which serve as food sources for aquatic insects. Ask students what they think "optimal conditions" might be for Didymo.
7. Tell the students that they will be using real population data to learn about the spread of Didymo and evaluate the effects of this invasion on the environment and native species.
8. Divide students into groups of two. Allow time for each group to access the interactive Google Earth link provided for the Gunpowder River (https://maps.google.com/maps/ms?hl=en&ie=UTF8&msa=0&msid=102249127972796766811.00045a8cff906ac644985&ll=39.560847,-76.659301&spn=0.11752,0.096286&t=h&source=embed). Ask each group to locate the headwaters of the Gunpowder River. Ask each group to locate the Falls, Masemore, and Bluemount Roads testing stations on the map. Ask each group to find an approximate distance in miles between the headwaters of the river and each testing station (students should record their measurements in the table located in the Thought Questions section).
9. Hand out copies of *Reign of the Rock Snot--Student Worksheet*. Ask each group to review the Didymo population data provided (including the information on coverage scores), taken from the three testing sites along the Gunpowder River between July 2008 and June 2013.
10. Have the students graph the Didymo abundance over time on the graph paper provided. Each graph should have three lines representing each testing station. Remind students to provide a title and key for their graphs, as well as proper labels for the x- and y- axes.
11. When student groups have finished their graphs, they should answer the Thought Questions listed on the *Student Worksheet*.
12. If time permits, host a discussion focusing on student graphs and responses to the Thought Questions (it may be helpful to create a graph ahead of time to use as part of your discussion).

Assessment Ideas:

1. Have students graph and interpret population data for Gunpowder Didymo abundance from July 2008 and June 2013.
2. Have students answer the Thought Questions on the attached *Student Worksheet*.

Extensions:

1. Have students contact DNR for Didymo abundance data in the Gunpowder River taken at other testing stations (Bunker Hill Road, Corbett Road, Glencoe Road, Phoenix Road, Sparks Road, and York Road) between 2008 and 2013. Have them evaluate monthly abundance trends as a function of distance from the Gunpowder headwaters at each station in order to assess a Didymo spread rate.

2. Have students contact DNR for data on water temperature, turbidity, velocity in the thalweg, and thalweg depth at each testing station. Student groups could each graph one factor and use the results to evaluate related Didymo growth trends.
3. Have students contact DNR for data on macroinvertebrate and trout populations in the Gunpowder River between 2008 and 2013. Have them graph the data sets and compare their results to their Didymo graphs to assess growth trends and make predictions about the future ecological impact of Didymo.

Lesson 25: Reign of the Rock Snot—Student Worksheet

The data provided below was compiled from surveys of Didymo populations at three testing stations along the Gunpowder River in Maryland between 2008 and 2013. Abundance figures are based on indices of *estimated bottom coverage* by Didymo in 50 to 100 meter segments that were visually surveyed at each station using viewing buckets; substrate samples were also examined microscopically. Coverage scores range from 1 to 5. If Didymo was present, the percent bottom coverage was considered a "0". An abundance score of "1" meant that the estimated visual bottom coverage was ≤20%, a "3" corresponds to coverage between 20% and 60%, and a "5" corresponds to ≥60%.

Using the data below, graph the Didymo abundance over time on the graph paper provided. Consider the following as you create your graph:

- ✓ *Your graph should have three lines representing data sets from the Falls, Masemore, and Bluemount Roads testing stations, respectively.*
- ✓ *Your graph should have a title and key.*
- ✓ *Your x- and y- axes should be labeled properly.*
- ✓ *When you are finished graphing your data, please answer the Thought Questions at the bottom of the page.*

Thought Questions

1. What is a *coverage score* as it relates to Didymo abundance in a watershed? Explain how the scoring system works.

2. Do any of the graphs for Didymo abundance at the testing stations show long-term trends between 2008 and 2013? Please explain, using examples from the data provided.

3. How does Didymo abundance between 2008 and 2013 compare between the three testing stations? Which station had the highest Didymo abundance during the testing period? Lowest? Use examples from the data to support your answer.

4. How would you explain the difference between the graphs for Didymo abundance at each station over the testing period?

5. Consider factors that might influence Didymo growth in the Gunpowder River (e.g. temperature, time of year, turbidity, velocity, thalweg depth, distance from the headwaters…etc). Which of these factors do you think might influence Didymo growth the least? Most? Use examples from the data provided to help explain your answer.

6. Using the data you have compiled, complete the table below for each testing station.

Testing Station	Distance from Gunpowder River	Abundance increase between 2008 and	Suspected reasons for increase (*e.g.*

	headwaters in miles?	2013? (Y/N)	*temperature, turbidity, depth…etc.*)?
Falls Road			
Masemore Road			
Bluemount Road			

7. Based on the data you have collected, how would you predict Didymo abundance to change at each station in 2014 and beyond? Please explain.
   a. Falls Road
   b. Masemore Road
   c. Bluemount Road

8. What kinds of impacts to the environment might be expected with increasing Didymo abundance in the Gunpowder River. Be specific.

9. Based on the data you have assessed in this activity, do you think we should be concerned about the spread and environmental impact of Didymo? Please explain.

		Monthy Didymo Abundance at Gunpowder River Testing Stations (July 2008-June 2013) (Coverage Score Range: 1-5)		
		Station 1: Falls Road	*Station 2:* Masemore Road	*Station 3:* Bluemount Road

2008	July	3	0	1
	August	3	1	0
	September	3	no data	0
	October	3	5	1
	November	3	3	1
	December	3	3	1
2009	January	3	3	1
	February	5	5	3
	March	5	5	5
	April	5	3	3
	May	3	3	3
	June	1	1	1
	July	1	1	1
	August	1	1	0
	September	1	1	0
	October	1	1	0
	November	1	1	0
	December	1	1	1
2010	January	3	1	1
	February	5	5	1
	March	5	5	3
	April	5	5	3
	May	1	1	1
	June	1	1	1
	July	0	1	0
	August	3	5	1

	September	1	1	1
	October	1	1	0
	November	1	3	1
	December	3	3	5
2011	January	3	3	5
	February	5	3	5
	March	3	3	3
	April	5	3	3
	May	3	3	3
	June	3	1	1

2011 (cont.)	July	3	1	1
	August	no data	no data	no data
	September	0	0	0
	October	no data	no data	no data
	November	1	0	1
	December	no data	no data	no data
2012	January	1	1	1
	February	5	3	3
	March	5	5	5
	April	5	5	5
	May	3	3	5
	June	3	1	1
	July	1	1	1

	August	1	0	0
	September	1	1	1
	October	1	1	1
	November	1	0	0
	December	1	3	1
2013	January	1	1	1
	February	1	1	1
	March	3	5	1
	April	5	5	5
	May	3	5	5
	June	0	1	1

Lesson 25: Reign of the Rock Snot—Student Worksheet Answers

The data provided below was compiled from surveys of Didymo populations at three testing stations along the Gunpowder River in Maryland between 2008 and 2013. Abundance figures are based on indices of *estimated bottom coverage* by Didymo in 50 to 100 meter segments that were visually surveyed at each station using viewing buckets; substrate samples were also examined microscopically. Coverage scores range from 1 to 5. If Didymo was present, the percent bottom coverage was considered a "0". An abundance score of "1" meant that the estimated visual bottom coverage was ≤20%, a "3" corresponds to coverage between 20% and 60%, and a "5" corresponds to ≥60%.

Using the data below, graph the Didymo abundance over time on the graph paper provided. Consider the following as you create your graph:

- ✓ *Your graph should have three lines representing data sets from the Falls, Masemore, and Bluemount Roads testing stations, respectively.*
- ✓ *Your graph should have a title and key.*
- ✓ *Your x- and y- axes should be labeled properly.*
- ✓ *When you are finished graphing your data, please answer the Thought Questions at the bottom of the page.*

SAMPLE GRAPH (The graph below reflects monthly data—students could also graph yearly averages. Breaks in any lines reflect months when data was not available.) As your students answer the questions, be sure to consider the fact that the data is relatively new. Trends in Didymo growth may not be obvious now compared to studies completed at a later date.

Thought Questions

10. What is a *coverage score* as it relates to Didymo abundance in a watershed? Explain how the scoring system works.

Coverage scores, relating to the estimated percent of bottom coverage from Didymo populations, range from 1 to 5. If Didymo is present, the percent bottom coverage is considered a "0". An abundance score of "1" means that the estimated visual bottom coverage is ≤20%, a "3" corresponds to coverage between 20% and 60%, and a "5" corresponds to ≥60%.

11. Do any of the graphs for Didymo abundance at the testing stations show long-term trends between 2008 and 2013? Please explain, using examples from the data provided.
Answers will vary based on graph interpretation and could include (1) trends during certain times of year, (2) seasonal trends, and/or (3) yearly trends.

12. How does Didymo abundance between 2008 and 2013 compare between the three testing stations? Which station had the highest Didymo abundance during the testing period? Lowest? Use examples from the data to support your answer.
Refer to the sample graph above. (Note that each station ranked highest and lowest at different points during different years.)

13. How would you explain the difference between the graphs for Didymo abundance at each station over the testing period?
Review the interactive map of the Gunpowder provided. Consider such things as the presence of urban areas, forested buffers, agriculture, paved areas, roads, public boat access/fishing, proximity to major cities…etc.

14. Consider factors that might influence Didymo growth in the Gunpowder River (e.g. temperature, time of year, turbidity, velocity, thalweg depth, distance from the headwaters…etc). Which of these factors do you think might influence Didymo growth the least? Most? Use examples from the data provided to help explain your answer.

Answers will vary based graphical analysis. Growth might increase relative to: temperature increase, seasonal trends (e.g. increased rainfall or human presence due to recreation such as fishing/boating), decreased turbidity (more access to sunlight), slower-moving water (would give colonies a chance to grow), decreased thalweg depth (more access to sunlight), decreased distance from the headwaters (larger initial populations growing exponentially)

15. Using the data you have compiled, complete the table below for each testing station.

Testing Station	Distance from Gunpowder River headwaters in miles? Headwaters—Pretty Boy Reservoir	Abundance increase between 2008 and 2013? (Y/N)	Suspected reasons for increase (*e.g. temperature, turbidity, depth…etc.*)?
Falls Road (closest to the headwaters)	Use the interactive map provided. Distance can be evaluated from the Pretty Boy Dam Road	Answers will vary based on monthly/yearly trend.	See Question 5.

	crossing—students can measure the distance using the key in the lower, left-hand corner of the map.		
Masemore Road	Use the interactive map provided. Distance can be evaluated from the Pretty Boy Dam Road crossing—students can measure the distance using the key in the lower, left-hand corner of the map.	Answers will vary based on monthly/yearly trend.	See Question 5.
Bluemount Road (farthest from the headwaters)	Use the interactive map provided. Distance can be evaluated from the Pretty Boy Dam Road crossing—students can measure the distance using the key in the lower, left-hand corner of the map.	Answers will vary based on monthly/yearly trend.	See Question 5.

16. Based on the data you have collected, how would you predict Didymo abundance to change at each station in 2014 and beyond? Please explain.

Answers will vary based on graphical analysis. Be sure to consider the significance of distance from the headwaters (Pretty Boy Reservoir), as well as the implications of a longer-term study.

a. Falls Road
b. Masemore Road
c. Bluemount Road

17. What kinds of impacts to the environment might be expected with increasing Didymo abundance in the Gunpowder River. Be specific.

Thick mats formed during blooms can completely cover substrate, trap sediment, and potentially disrupt food webs. The mats could be a threat to biodiversity because they can smother benthic macroinvertebrates, native diatoms, and aquatic plants, thereby reducing food and habitat for fish. The Gunpowder also flows into the Chesapeake Bay, so answers here should take the larger Bay watershed into consideration.

18. Based on the data you have assessed in this activity, do you think we should be concerned about the spread and environmental impact of Didymo? Please explain.

Answers will vary based on student response. Didymo growth trends may not be obvious at this point, so be sure to consider the implications of a longer-term study.

		Monthy Didymo Abundance at Gunpowder River Testing Stations (July 2008-June 2013) (Coverage Score Range: 1-5)		
		Station 1: Falls Road	*Station 2:* Masemore Road	*Station 3:* Bluemount Road
2008	July	3	0	1
	August	3	1	0
	September	3	no data	0
	October	3	5	1
	November	3	3	1
	December	3	3	1
2009	January	3	3	1
	February	5	5	3
	March	5	5	5
	April	5	3	3
	May	3	3	3
	June	1	1	1
	July	1	1	1
	August	1	1	0
	September	1	1	0
	October	1	1	0
	November	1	1	0
	December	1	1	1

2010	January	3	1	1
	February	5	5	1
	March	5	5	3
	April	5	5	3
	May	1	1	1
	June	1	1	1
	July	0	1	0
	August	3	5	1
	September	1	1	1
	October	1	1	0
	November	1	3	1
	December	3	3	5
2011	January	3	3	5
	February	5	3	5
	March	3	3	3
	April	5	3	3
	May	3	3	3
	June	3	1	1
2011 (cont.)	July	3	1	1
	August	no data	no data	no data
	September	0	0	0
	October	no data	no data	no data
	November	1	0	1

	December	no data	no data	no data
2012	January	1	1	1
	February	5	3	3
	March	5	5	5
	April	5	5	5
	May	3	3	5
	June	3	1	1
	July	1	1	1
	August	1	0	0
	September	1	1	1
	October	1	1	1
	November	1	0	0
	December	1	3	1
2013	January	1	1	1
	February	1	1	1
	March	3	5	1
	April	5	5	5
	May	3	5	5
	June	0	1	1

Lesson 26— Historic Chestnut Background

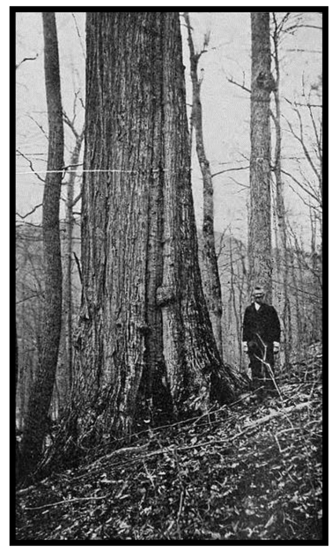
Instructional Goal

At the end of this lesson, SWKABAT:

Describe aspects of the historic American chestnut tree and its function in the historic ecosystem of the eastern forests of the U.S.

Explain how the chestnut blight eradicated the American chestnut tree from these forests changing the ecosystem forever

Explain how organizations like the American Chestnut Foundation are breeding resistant trees and reintroducing them into the ecosystem



Next Generation Science Standards Addressed

Science & Engineering Practices:
Engaging in Argument From Evidence
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics
HSLS4: Biological Evolution: Unity & Diversity

Cross-Cutting Concepts:
Stability & Change
Systems & system Models

Common Core Standards Addressed:

English Language Arts Standards- Science & technical Subjects:
Integration of Knowledge & Ideas- CCSS.ELA-Literacy.RST.11-12.8
Range of Reading & Level of Text Complexity- CCSS.ELA-Literacy.RST.11-12.10

Maryland Environmental Literacy Standards Addressed

Standard 7: Environment & Society Topic A: Environmental Quality
Standard 4: Populations, Communities, & Ecosystems Topic B: Population Dynamics
Standard 5: Humans & Natural Resources Topic B: Human Impact on Natural Resources

Teacher Background:

The American Chestnut Tree dominated much of the Eastern United States mountain regions and surrounding areas before the turn of the 20th century. It made up at least 25%of these forests and was the most numerous tree species in them. They grew in mixed forests with other hardwood species like oaks and tulip poplars. But the American chestnut towered over many of the rest, growing to heights of 100-120 feet and a diameter of 12 feet or more, they were the giants of the forests. Legend has it that a squirrel could travel from Maine to Georgia by way of the chestnut canopy without ever having to touch the ground. The Latin name is Castanea dentate, named this because the edges of the leaves look like rows of sharp teeth.

Chestnuts were the most valuable wildlife food source in eastern forests. They are high in fiber, protein, vitamin C and carbohydrates while low in calories and fat. Chestnuts, being the most abundant tree, had a more reliable nut crop than any other species. A single tree could produce 6,000 nuts annually and dependably. As a result, chestnuts provided more nourishment than any other member of the plant kingdom in the area.

In the early 1900s a non-native blight fungus began killing American chestnut trees. This non-native fungus quickly became invasive, spreading rapidly across the entire native range of the American chestnut over the course of 50 years. This terrible blight changed the east coast forests forever by wiping out the American chestnut.

Where did the blight come from? The blight likely originated on Japanese Chestnut trees that were brought into this country under extremely loose importation laws. American began importing these foreign relatives of the American Chestnut in the 1870s. Over the next several years, thousands of Japanese chestnut trees were brought in and sold by nurserymen, shipping all over the country. This is why pockets of blight began to show up all over the range; New York was simply the first place it was noticed.

The American Chestnut Foundation has been breeding chestnut trees that they hope will have more resistance to the chestnut blight. They have bred Chinese with American chestnuts and then backcross bred the offspring with American chestnuts in order to create a resistant chestnut tree that is a majority American chestnut DNA.

Lesson Procedure

1. Lead a discussion about native species and why they are important. Discuss invasive species. What do the students think of when they hear the term invasive species?

2. Have students read through the background of the American chestnut. Discuss this information in groups or as a class.

3. Have students complete an American Chestnut Web Search. Have students answer the following questions on a separate sheet of paper.

1. How does the carbon sequestration of the American chestnut compare to other native tree species?

2. What are the main differences in characteristics between the American Chestnut and it close relative tree species?

3. What is TACF and why and how do they want people to plant pure American Chestnut trees even though they may be in danger of developing chestnut blight?

4. Why are Chestnut Trees at less risk for having damage done to their flowering/fruit due to frost that species such as oaks?

5. What is the American chestnut tree’s response to fire and how does the chestnut tree respond to fire compared to other native trees?

6. What other factors can cause a reduction in an oak tree’s acorn yield each year?

7. What do the wildlife that had relied so heavily on chestnuts to survive the winter now eat during winter months?

8. What is hard mast year? What is a poor mast year? How does it affect the native wildlife?

9. How do you think the rapid loss of the American chestnut effected wildlife populations throughout the entire food web of eastern forests?

10. Why was the America chestnut tree important to the residents of the mountains where most of the chestnuts stood?

11. What impact did the loss of the tree have on these residents?

Websites that you may find helpful: The American Chestnut Foundation http://www.acf.org/
US Department of Agriculture Forest Service Northern Research Station
http://www.nrs.fs.fed.us/atlas/tree/RFtreemod_421.html# University of Tennessee article from the Rawlings Consulting Forestry Publications Library http://library.rawlingsforestry.com/ut-extension/how_do_acorns_develop/acorns.pdf

The DNA behind the American Chestnut Breeding Program activity- Have students read the two articles provided and answer the questions below. Students can then be asked to do further research into the American Chestnut Foundation's Backcross Breeding Program.
Guide questions are provided below. Articles Included: *Rate of Recovery of the American Chestnut Phenotype Through Backcross Breeding of Hybrid Trees* By: Matthew B. Diskin and Kim C. Steiner and *Selection for Chinese vs. American Genetic Material in Blight Resistant Backcross Progeny using Genomic DNA* By: Song Liu and John E. Carlson.

Follow-Up Questions for the articles:
What supporting DNA evidence was seen in this study for the Backcross Breeding Program?
Did the result match what the researchers were expecting?
Do you feel the number of trees used for this study was large enough to give representative results?
How might the results have differed with a larger test group?
Extension Research Guide Questions:
How does the American Chestnut Foundation create a BC_3F_3?
Do you think the DNA of the BC_3F_3s, if tested against pure American chestnut trees, would be closer in DNA than those tested in the articles you read above?
Do you think that BC_3F_3s could be used to repopulate Eastern forests with American chestnut trees?
Do you think the BC_3F_3s *should* be to repopulate the native range forests?
What impact do you think reintroduction of backcross bred chestnuts could have on the ecosystem of these forests if reintroduction was successful?
What is Hypovirulence? And what role does it play in restoring the American chestnut?
5. A great STEM extension to this activity would be the Maryland Loaner Labs provided free to all Maryland schools through the Towson University Center for STEM Excellence. These can be found at http://www.towson.edu/cse/beop/mdll/index.asp Look for the Chestnut Tree Lab. Reservations for use of these labs can be made online through the website.

6. Extension Debate- Have students hold a class debate on whether or not backcross bred American chestnut trees should be reintroduced into our eastern forests. Have them prepare arguments for and against the reintroduction and have them support their opinion. A panel of judges can be chosen to hear these arguments and make a final decision/recommendation on this issue.

Lessons 27-29— Chestnut Acres Debate (Three class periods)

Instructional Goal

At the end of this lesson, SWKABAT:
Describe the importance of American chestnuts to communities and natural areas
Explain the process of creating transgenic organisms
Debate the pros and cons of introducing transgenic organisms into natural areas

Next Generation Science Standards Addressed

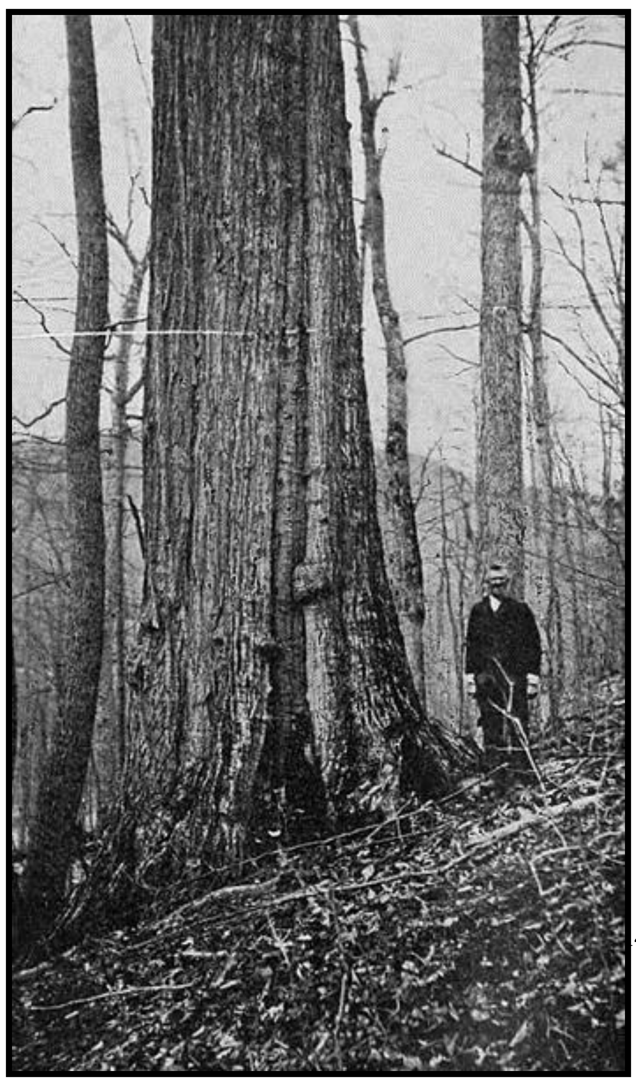
Science & Engineering Practices:
Engaging in Argument From Evidence
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics
HSLS4: Biological Evolution: Unity & Diversity

Cross-Cutting Concepts:
Stability & Change
Systems & system Models

Common Core Standards Addressed:

English Language Arts Standards- Science & technical Subjects:
Integration of Knowledge & Ideas- CCSS.ELA-Literacy.RST.11-12.8
Range of Reading & Level of Text Complexity- CCSS.ELA-Literacy.RST.11-12.10



Maryland Environmental Literacy Standards Addressed

Standard 7: Environment & Society Topic A: Environmental Quality
Standard 4: Populations, Communities, & Ecosystems Topic B: Population Dynamics
Standard 5: Humans & Natural Resources Topic B: Human Impact on Natural Resources

Materials

- copies of student pages

Advance Preparation

Make copies of the student pages.

Teacher Background:

At one time, the **American chestnut** (*Castanea dentata*) dominated approximately 200 million acres of land from Maine to Mississippi. In some areas, it is estimated that American chestnuts covered roughly 20% of the

Appalachian forest while other areas contained almost pure stands of trees. Chestnut trees grew up to 100ft tall and often averaged several feet in diameter. The trees were important for wildlife as they produced edible nuts in the fall. One large tree could produce up to 10 bushels or more of nuts! Ruffed grouse, white-tailed deer, black bears, raccoons, squirrels and wild turkeys are just some of the species which foraged on American chestnuts. The trees were also used in the lumber industry to build fences, casket and cabins while the bark and inner cordwood were used to tan leather hides.

Unfortunately, during the late 1800s, an **invasive species**, the **chestnut blight** (*Cryphonectria parasitica*) was accidentally introduced to the United States from Asia. Invasive species are non-native organisms that create biological, economic and/or human-health related harm. The blight is an invasive fungus that quickly spread through American chestnut stands. Just a few decades after the blight's introduction, over 9 million trees died. By 1950, the American chestnut was nearly gone from the landscape, and today, only a handful of plants survive.

Large American chestnut by U.S. Forest Service

The fungal spores of chestnut blight spread from tree to tree by animals and the wind. The spores infect cuts in the bark and create a rusty-colored **canker** (blister) on the surface of the tree. At the site of the canker, the blight fungus produces high levels of **oxalate** which lowers the pH of the surrounding tissue and binds to calcium needed for growth. In addition, oxalate inhibits lignin production which is important for compartmentalizing (or sectioning off) infected cells. Below the surface, a network of **hyphae** (fungal strings) grows in the **vascular tissue** (xylem and phloem) which are responsible for food and water transport. As the hyphae plug up the vascular tissue, the tree slowly begins to die due to the lack of food and water reaching its living tissues.

Recently, advances in technology have created **transgenes** that may be used to combat chestnut blight. A transgene contains a gene of interest plus extra DNA that encodes for how the gene works. These transgenes then can be inserted into the DNA of another organism. In terms of American chestnut, the enzyme **oxalate oxidase** has been isolated from wheat tissue. The enzyme breaks down oxalate, which is used by the chestnut blight. By inserting the oxalate oxidase transgene into the American chestnut DNA, researchers can produce chestnut trees that are more resistant to the blight. However, there is concern over introducing genetically modified trees into natural areas.

For this activity, students will research different sides of the transgenic American chestnut tree debate and will decide on whether or not they should plant transgenic American chestnut trees in a fictional town named Chestnut Acres .

Lesson Procedure

1. Tell your students that the American chestnut once covered almost 20% of our forests in the eastern United States. Tell them how large chestnut trees used to get. Ask them if any have seen an American chestnut. Very likely, few to no students will answer yes. Ask them if they know why the American chestnut is no longer abundant. Tell your students about the chestnut blight fungus and how it infects and kills trees. Define invasive species and how they differ from native species.
2. Tell your students that one option to combat the fungus is to produce transgenic trees. Define transgenic and briefly go through the process of gene insertion into the chestnut DNA. You may want to define what DNA and genes are to your students as well.
3. Tell your students that the concept of transgenic organisms is still not fully accepted by everyone. Tell them that they will be representing different sides of the transgenic chestnut debate.

4. Break students into 4 groups and pass out copies of the Chestnut Acres student page as well as the information on the interest group they represent. The groups are as follows:
    a. A private landowner
    b. An ecologist
    c. A local forester
    d. A biotech company
5. Have the students read the student page on the fictional Chestnut Acres. Tell them that they will now work in their interest groups to present a proposal on why or why not the transgenic trees should be planted on community property.
6. Allow students at least one class period to research transgenic American chestnuts and genetically modified organisms (GMOs). Have students write down important points related to their position on the introduction of transgenic trees. Encourage students to print out sources to bring to the discussion.
7. During the next class period, hold a public hearing in which each group presents its proposal. Allow students to spend time debating their proposals. You may want to help prompt their debate.
8. Following the debate, have each student anonymously vote on the best proposal. Tally the votes and tell the students what decision was made for Chestnut Acres.
9. After the vote, discuss the following questions:
    a. Was it easy or difficult to decide what to do? Explain your answers.
    b. What are the most important points raised by each group?
    c. What additional information would you like to know before reaching a final decision?

Extensions:
1. In addition to transgenic chestnuts to create blight resistant plants, researchers have also selectively bred and cross bred chestnut. Define selective breeding and cross breeding. Compare and contrast the pros and cons of selective breeding, cross breeding and transgenics.
    a. Classical vs transgenic breeding video http://www.teachersdomain.org/resource/tdc02.sci.life.gen.breeding/
2. Have students research information on genetically modified organisms (GMOs) commonly used for food. What are some of the issues with GMO produce and livestock? Are these issues similar to the ones discussed during the debate?
3. Have students create virtual transgenic flies online:
    a. http://media.hhmi.org/biointeractive/vlabs/transgenic_fly/index.html

Resources:
1. The American Chestnut Research and Restoration Project http://www.esf.edu/chestnut/

Lessons 27-29: Chestnut Acres— Student Pages

Chestnut Acres was founded around the trade of American chestnuts. A local lumber company employed many citizens who harvested the prized chestnut timber. While most of the wood was exported out of town, the local furniture shop would purchase some of the pieces to craft cribs, chairs and caskets. Scraps of bark and cordwood were also sent to the local tannery that tanned and exported hides from game animals like deer, bear and foxes. These animals were particularly abundant in the fall when the trees would produce chestnuts. Chestnuts were an important food resource for many wildlife species. Many of the residents collected and sold bushels of chestnuts, and each year, the town held a chestnut festival to celebrate the harvest.

In the late 1800s, word passed through town that a disease was killing American chestnuts to the north. By 1920, the disease, American chestnut blight, reached Chestnut Acres. In less than 20 years almost all of the chestnuts in town died. The local tannery and furniture store shut down. The local lumber company switched to harvesting oaks, hickories and cherries instead of chestnuts, but they decreased their factory by half. Many residents left town in search of work.

By 2013, the American chestnuts of Chestnut Acres were mostly a memory. A few old of the older citizens could recall the days when chestnut trees were plentiful, though one local landowner has three trees that somehow escaped the blight. Many of the citizens employed in town work at a local biotech company while the others commute to jobs in distant cities.

Recently, the biotech company has announced that it has successfully inserted a gene produced by wheat into the DNA of American chestnut. This transgene encodes for an enzyme that breaks down oxalate, an acid produced by the blight fungus to inhibit lignin production, to lower the pH of the canker wound and to bind to calcium. American chestnuts with these transgenes are less susceptible to the blight. In an effort to restore the American chestnut to the landscape, the biotech company has proposed planting 100 acres of transgenic American chestnuts on community property outside of town.

A town hall meeting has been scheduled to discuss this proposal. Four interest groups will be presenting at the meeting:

- A private landowner
- An ecologist
- A forester
- The BioTech company

You will be assigned to one of the four interest groups. As a group, you have to decide whether or not your group will support planting the transgenic American chestnut trees. Be sure to present facts to support your case to the rest of the class. What are some of the advantages of planting the trees? What about the disadvantages? Prepare a proposal with your group's decision to present to the class.

Interest Groups

Private landowner-

Your group represents a private landowner who has three remaining American chestnut trees unaffected by the blight on your property adjacent to the proposed planting area. You are concerned that the transgenic trees may eventually cross pollinate with your American chestnuts, producing hybrid seedlings and polluting the gene pool. You also worry that the transgenic trees may produce a strain of blight that is resistant to the transgenes which will be harmful to your remaining trees as well as others which have been resistant to the blight.

Ecologist-

Your group represents an ecologist who is concerned about the long-term impacts of transgenic chestnut to the ecosystem. While the transgenic trees may be resistant to the blight, you are concerned that the wheat transgenes will alter the pollen or the fruit of the chestnuts which could have unknown impacts on wildlife. In addition, you worry that the transgenic trees may produce a super strain of chestnut blight.

Forester-

Your group represents a forester who is tasked with managing forested lands for economic, recreational, and conservation purposes. You are interested in the idea of restoring the American chestnut as its wood was highly valued in the lumber industry. In addition, the chestnuts supported many species of wildlife.

BioTech Company-

Your group represents a biotech company which has patented the transgenic gene that has been inserted into the American chestnuts. You are eager to sell your product and market it as a way to restore the mighty chestnut to its former glory. If this project is successful, then it can pave the way for future restoration projects to save native trees against diseases such as Sudden Oak Death and Dutch Elm Disease. Your company employs many of the local residents of Chestnut Acres.

Lessons 30-32: Land Biodiversity- Berlase Funnels

(adapted from LeAnn Hutchison, Easton High School and MSDE)

Instructional Goal

At the end of this lesson, SWKABAT:

Use an experimental protocol to study the biodiversity of arthropods located on the school campus and recognize the relationship between organism type and number to specific habitat

Write a technical research paper highlighting the procedure and results

Next Generation Science Standards Addressed

Science & Engineering Practices:
Asking Questions
Planning & Carrying Out an Investigation
Analyzing & Interperting Data
Using Mathematical & computational Thinking
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics
HSLS4: Biological Evolution: Unity & Diversity

Cross-Cutting Concepts:
Patterns
Systems & system Models

Common Core Standards Addressed:

Mathematics:
Quantities- Reason quantitatively and use units to solve problems
Mathematical Practices- Reason abstractly and quantitatively
Attend to precision
Construct viable arguments and critique the reasoning of others
Model with mathematics

Maryland Environmental Literacy Standards Addressed

Standard 4: Populations, Communities, & Ecosystems Topic E: Diversity

Materials

Field component:
flags
tape measures
field guides to trees and shrubs
one-gallon ziplock bags
index cards
clipboards
paper & pencils
Optional: wind meters, air and soil thermometers, sling psychrometer
Lab component:
poster board & masking tape (to construct Berlese Funnel)

gooseneck lamps
250 ml beakers
isopropyl alcohol
compound microscopes
dissecting (binocular) microscopes
ring stands
depression slides, Petri dishes
identification guides to Phylum Arthropoda

Advance Preparation

Review such topics as adaptation, habitat and niche, abiotic vs. biotic factors, and taxonomy. If you plan to emphasize climatic factors which may influence arthropod diversity, prep your students on the use of equipment such as a sling psychrometer, wind meter and soil thermometer. You may need to review basic statistical methods prior to modeling for your students.

Teacher Background:

This activity is designed to study the biodiversity of arthropods located on the school campus and to help the student recognize the relationship between organism type and number to specific habitat. Phylum Arthropoda, which includes more than one million species, is the largest in the animal kingdom and is represented by nine classes of segmented animals with paired, jointed appendages and a hard exoskeleton. This activity integrates several concepts and teaches a variety of field and laboratory skills in a short period of time. Work is conducted outdoors for one class period and in the lab for at least two class periods. Some of the concepts include taxonomy, population dynamics, habitat and niche, soil types, forestry, climatic conditions, seasonal variance, animal behavior, and developmental biology. The skills accomplished include proper field collection technique, sampling methods, calculation of biodiversity, preservation of organisms, microscopy, quantitative technique, and field guide use. Sampling a small area helps students generate inferences regarding the organisms present in the entire area, and allows them to compare arthropod biodiversity in a terrestrial habitat to the local aquatic habitats examined prior. Students write their own hypotheses; however, a sample hypothesis is something to the effect that some sites will be more diverse than others due to certain environmental factors such as moisture, temperature, or vegetative type. Another possible hypothesis may be something to the effect that abiotic factors can affect the species diversity of a certain site. After completing the aquatic biodiversity studies, most students will recognize the relationship between plant leaf type, moistness of leaf litter and/or soil, amount of sunlight received and effects of other influences on arthropod biodiversity. In summary, students will conduct their study with the intention of determining the factors affecting both quantitative and qualitative results.

General tips (relating to the procedure or process)

Differences and similarities of the various quadrats will be found. For example, students should see some correlations between climatic conditions and vegetative type and the biodiversity of their sites. Arthropod preference for certain conditions may or may not be evident. Specific comparisons of vegetation and associated organisms at different sites
will help students make inferences. (i.e. termites in large quantities on the site with fallen logs might indicate that these organisms had a plentiful food source and thus reproduced prolifically….)
Students should use arthropod identification guides, or if identification is not important to the lesson, descriptive names can be assigned and agreed upon prior to quantitative analysis. Samples of each organism type can be mounted with glue on an index card for class display and ease of further identification. Once all counts have been completed, biodiversity can be calculated by various methods, depending on level of student ability and teacher preference. This author uses the Shannon-Weiner Diversity Index (see reference section – Stiling. Also see formula and

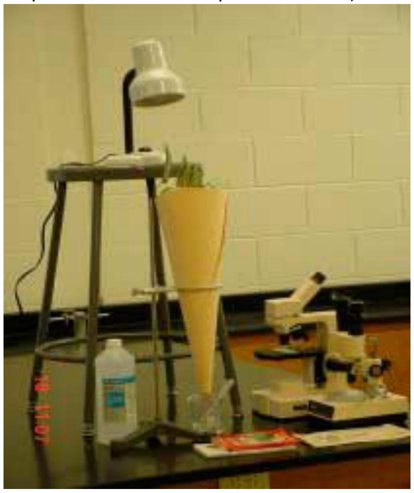
sample student data results in Sample Data section.) Each team should share its findings by writing data on the board or by entering onto a desired computer format such as EXCEL and printed for each student to analyze, make
interpretations, and write conclusions. The biodiversity values can give students a general idea of which sites were supposedly more stable and healthy; however, they should explore variables and factors which may or may not account for differences in results. This includes an analysis of team error.

Potential Problems

Common errors in procedure include varying quantity of actual leaf litter collected (bag filled tightly vs. loosely), funnels constructed with too large or too small openings, varying perseverance to find and identify all organisms accurately, and failure to calculate biodiversity accurately.

Possible Variations

This activity can be modified in many ways, depending on the specific concept being taught. If time permits, two days can be spent on the field component (one day tree id and mapping and second day collection, site descriptions, and Berlese funnel set-up) and unlimited days in the lab are possible. Students usually are very enthusiastic about counts
and the periods go by quickly. Videomicroscopy can be used if available. If time is short, teacher can make the Berlese funnels ahead of time and have each station set up prior to retrieval of leaf litter. (See photo of experimental setup in the lab)


Experimental Setup: Berlese Funnel Apparatus

Note: Teacher must turn off lamps overnight and turn back on the next morning. Organisms will begin dropping into alcohol within about 30 minutes; however, quantitative analysis is best postponed until the next day.

Group Size

Research teams of 3-5 students, depending on class size. At least five different teams, each assigned to a unique site, is desirable.

Lab Length

Three class periods – day one in the field, days two and three in the lab. A fourth day may be desirable for data analysis and class sharing/presentation.
Arthropod counts can be shortened as long as students understand that this might account for error in analysis of data. If taxonomy is the lesson, there are endless possibilities. Characteristics and adaptations of each group of organisms could be studied. Among the members of phylum Arthropoda, the classes most commonly encountered are arachnida, chilopoda, diplopoda, and insecta. Your students may collect members of phyla other than Arthropoda. Examples include phylum Mollusca, class gastropoda (tiny snails are not unusual in moist areas), phylum Annelida, class oligochaeta (earthworms – if seen, remove them and return to outdoors prior to placement of leaf litter in funnel), and phylum Onychophora

(caterpillar-like worms). If your school grounds do not have trees or shrubs which shed leaves, soil can be analyzed for organisms. There are several alternatives to equipment and materials. An alternative to a measuring device is to walk off the area with large strides (one stride equals roughly one meter). Take ten strides in each of four directions to make a ten meter square plot. Any marker can be substituted for flags – even four rocks placed or four pencils or sticks driven into the soil at each corner will suffice. Instead of ziplock bags, any agreed upon container can be used (just be sure all teams use the same volume of collected leaf litter) If field guides are not available, have students sketch each vegetative type and agree upon a name to use for purposes of assessing biodiversity at each site. The same can be done with study of the arthropods.

Formula and Sample Data

(see Shannon-Weiner Diversity Index page)

Post-Lab Analysis & Typical Discussion Questions

After data gathering and calculations of biodiversity at each site have been accomplished, and as students are preparing to write their individual research papers, prompt them with the following questions:

- What factors might have affected your quantitative and qualitative results?
- How did negative phototaxis affect the type and number of arthropods dropping into your alcohol-filled beaker?
- Which site had the highest biodiversity? The lowest? (Students should consider their Shannon-Weiner Diversity calculations)
- Why are some sites more/less diverse? (Possible responses might be higher or lower moisture in the detritus, leaf type preference by arthropods, amount of decomposing material at a site, type of activity taking place at a site such as excessive logging which may increase certain species such as termites)

Extensions

As an extension, invite an entomologist or other field expert to be a guest speaker for your class. This expert will also be a great resource for students learning to write high quality lab reports and scientific papers.

Have students relate findings temporally (seasonally) and spatially OR relate to pollution problems of a particular site.

References and Resources

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Stiling, Peter D. 1996. Ecology: Theories and Practice. Upper Saddle River, NJ: Prentice Hall. Pages 279-280.

Weisgerber, Robert A. 1995. Science Success for Students With Disabilities. Addison-Wesley Publishing Co., Ca.

Zim, H. and C. Cottam. 1987. Insects. Golden Press, NY

An introduction to the Arthropoda can be found at
www.ucmp.berkeley.edu/arthropoda/arthropoda.html

Information on biological communities, particularly microscopic soil arthropods can be found at www.blm.gov/nstc/soil.arthropods

Information on biodiversity among arthropods can be found at
www.animaldiversity.ummz.umich.edu/arthropoda.html
www.werc.usgs.gov/socal/abstra.html
www.soils.usda.gov/squ/files/biodivers.pdf

A full color interactive dichotomous key to the common tree species can be found at www.fw.vt.edu/dendro/forsite/Idtree.htm

Calculating Shannon-Weiner Diversity Index

H1 = -E pi x lnpi
Where H1 = The Shannon Index
E = the sum of
pi = frequency rating
lnpi = natural log of the frequency rating
pi = ni/N (ratio is how many of each kind divided by total count)
ni = how many found of kind
N = total number of organisms

Sample Student Data

Shannon-Weiner Diversity Index: Site #1 Windmill Branch Forest
Organism ni pi lnpi pi
x lnpi
Subterranean Termite 5 5/24 -1.568 -.3267
Thrip 3 3/24 -2.079 -.259
Ground Beetle 1 1/24 -3.18 -.132
Phalangidae 1 1/24 -3.18 -.132
Swallowtail 1 1/24 -3.18 -.132
Springtail 12 12/24 -.693 -.3465
Caddisfly 1 1/24 -3.18 -.132
N = 24 H1 = 1.4602
Remember that the Shannon index has a minus sign in the calculation, so
the index actually becomes 1.4602, not -1.4602.
Values of the Shannon diversity index for real communities are often found
to fall between 1.0 and 6.0.

Lessons 33-42: Land Biodiversity Survey and Inquiry Experiment

This activity is used as a comparison to the aquatic biodiversity inquiry study completed earlier in the unit. The focus of the terrestrial biodiversity survey is to examine the impact of humans upon the environment. Through a series of investigations students develop their own hypothesis about human impact and then test this on a site not previously examined. Final analysis and discussion of the results allows the students to develop a theory about the impact of humans upon biodiversity. Students also are given another opportunity to practice experimental design and the use of statistics to determine whether to accept or reject a hypothesis.

The sequence of activities should take approximately 10 class days. This works extremely well if following a block schedule. Students are more focused and discussions more powerful.

CLASS TIME	Performing Survey, post lab discussion	
	Surveying 3 terrestrial sites	3 Hrs
	Data analysis	2 Hrs
	Hypothesis development	
	Experimental design	1-2 Hrs.
	Survey of final terrestrial site	1 Hr.
	Data analysis and discussion of acceptance or rejection	2 Hrs.
	TOTAL CLASS TIME:	10 Hrs. (approx)

Next Generation Science Standards Addressed

Science & Engineering Practices:
Asking Questions
Planning & Carrying Out an Investigation
Analyzing & Interperting Data
Using Mathematical & computational Thinking
Constructing Explanations
Obtaining, Evaluating, & Communicating Information

Disciplinary Core Ideas:
HSLS2: Ecosystems: Interactions, Energy, and Dynamics
HSLS4: Biological Evolution: Unity & Diversity

Cross-Cutting Concepts:
Patterns

Systems & system Models

Common Core Standards Addressed:

Mathematics:

Quantities- Reason quantitatively and use units to solve problems

Mathematical Practices- Reason abstractly and quantitatively

Attend to precision

Construct viable arguments and critique the reasoning of others

Model with mathematics

Maryland Environmental Literacy Standards Addressed

Standard 1: Environmental Issues Topic A: Environmental Issue Investigation

Materials

- 1 plant press per class
- 1 note book per team
- 3-4 10 m measuring tapes
- Arthropod/insect ID books or taxonomy keys
- Plant/shrub ID books or taxonomy keys
- Animal tracks/scat ID books

Advance Preparation

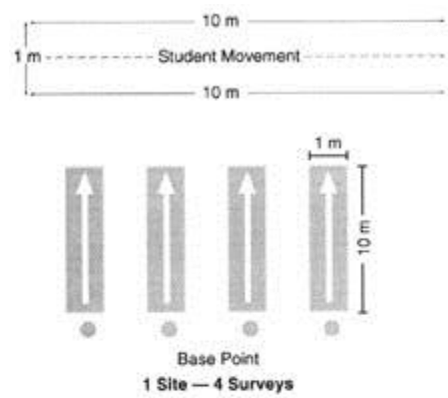
Sites for the surveys need to be inspected prior to class and should pose few or no obstacles. Try to have a plant taxonomist help check your sites because you will sample the plants and you don't wish to remove rare species. You might be surprised at what you have locally. Students on crutches and in wheel chairs can do many of the activities if site is well selected. It is suggested that the teacher run their own biodiversity survey in two other sites first to see firsthand what types of plants the students might find in the local area.

Lesson Procedure

Sampling With Line Surveys **Student teams of 5 (1 recorder, 2 animal surveyors, 2 plant samplers)*

Three to Four sites will be needed for the survey in order to see patterns. One site should have little or low human impact. A second site should have moderate human impact and a third should have high human impact. (This can be run in the parking lot or football field). A four site is where the students will check their predictions. It can be have any level of impact you wish.

A site is selected and a base point selected (see drawing) from which a straight line will be measured. Several line surveys may be run per site.



1. Students first OBSERVE over the site any organisms that cross an imaginary straight line. Organisms may fly, crawl or move across the line. Do for 5 minutes and record all observations and time of day (some animals are active only at particular times of day).
2. Shoulder to shoulder the two animal surveyors crawl the 10 meter line and call out every single SIGN or type of animal... as long as they can tell they are different. This might be foot prints, scat, pop cans (sign of humans), animal burrows, trails, the different insects, rodents, birds, other arthropods. Lift up all leaves, branches, rocks...everything.
3. Recorder notes the data. We want the number of different TYPES (richness). You can expand the study to include the number of each type as well (evenness).
4. After the animal survey, the plant samplers go in and collect one of each type of plant. All they need to do is be able to tell one plant is different from another. Collect the plants properly, by including the root system. Place properly in plant press. These may be used for later plant taxonomy. Again, we're trying to survey the number of different types (richness), but you may wish to know how many of each type (evenness).

Analysis Of Data

Chart the data for each site, and how many types of organisms (be sure to keep a record of the different categories organisms). You may also chart how many of each species as well. Compare the data from each site. Note and discuss trends.

Hypothesis Development And Experimental Design

Based upon the data, have students individually or in teams develop a hypothesis. The hypothesis must be measurable. Keep it simple if possible! Have students design their procedure for testing their hypothesis and other students are used to check to make certain it is understandable. Review and discuss as needed.

Discuss how will they know if their hypothesis should be accepted or rejected. Avoid use of "we prove", "We don't prove", "WE SUGGEST". Introduce the ideas of sample sizes, significance and how math is used to decide what we accept or reject. This could easily launch into other discussions about how "good or poor" a theory is.

Run The Experiments

Have the student run their experiments and analyze the data. Present the data in a lab report and chart and display for class discussion. Did they support their hypothesis? How can we check it mathematically?

Reflections And Conclusions

If desired, students can once again write up their results in a formal report

Typical Questions to be answered individually, collaboratively, cooperatively.

- Did any patterns emerge in the biodiversity? What might they mean?
- Can we use these patterns to predict biodiversity in other places in the country or world?
- Check the pattern (theory) for another place in the world or country. Was it confirmed?
- Why or Why not...what might influence the theory? Does that mean its wrong?
- Do we find variables?
- What did we learn about:
  -- the environment
  -- scientific method, sampling, hypotheses, theories
  -- biodiversity
  -- working as a team
  -- need for taxonomy
  -- human impact locally, regionally, globally
- What can students do differently in:

-- the environment
-- the test design
-- in reading, interpreting other tests or experiments

Lessons 43-45: Socioscientific Issues and Biodiversity

Summary

In this three-day mini-unit, students will be introduced to scientific arguments as the way that we answer questions in science. Through reading about and discussing a socioscientific issue, they will learn that scientific arguments are useful in our day-to-day lives beyond the science classroom. Students will read arguments presented by stakeholders who represent different perspectives regarding a socioscientific issue. The students will come up with criteria they think are important for evaluating the arguments, and then the students will evaluate different arguments about the issue using their own criteria. Next, the class will be introduced to some criteria that the scientific community uses to evaluate scientific arguments. Through class discussion, arguments will be re-evaluated using several of the scientific criteria, and comparisons (similarities and differences) between science community criteria and students' criteria will be discussed. Finally, students will consider how and why scientific arguments may be important beyond the science classroom, and the limitations of scientific arguments for helping us decide what to do about socioscientific issues.

Background/Rationale

This unit introduces the method of claims, evidence and reasoning (CER) as an evaluation of scientific arguments tool to use throughout the year with your students, drawing on multiple media sources that are available to you. A central goal of this unit is engaging students in evaluating scientific arguments from different sources (e.g., popular media, scientific articles). Evaluating other peoples' scientific arguments is an important scientific practice that extends beyond the classroom --- students will need to evaluate scientific arguments that they encounter in their lives and need to make decisions about after they graduate from high school.

Start with some of the articles included in this mini-unit and expand your selection as the year continues. Practice does make better performance. Some articles included in this unit contain enough information to complete the CER format and have "good" science to back them up, others do not. This mix reflects the kinds of information students will likely encounter when they read about or research socioscientific issues in the popular press and online. So engage your students in a journey where they learn to think for themselves and make good judgments about socioscientific issues at hand.

Time/Scheduling

- At least three one-hour class periods.
- An optional application lesson is provided as well.
- Teachers may also choose to revisit practices introduced in this unit using different socioscientific issues over the course of the school year.

Learning Objectives

As a result of engaging in this lesson, students will:

- Understand that in science, we use ***scientific arguments*** to answer scientific questions.
- Be able to distinguish between questions that can be addressed by science, and those that cannot.

- Understand that a scientific argument includes
  - A ***claim*** (a statement that answers a scientific question),
  - ***evidence*** (scientific data that supports a claim),
  - and ***reasoning*** (an explanation that supports a claim by providing a logical connection between the evidence and the claim).
- Understand that in science, we use specific criteria such as replication, peer review, experimental control, multiple measures, etc. to evaluate scientific arguments.
- Be able to read multiple sources' stances on a socioscientific issue and identify claims, evidence, and reasoning presented by each source.
- Be able to evaluate the credibility of different sources' arguments through relying on at least one scientific criterion for judging an argument.
- Understand that science is just one lens for considering socioscientific issues, and that other lenses including personal values, economic values, social justice, etc. can also contribute to understanding and evaluating these issues.

Next Generation Science Standards Addressed

Science & Engineering Practices:
Obtaining, Evaluating, & Communicating Information
Engaging in Argument from Evidence

Common Core Standards Addressed:

English Language Arts Standards- Science & Technical Subjects:
Integration of Knowledge & Ideas- CCSS.ELA-Literacy.RST.11-12.8
Range of Reading & Level of Text Complexity- CCSS.ELA-Literacy.RST.11-12.10

Maryland Environmental Literacy Standards Addressed

Standard 7: Environment & Society Topic B: Individual & group Actions & the Environment; Topic C: Cultural perspectives and the Environment; Topic C: Cultural Perspectives & the Environment; Topic F: Technology & the Environment

Materials

- Student Handouts for each student
- Ability to project online video from PBS
- Copies of articles for students

Activity One *(About 30 minutes):*
Introduce Scientific Argumentation through Video Experience

1. Introduce the unit by telling students the class will be considering scientific arguments for the next few days. Ask students their ideas about what a scientific argument is and how scientific arguments are similar to and different from arguments that people have in their everyday lives. You may want

to write students' ideas on the board in two columns --- characteristics of scientific arguments and characteristics of everyday arguments.

2. Handout page one of the *Let's Get Into An Argument* student pages. Students should read the page. After students have finished reading, ask if anyone has any comments or questions.

3. Next, tell students they will watch a video to provide a real world example to help think through the terms they've just read about. Play the short video (3.5 minutes) "Hygiene Hypothesis" available online at:
   http://www.pbs.org/wgbh/evolution/library/10/4/l_104_07.html 0-3:30
   http://www.youtube.com/watch?v=kVrJZomC31M 0-3:30

4. At this point, students should be organized into small groups of about 3 to 4 students. Handout pages 2 and 3 of the student pages and ask students to discuss and answer the questions on page 2 in their small groups. They can use the video transcript on page 3 to help remember what was said.

5. After students have discussed and answered the questions in their small groups, lead a whole class discussion of the questions on the handout. Direct each question to a different group. After a group answers, ask the other groups if they agree or if they have anything they would change or add. By the end of this discussion, students should have an initial understanding of the introduced terms, including as related to the video they watched.

Activity Two *(About 60 minutes – begin on day one and finish on day two)****:***
Provide Several Alternative Scientific Arguments Addressing a Scientific Question and Ask Students to Develop Criteria and Use them to Evaluate Arguments

1. Ask students, "Are all scientific arguments good scientific arguments?" "How can you tell the difference between a good scientific argument and a not-so-good scientific argument?" After students share some ideas with the class, let students know that they'll have the opportunity to explore these questions further through examining some different scientific arguments.

2. With students in their small groups still, hand out to students the short articles that briefly provide several different arguments about a socioscientific issue (choose from options provided or choose your own articles). Also provide each student with the Activity Two student handout, "What's the Argument Here?" The groups should read the articles and identify the socioscientific issue and scientific question that is being addressed. Students can then complete the rest of the table, describing several scientific arguments addressed in the articles. Depending on what you think is most appropriate for your students, you may choose to jigsaw the articles so that an individual student only has to focus on one article. If you'd like, take time for the groups to report out to check that students have identified appropriate elements of scientific arguments in the articles. Reporting out will be especially important if you follow a jigsaw format.

3. Next pass out to each student a copy of the Activity Two handout, "What Makes for a Strong or Weak Scientific Argument?" Ask the groups to think about what they think makes a scientific argument stronger or weaker. Each group should come up with a list. Groups can use the articles they have read to help as examples if they'd like. You may want to begin with a short whole group discussion to get students started. Eliciting and discussing an example may help students understand what is being asked of them.

4. After students make their list, they should apply their list to judge the strength of the different scientific arguments they described from the articles. (Give students the "Evaluating Arguments in the Articles" handout for this task. You will need to make enough copies of this handout so that students have one copy for each argument they evaluate --- probably two total.) When students have finished this task in a small group, lead a whole class discussion asking students to share out. First, generate a class list of factors students used to judge arguments. Ask students to discuss whether or not they agree with all of the factors on the list or not. Next, have groups share out ideas about strengths and weaknesses of the arguments (using the evaluation factors they generated). This handout also asks students to provide their own opinions about what should be done about the issue. After discussing the strengths and weaknesses of the arguments, you might also ask the students to discuss/share what they think should be done about the issue and why (and/or what they could do themselves about the issue).

***Activity Three** (About 30 minutes):*

Introduce Argument Evaluation Criteria Common to Scientific Communities

1. Optional Discussion:*(Consider your students' backgrounds and sophistication with practices of scientific communities. If you think your students will have some ideas – they don't have to be perfect ideas – about how scientists evaluate arguments and evidence, start with this optional discussion. If you think your students will have very few ideas about how scientists evaluate arguments, skip this optional discussion and move on to the continuation of the activity in the next paragraph.)*Working first in small groups, then discussing as a whole class, ask students how they think the list of factors they generated might be similar to or different from a list that a group of scientists might generate. Have the students generate a list of factors for evaluating the strength of arguments that they think a group of scientists might use. Students can work in small groups and report out, or you may decide to just discuss as a whole group.

2. Then pass out the handout for Activity Three, "How Do Scientists Evaluate Arguments?" Provide time for students to read through and make comments about or ask questions about the list of criteria scientists use to evaluate arguments. Then provide time for students to work on the questions in this handout in their small groups.

   Note on use of scientific criteria with students: The goal here is not for students to have a perfect understanding of how scientists evaluate arguments. Rather, this mini-unit is intended as a first introduction to help students develop initial awareness of scientific criteria for evaluating arguments. For this reason, some of the scientists' criteria are left intentionally a little vague.

   For instance the criterion about sample size only indicates that the sample size should be "big enough." What is big enough? Scientists often determine sample size through use of statistical power analyses. These are probably beyond the scope of what you'll address with your students (although with high school students, this is an appropriate place to tie in quantitative reasoning if you are feeling ambitious). For most students however, for the purposes of this mini-unit, it will be sufficient for students to rely on personal inferences about what is "big enough" for a sample size. Just knowing that sample size is important is the goal for this activity --- not actually being able to determine appropriate sample size through statistical means.

   The intention is similar for other criteria on the list that may also seem a bit vague. Often, how scientific criteria are applied will depend on the specific scientific question being addressed. You can use the examples of the scientific questions and issues you investigate with your students to discuss what some of the different criteria mean in context – for example looking at the methods discussed in one of the articles to talk about what it means for data collection to be rigorous.

3. Next, use the small group/whole group discussion format to allow students a venue to discuss and share their ideas about the four questions on the handout page. Consider recording students' ideas on whiteboard or Smart Board.

Activity Four *(About 60 minutes):*

Why Should We Care About Scientific Arguments?

The final activity engages students in a discussion of why scientific arguments might be important beyond science class. Students and teacher should discuss some of the questions in the activity four handout, "Scientific Arguments, Do They Only Matter in Science Class?" Students should discuss and write down ideas about the questions in their small groups first then discuss as a whole class. Consider using the socioscientific issue the students considered in the articles they read as a context to help discuss the questions, rather than discussing in vague terms. Students should also be welcomed to introduce examples of other socioscientific issues as well. You may want to get the class started with question one as a whole group to make sure students have some good examples to start thinking about.

Optional Application Activity

Have students investigate socioscientific issues of their choosing that have a biodiversity focus. Modify this application activity as appropriate for your class --- including deciding whether students will complete the assignment individually or in groups, how much in class time will be provided, etc. Some guidelines for what the students might be asked to do are provided below.

1. Identify articles that represent different stakeholders and their arguments
2. Identify socioscientific issue, scientific question, and scientific argument (including claim, evidence, and reasoning)
3. Evaluate strengths and weaknesses of scientific arguments from different stakeholders using scientific community criteria
4. Indicate what student thinks should be done about issue and why. The student should describe what factors (which could include scientific, cultural, personal values, economic, etc.) contributed to their decision and how?
5. Students present their issues, evaluation of arguments, and opinions about what should be done about the issue and why to other students.

Student Guide: What is a Scientific Argument?

To introduce the topic of scientific argumentation, we'll watch a video and talk about a few questions including, "what is a scientific question?" and "what is a scientific argument?" Let's start by considering a few terms…

Scientific question: A scientific question is a question that can be addressed through scientific investigation. In order for a question to be scientific, it isn't necessary for science to be able to answer it with exact precision (uncertainty can often be managed, but not eliminated in scientific investigations), but it must be possible to use scientific methods to study the question. Consider a few examples…

Example scientific question – How much carbon from fossil fuel combustion did the United States emit into the atmosphere in 2011?

*Example **non**-scientific question* – Should the United States pass a law requiring all passenger cars to average at least 40 miles per gallon of gas consumption?

Scientific argument: In science, we use scientific arguments to answer scientific questions. Scientific arguments include:

A claim - A statement that answers a scientific question

Evidence - Scientific data that supports a claim

Reasoning - An explanation that supports a claim by providing the underlying scientific concept that connects the evidence to the claim

Socioscientific issue: A socioscientific issue is an issue that confronts society that includes both scientific questions and non-scientific questions to be considered and addressed. For example, in order to deal with the socioscientific issue of climate change, people will need to answer both scientific questions about how and why climate change occurs, and non-scientific questions concerning what we should do about climate change. In order to decide what to do about a socioscientific issue, people can consider science, but they can also consider other things such as the economy, laws, justice, liberty, culture, etc.

Let's watch a short video to provide a real world example we can consider. After watching the video, answer the questions below in your small group. You can use the video transcript on page 3 to help remember what was said.

1. What scientific question is addressed in the video?

2. What scientific argument did Dr. von Mutius (and the narrator) make?

    a. What was her claim?

    b. What was her evidence?

    c. What was her reasoning?

3. What socioscientific issue (that is, issue that involves both social and scientific aspects) is this scientific argument relevant to?

4. If you wanted to decide what ought to be done about the socioscientific issue you've identified, what other scientific questions in addition to the one in the video would you want to consider?

5. What non-scientific questions would you want to consider?

Hygiene Hypothesis Video Transcript

Narrator: Are we making our world too clean? Consider the research of Pediatrician Erika von Mutius. She treats allergies and asthma, conditions in which the immune system overreacts to harmless substances. Rates of both disorders are on the rise in affluent, industrialized regions. Perhaps children are growing up in surroundings too germ free for their own good.

von Mutius: Microbes do a lot of harmful things to us, but they may also be important for our immune system to learn how to deal with the environment and how to tolerate and fight viruses, bacteria, and infections.

Narrator: To understand the causes of allergies and asthma, von Mutius is conducting research in a place where these conditions are rare, the Bavarian countryside. She wants to sort out exactly which environmental factors may be protecting children who grew up here.

von Mutius: The study we are doing is a comparison within little villages. So we compare children who live on the farm to children in the same village who do not live on the farm.

Narrator: She has enlisted over 800 families with children between the ages of 6 and 12 to participate in a detailed survey of health and lifestyle.

von Mutius: In this questionnaire we asked for allergic conditions and then most importantly we asked for the contact to farm animals and farming activities.

Narrator: Her goal is to create a profile of environmental exposures for each child. Her team analyzes dust samples from carpet and bedding throughout the house for the presence of animal hair, dust mites, and microorganisms. If the family keeps livestock, samples from the stables are screen for microbes released in the shedding and droppings of animals. The study is in progress but preliminary results suggest one very strong correlation.

von Mutius: One of the factors that seems to be important is contact with the livestock. That these children, the more they are in the stables and the earlier they are in the stables, that this gives a protection against the development of allergies.

Narrator: High levels of microorganisms in the stables may help prime a child’s immune system for life.

von Mutius: Microbes have been around us always and probably we need to find the balance between eradicating the harmful effect of bacteria and maybe also taking the beneficial components of this. But this is really into the future.

What's The Argument Here?

Read the article(s) provided and complete the table below to consider the arguments in the articles. Then, with your group, discuss and refine your answers. Be prepared to share your ideas with the class.

Titles of Articles You Read (use as many lines as you need): 1. 2. 3. 4.	
What socioscientific issue do the articles address?	
What scientific question do the articles address?	
SCIENTIFIC ARGUMENT ONE What is <u>one</u> scientific argument made in the articles? (Complete Claim, Evidence, Reasoning below)	
In which article(s) was this argument made? (You can list the numbers corresponding to titles at the top of this table):	
What is the scientific <u>claim</u>? (Hint: A scientific claim is an answer to the scientific question.)	
What scientific <u>evidence</u> is provided? (Hint: Scientific evidence is data and observations that support the claim)	
What <u>reasoning</u> supports the claim? (Hint: Reasoning describes how an underlying scientific concept connects the evidence to the claim. The reasoning could be in the article, or you may have to use your background knowledge about science to develop the reasoning.)	

SCIENTIFIC ARGUMENT TWO What is <u>another</u> scientific argument made in the articles? (Complete Claim, Evidence, Reasoning below)	
In which article(s) was this argument made? (You can list the numbers corresponding to titles at the top of this table):	
What is the scientific claim? (Hint: A scientific claim is an answer to the scientific question.)	
What scientific evidence is provided? (Hint: Scientific evidence is data and observations that support the claim)	
What reasoning supports the claim? (Hint: Reasoning describes how an underlying scientific concept connects the evidence to the claim. The reasoning could be in the article, or you may have to use your background knowledge about science to develop the reasoning.)	

What Makes for a Strong or Weak Scientific Argument?

How can you tell whether a scientific argument is strong or weak? Discuss with you group and list criteria (factors) below that you can think of that you would use to judge the strength or weakness of a scientific argument.

<u>Criteria (Factors) for Evaluating the How Strong or Weak a Scientific Argument Is</u>

Evaluating Arguments in the Articles

In your group, consider the scientific arguments you identified. Complete a table below for each scientific argument you identified. Which criteria (factors) can you comment about for each argument? For each criterion that is relevant to an argument, indicate whether the scientific argument is strong or weak for that criterion and explain why.

Scientific Argument One

Restate the claim for this argument:		
Criterion (Factor)	Strength (S), Neutral (N), or Weakness (W)	Explain why the scientific argument is strong or weak for each criterion you list.

Scientific Argument Two

Restate the claim for this argument:		
Criterion (Factor)	Strength (S), Neutral (N), or Weakness (W)	Explain why the scientific argument is strong or weak for each criterion you list.

Now that you've evaluated a few arguments related to this socioscientific issue, stop to think about your own opinion about what's going on. Write down your own personal ideas about the questions below. Then discuss with your group/class.

What is your opinion about what should be done about this issue and why?

Is there anything that you could do to impact this issue? What are some things you could do and how might they impact the issue?

How Do Scientists Evaluate Arguments?

Some Criteria (Factors) Scientists Use to Evaluate Scientific Arguments

- Is there scientific evidence to support the claim?
- Is the sample size for collecting data sufficient (in other words, is the sample big enough)?
- Were appropriate measures used in collecting data (in other words, did scientists measure the right variables to answer the scientific question)?
- Was the data collection procedure for gathering evidence rigorous and careful?
- Have the results been replicated (has similar evidence found in multiple separate instances)?
- Have multiple scientists found similar results?
- Is there an underlying scientific concept that links the evidence to the claim?
- Is there consensus (agreement) among scientists about the argument?
- Have the results been published in a peer reviewed, reputable publication?
- Did someone who might have a bias fund or carry out this work (for example, was the work paid for a company that has an interest in getting certain results)?

Discuss with your group and write down your ideas about the following questions:

1. Why do you think the criteria on the list above are important to scientists?

2. Are there some factors on the list we developed as a class that are the same as or similar to criteria on the scientists' list? If yes, which ones from the class list are similar to which ones from the scientists' list?

3. Considering the scientists' list, are there any changes you would make to your evaluation of the strengths and weaknesses of the arguments provided by the stakeholders in the articles? Using different color ink, make any additions or changes to your original lists of strengths and weaknesses for the arguments.

4. Now that you've considered how scientists might evaluate the scientific arguments in this issue, has your opinion about what should be done about the issue changed at all? (Circle one) YES NO

   If you circled yes, describe how your opinion has changed and why.
   If you circled no, describe why your opinion didn't change.

Scientific Arguments --- Do They Only Matter In Science Class?

1. What are some socioscientific issues that you know about and/or that are important to you?
2. For one issue you've identified, what are some scientific questions that investigating could help people understand the issue better?
3. Can answers to scientific questions provide us with all the information we need to make a good decision about what to do about a socioscientific issue? Why or why not?
4. If not, what other information would be needed?
5. Is there generally a right and wrong answer to what should be done about a socioscientific issue? Why or why not?
6. If two people had the same exact information available to them about a socioscientific issue, could they make different decisions with both being considered informed decisions? Why or why not?
7. Can all scientific questions be answered with 100% certainty? If not, can investigating these questions still help us to understand issues better, or is science only useful if it provides definite answers?
8. Has this set of activities changed the way you'll consider scientific arguments in the future? If yes, how will what you do be different from what you've done before?

Example Responses to Video Questions for Teachers

Let's watch a short video to provide a real world example we can consider. After watching the video, answer the questions below in your small group. You can use the video transcript on page 3 to help remember what was said.

6. What scientific question is addressed in the video?

Are we making the world too germ free, causing people to have allergies or asthma more often?

7. What scientific argument did Dr. Werely make?
   a. What was his claim?

      Exposure to livestock gives protection against the development of allergies.

   b. What was his evidence?

      Detailed health and lifestyle surveys of 800 families with children between the ages of 6 and 12 in small villages in Bavaria, Germany.Samples of animal, hair, dust and microbes from where children live.There was a correlation between contact with livestock and health of child.

   c. What was his reasoning?

      Exposure to microbes helps the immune system learn how to dealwith the environment and how to tolerate and fight viruses, bacteria, and infections. High levels of microorganisms in the stables may help prime a child's immune system for life.

8. What socioscientific issue or issues is this scientific argument relevant to?

   Students' responses will vary but they may have something like:

   It could be that we are raising our children in homes and environments that are too clean and that is making them more likely to be sick.

9. If you wanted to decide what ought to be done about the socioscientific issue you've identified, what other scientific questions in addition to the one in the video would you want to consider?

   Students' responses will vary but they include questions such as:

   --Does living near animals and their microbes cause any health problems?

   --Does living in a house that is not clean in non-animal ways give the same benefits as interacting with livestock?

   --Does interacting with domestic animals give the same benefits as interacting with livestock?

10. What non-scientific questions would you want to consider?

    Students' responses will vary but they include questions such as:

    --Are the characteristics of a less clean home (e.g., dusty, smelly) worth children having allergies or asthma less often?

    --Should we spend money to develop ways people can get the benefit of interacting with livestock without actually having farm animals?

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