Entomological Extensions & Activities for Use with Youth:

Aligned with the Project Learning Tree Activity Guide

by
Dr. John Guyton, Extension Entomologist
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Department of Biochemistry, Molecular Biology, Entomology, and Plant Pathology
Mississippi State University

Children like bugs, and teachers or naturalists can take advantage of this natural curiosity to sustain students' interest in science and provide them with an avenue through which they can explore their world. In this session we will look at how teachers can set up learning stations to supplement PLT activities with entomological activities or extensions and we will work through several key activities that will provide the essential foundation for a sustained entomological experience. This manual contains entomological activities and/or extensions for each activity in the PLT pre K–8 activity guide. Each extension is indexed to the corresponding PLT activity number and name.

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Introduction

Consistent with PLT's mission, I am still climbing through that "window" into the world and I have been thinking more about the small animals, arthropods and insects in particular, in recent months. In *Marginalia* I relayed a handful of activities where insects would make useful extensions to PLT activities, but in this manual I am suggesting an entomological extension and/or activity for every activity in the *Project Learning Tree Pre K–8 Environmental Education Activity Guide*.

Children love bugs and it is unfortunate that so many teachers know so little about the most abundant animals on the planet. Too often, they negatively sensitize children to insects with statements like, "Don't touch that. It may bite or sting you," and that is unfortunate because our most frequent encounter with other creatures on the earth is with insects and other arthropods, and the vast majority of these are beneficial! Arthropods are also the most successful animals on the planet! Our ill-fated attempt to exterminate everything with 6 or more legs has already made earth less colorful and interesting, not to mention a more dangerous place. We are just beginning to understand that a diverse world is a healthy world. In this PLT supplement I have endeavored to provide age appropriate and interesting yet challenging introductions to aquatic, forest, soil and other related arthropods. Extensions for each activity in the PLT guide contain pertinent background information and most also contain activities.

Enjoy,
JWG

Acknowledgments

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Much of the clipart is courtesy of The Florida Center for Instructional Technology (FCIT), located in the College of Education, University of South Florida, at Tampa, Florida. It is free for educational uses! http://etc.usf.edu/clipart/

Most of the photographs and the scanning electron microscope images were taken by the author and Peggy Guyton.

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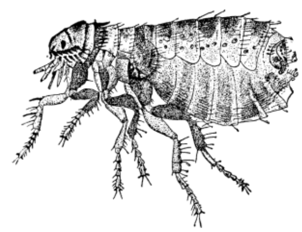
Diversity

1 The Shape of Things

Research has revealed that butterflies have pattern recognition and can even recognize cutout shapes of butterflies of their own species. Use the *Golden Guide to Butterflies and Moths* and allow students to cut out butterflies and moths from construction paper to tape to the windows or incorporate into a mobile. You can also use tangrams to make other insect shapes. Discuss why insect have different shapes and what the advantages are to the shapes they have. Birders use bird silhouettes to practice identifying birds and children can learn to identify butterflies the same way.

An excellent experiment can be performed using two identical water stations for butterflies. At one, attach cardboard or aluminum cutouts, painted black, to pieces of coat hanger wire. Do not put cutouts at the second station. Students can record the number of different butterflies that visit each station. If butterflies recognize shape, one would expect the water station featuring the cutouts would have more of the target butterflies. See also Activity 52 *A Look at Aluminum* for working with aluminum.



Fleas have a very interesting shape. Their bodies are compressed (flattened from side to side), which enables them to wander through animal hair with ease.

2 Get in Touch with Trees

Watch for click beetles when you are in the woods. They are easy to find at night using a flashlight on a night hike. Carefully examine the tops of fallen logs. They are also attracted to lights adjacent to woods. Blindfold the students, in turn, and allow them to gently hold a click beetle upside down in their cupped hands for a few minutes. Assure students that click beetles are harmless and do not bite or sting. When threatened or placed on its back, it flips itself 2 or 3 inches into the air. This clicking action comes with a "click" sound from which its name is derived. Watch carefully, because it is likely that two or three will drop the beetle. If it flies away, you may not be able to follow it if you are not paying attention! While the beetles' acrobatic antics are their great appeal, there are even species that glow in the dark! Of course you could put the click beetle in the mystery box…

The eyed click beetle in the eastern United States has two large black fake eye spots with white rings on its pronotum (the top of the first segment of the thorax) that are startling to predators, including people. Its real eyes are much smaller and located at the bases of its sawtooth-shaped antennae. Incidentally the males' antennae are longer than the females'.

3 Peppermint Beetle

When pine beetles attack a pine tree they produce aggregation pheromones that attract more beetles to the tree to overpower the tree's countermeasures or defenses. When the beetles reach a saturation point they release anti-aggregation or repellent pheromone to prevent too many beetles from congregating. These anti-aggregation chemicals are now being manufactured and have been effective in controlling some beetles.

Renowned entomologist E. O. Wilson, in a NOVA YouTube video from the PBS program *The Ant Whisperer*, describes using ant trail pheromones to lead fire ants to food. He places a sheet of paper with a freshly killed insect on it close to a fire ant hill and places another freshly killed insect at the opposite end of the paper, away from the fire ant hill. Then he takes a fire ant and, using forceps, squeezes its abdomen and collects the pheromones that are released from it onto a pointed stick. When he draws a pheromone line with the stick from the insect the ants have already found to the one farther away, ants immediately begin to follow the trail, and soon the more distant dead insect is covered with ants.

If you draw two pheromone lines, one over the other, to a dead insect, will the fire ants find it more quickly than following a single line? What would this indicate?

Now that you have learned to guide ants along a trail of your design, can you find a spice that when sprinkled across the line deters the ants?

4 Sounds Around

The frequency of cricket chirps is a function of the species and the temperature. The snowy tree cricket has a low enough frequency that the chirps are easy to count. Instead of looking for a particular cricket, listen for one whose chirps you can count. The male sings by rubbing a scraper or a ridge on one wing against wrinkles that resemble a file on the other. The tone, incidentally, depends upon the distance between the wrinkles.

The frequency of a cricket's chirping can be used to determine the approximate temperature. Count the number of chirps in 15 seconds and then add that number to 38 for the approximate temperature in degrees Fahrenheit where the cricket is located.

Number of chirps in 15 sec + 38 = Approximate temperature in degrees Fahrenheit

It is easy to test two different temperatures when you get a chirper inside the house. When it goes to chirping, count the chirps and estimate the temperature as above. Then change the temperature in the room by adjusting the thermostat by 5 or 10 degrees using the central air conditioning or heating system. When the temperature has stabilized at the new setting and the cricket has begun to chirp again, count the chirps and recalculate the temperature. The formula changes for different species and different regions of the country, so you have to make some adjustments.

The relationship between temperature and cricket chirps was discovered by Amos Dolbear in 1897 and published in an article he wrote called *The Cricket as a Thermometer*. The equation he formulated, which will give you a little more accuracy, follows.

Temperature in degrees Fahrenheit = 50 + (Number of chirps in a minute – 40) / 4

If you make a recording of a male cricket and play it back with a female in the room, the female will most often respond to the false invitation!

5 Poet-Tree

Spend a little time looking for insects in trees then use tree and insect keys or the internet to determine what the tree and insect are and how they are related. For example, the pawpaws (*Asimina triloba*) are the host plant for the zebra swallowtails, which are reminiscent of long-tailed kites. Invite each student to write a poem that describes the relationship of the tree and the insect. Combine the class's work into a poets' field guide to tree and plant hosts and their insect companions.

Zebra is a sign,
Pawpaw will be the next find,
They go together!

6 Picture This

It is estimated that 71.8% of all known species are invertebrates (from table in Activity 6), seeming to suggest invertebrates should comprise 71.8% of this activity. So what are these invertebrates? *Invertebrates are any animal without a spinal column, and it turns out about 97% of all animals are invertebrates*. There may be 1.3 million species. The greatest diversity on earth is also among the invertebrates. The major invertebrate phyla include the following. (Note: Young children do not need to know the following phylum names, just some of the organisms they are already familiar with that are invertebrates.)

Porifera (10,000 species)—pore bearer or sponges were originally mistaken for plants. The freshwater and marine organisms have specialized collar cells that pump a current of water into their pores, where the sponge filters out nutrients.
Cnidaria (9,500 species)—possess stinging cells and are carnivores. They include jellyfish, sea anemones, and corals. They only have one body opening that serves as both mouth and anus. They have no brain or heart, just specialized tissues that coordinate bodily functions.
Platyhelminthes (20,000+ species)—flatworms have been called nature's freeloaders and the tapeworm is a good example. Tapeworms do not have mouthparts or a digestive system but absorb their hosts' nutrients while living in their gastrointestinal tracts.
Nematoda (80,000 species)—the round worms, including human and domestic animal parasites such as the species that causes heartworm in dogs. Most are free living and not parasitic or harmful to humans. Nematodes are found in all aquatic and terrestrial environments from arctic seas to deserts and as parasites in many animals.
Annelida (9,000–30,000+ species)—the segmented worms, including marine and earthworms as well as leeches. Earthworms, favored by fishers and gardeners, eat their way through soil, absorbing the nutrients they need and enriching the soil as they go, leaving castings behind.
Arthropoda (1,000,000 species)—comprises three-quarters of the world's animal species and you hardly miss a day without encountering at least one! They inhabit air, land, and water and have been here longer than most animals so they are adapted to most environments. Insects make up around 90% of the arthropods. The arachnids include spiders, scorpions, and crustaceans (lobsters, crabs, and barnacles).
Echinodermata (6,000 species)—is composed of "spiny skinned" marine invertebrates such as starfish and sea urchins. All species possess five-point radial symmetry (five sets of organs, five arteries, and sometimes five appendages).

Information from the National Museum of Natural History was used in these descriptions.

Activity: Draw a large circle on a flip chart and have students use the table of known species in the PLT activity guide and the internet to draw a species for each percentage, i.e., 72 invertebrates, 16 plants, etc.

7 Habitat Pen Pals

Have students adopt an insect from a particular order to learn more about and use as their persona. This could be particularly interesting because insects' diminutive size results in a new and different perspective of their habitat. For example, water striders routinely walk on water and springtails not only can jump on the surface of water but they work their way up through snow and frolic on its surface. Other insects live in rotting logs, under the bark of trees or inside their leaves, and some aquatic insects carry a drop of air with them underwater like a scuba diver. See a list of orders and representative insects below in Activity 10 *Charting Diversity*.

8 The Forest of S.T. Shrew

Shrews are nocturnal mole-like insectivorous mammals. The pigment in their dark-tipped teeth is from iron and probably gives them the lifetime ability to crunch through insects' exoskeletons. Shrews are known to eat beetles, butterfly and moth larvae, crickets, grasshoppers, ichneumonid wasps, snails, spiders, earthworms, slugs, centipedes, and millipedes. Shrews also eat small birds, mice, small snakes, and even other shrews when the opportunity presents itself. Seeds, roots, and other vegetable matter are also eaten by some species of shrews.

The following math activity is most appropriate for upper primary or middle school students.
Since shrews are so small, they have a proportionally high surface area–to–volume ratio and the loss of body heat can be a problem. Let's use math to see why size is so important to the loss of body heat. Let's use spheres instead of trying to determine the volume and surface area of a shrew's body to make the calculations easy while we examine the *surface area–to–volume relationship*. Remember, as organisms get smaller in volume their surface area, in proportion, gets larger, and the more surface area, the greater their heat loss. Many blood vessels are close to the skin, and just as a car radiator gives off heat from the engine, the blood vessels give off body heat. The greater the size of a radiator for a car, the more heat it is able to dissipate and the cooler the engine will run. For small animals such as a shrew, this is a disadvantage because they have to eat more to keep their metabolism generating heat. Now, let's burrow into the math.

The formula for the **volume** of a sphere is $4/3\ \pi r^3$, where r is the radius and π is 3.14. Both the volume and weight, incidentally, increase and/or decrease with the *cube of the radius* of a sphere.

Surface area, on the other hand, increases or decreases with the *square of the radius*. The formula for the surface area of a sphere is $4\pi r^2$.

Note that the difference in volume increases with the *cube* of the radius while the surface area increases with only the *square* of the radius.

Now let's look at 3 spheres with different radiuses. Let's use spheres with radiuses of 9, 5, and 2 inches. An example of a mammal with a 9-inch radius would be medium-sized dog (18 inches in diameter if we bundled it in our arms).

Volume (*V*), surface area (*SA*), and surface area–to–volume ratio (r) for a sphere with a 9-inch radius (medium-sized dog)

$V = \frac{4}{3}\ \pi r^3$ $SA = 4\pi r^2$ r = SA/V

$V = \frac{4}{3}$ 3.14 x 9^3 SA = 4 x 3.14 x 9^2 r = 1,017.4 / 3,052.0

V = 3,052.0 cubic inches SA = 1,017.4 square inches r = 0.33

Volume (*V*), surface area (*SA*), and surface area–to–volume ratio (r) for a sphere with a 5-inch radius (small squirrel)

$V = \frac{4}{3}\ \pi r^3$ $SA = 4\pi r^2$ r = SA/V

$V = \frac{4}{3}$ 3.14 x 5^3 SA = 4 x 3.14 x 5^2 r = 314.0 / 523.3

V = 523.3 cubic inches SA = 314.0 square inches r = 0.6

Volume (*V*), surface area (*SA*), and surface area–to–volume ratio (r) for a sphere with a 2-inch radius (close to a shrew's size)

$V = \frac{4}{3}\ \pi r^3$ $SA = 4\pi r^2$ r = SA/V

$V = \frac{4}{3}$ 3.14 x 2^3 SA = 4 x 3.14 x 2^2 r = 50.24 / 33.49

V = 33.49 cubic inches SA = 50.24 square inches r = 1.5

From our calculations you can see that as the size of a mammal decreases the surface area–to–volume ratio (r) increases, meaning that for their size the smaller mammals have a proportionately greater surface area through which they can lose heat. As the mammal became smaller, from a 9-inch radius to a 2-inch radius, r increased from 0.33 to 1.5. The surface area–to–volume ratio is higher or larger for smaller mammals or spheres, so they can lose a proportionately greater amount of body heat. Therefore, shrews are more vulnerable to heat loss than larger mammals.

Incidentally, I first worked up this example to illustrate the problem smaller insects have with water retention. The smaller the insect, the greater the surface area through which they lose water to their environment.

9 Planet Diversity

There is a huge amount of animal diversity in a square yard of ground. The problem is that most of it is underground and not so obvious. In the top five inches of soil from a 3-foot x 3-foot plot in a southeastern U.S. survey, 25,309 animals were recorded. Of these, 18,595 were mites, 5,785 were springtails, and 929 were other insects. Yep, mites are among the most abundant and diverse groups of animals and they live everywhere from 125 feet deep in the ground to your forehead! And springtails, though very small, are just too neat to not know about!

Most of the earth's diversity is in the small stuff! The insect collection in the picture contains 20 orders of insects in a box that measures 2 ½ x 3 inches. That will get a student through almost any school insect collecting requirement, and it will drive the teacher nuts—they know the big insects normally collected, but will have to learn a little more about the most abundant and diverse groups of insects to grade the project!

Planet Diversity works better if the entire yard is used for the investigation and all animals seen from this yard count, including birds overhead and the neighbor's dog. Allow children to draw, describe, or photograph what they cannot identify.

10 Charting Diversity

Insects are great here—in most places everyone can find a variety of insects, arachnids, or a few isopods. How many orders did you find? Capture them in paper cups and use a digital camera to record the finds before their release. You will be surprised how much diversity is on many schoolyards. Consider conducting a school *Bioblitz*, where an entire day is devoted to identifying all of the plants, animals, etc. on the school grounds. You could likely entice several biologists to assist with identification. Make a virtual collection or record of the biodiversity in the schoolyard.

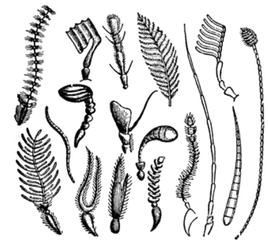
I have included a section on using wings and antennae to identify insects to order below. This came from the *Mississippi 4-H Entomology Manual*. Students should not try to identify insects to species—just common names are satisfactory.

Most, but not all, insects possess **wings** in the adult stage, a feature that separates insects from other arthropods, such as millipedes, pillbugs, and spiders. Most insects have two pairs of wings attached to the second and third segments of their 3-part thorax. The notable exceptions are flies, members of the order Diptera (meaning "two-wing"), which lack hind wings. Mosquitoes, blow flies, house flies, and robber flies all are members of this common insect group. Linnaeus, the Father of Taxonomy, was the first to use wing form to divide insects into 7 orders.

Lepidoptera (moths, butterflies)—wings are covered with fine scales or "dust."
Trichoptera (caddisflies)—wings are covered with fine hairs.
Coleoptera (beetles)—forewings (called elytra) are hardened and cover the membranous hind wings.
Neuroptera (lacewings, snakeflies)—the "nerve-wing" insects, a reference to the very large number of veins on their wings.
Thysanoptera (thrips)—edges of the wings are bordered by long hairs, making these the "fringe-winged" insects.
Diptera (flies, midges, mosquitoes)—only possess a single pair of wings, the forewings.
Isoptera (termites)—in reproductive king and queen stages that possess wings, both the forewing and the hind wing are of equal length.
Hemiptera (true bugs)—the forewings are patterned with two different designs. The base of the forewing is thickened, while towards the tip it becomes more membranous. A V-pattern typically forms behind the head when the wings are folded. Note: the homopterous insects in this order (e.g., aphids, leafhoppers, scales, cicadas, whiteflies) do not have this type of wing.

Dermaptera (earwigs)—the very short wing covers are distinctive with this order, although the rove beetles (Coleoptera: Staphylinidae) also share this characteristic. Only earwigs have the combination of short wings and distinctive cerci (paired appendages on the insect's hind end.)

Siphonaptera (fleas)—no wings occur with this group in any life stage.



Antennae are used by insects to sense odors and vibrations in their environment—functioning somewhat as does our nose. However, insects have antennae of various, and sometimes fantastic, design. These can also be used to identify the adults of many different insect groups.

Lepidoptera (butterflies)—have long, thin antennae that end with a knob; skippers have long, thin antennae that end with a hook; moths' antennae are variable but often feathery and large. Males typically have larger antennae than females.

Diptera (flies)—many of the most common flies, such as house flies and blow flies, have antennae that appear as small lobes on the front of their head with a hair sticking out of them. These are called aristate antennae. Mosquitoes, midges, crane flies and related flies have antennae that appear as filaments or plumes.

Orthoptera (grasshoppers, crickets), **Blattodea** (cockroaches), **Mantodea** (mantids)—these orders are characterized by very long filament-like antennae.

Coleoptera (beetles)—No order has such a wide range of antennae as do the beetles. Some families have long thin antennae—the extreme being the wood borers known as longhorned beetles, which may have antennae almost twice as long as their bodies. Scarab beetles have peculiar clubbed antennae, while those of other species may be feathery.

Neuroptera (antlions, lacewings)—long antennae with a club-like tip.

Odonata (dragonflies and damselflies)—small, hair-like antennae between the eyes.

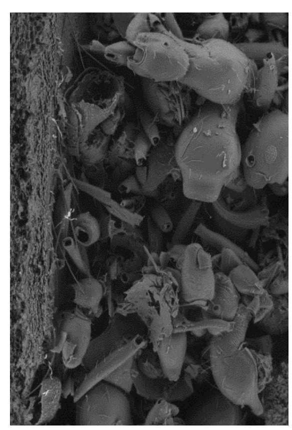
Isoptera (termites)—antennae appear as a string of beads.

Hymenoptera (ants, hunting wasps)—antennae are elbowed, with an extended first segment and smaller segments towards the tip.

Hymenoptera (parasitic wasps)—antennae very long and made of many tiny segments.

11 Can It Be Real? An unusual plant and why it eats insects!





The insectivorous pitcher plants (left) live in nitrogen-poor soil, and in this case have been "eating" fire ants. In the scanning electron microscope image (center) you will notice some of the pitcher's side has been cut away to show the insect bodies. Plant tissue is visible on both sides in this picture, and you can see the accumulation of fire ants that were attracted to the plant and have been disassembled by enzymes in the plant to access and absorb their nitrogen. The image is enlarged (right) to show the soft tissue that connected the various exoskeleton pieces has been completely dissolved, leaving a "bone yard" of exoskeleton pieces. Each year the plant produces new pitchers, or leaves, and the old leaves and their accumulation of exoskeletons eventually decay.

Activity: Ask your teacher if there are insectivorous or carnivorous plants in your area. If so, carefully examine them with a hand lens and use the internet to learn as much about them as you can. The old brown pitchers contain evidence of the past year's diet and are no longer of use to the plant.

12 Invasive Species

The United States is under attack by armies of insects that are hitchhiking rides from many foreign countries on ships, airlines, and the wind. When they arrive in the U.S., they quickly respond to the lack of natural predators that keep them under control in their home regions, and begin crowding out our native species, which are normally kept in check by the ecosystem in which they evolved.

One noteworthy invader is the ambrosia beetle from Asia that is spreading across the Gulf Coast with alarming speed, devastating plants in the laurel or Lauraceae family. The red bay and sassafras trees are being especially hard hit. The ambrosia beetle brings a symbiotic fungus with it that it uses to start a fungal garden under the bark of its chosen tree in which it feeds. This fungus plugs the sap-producing cells, killing the tree. When the tree dies, the beetles move to the nearest tree and replant their gardens.

On the Gulf Coast, residents frequently give newcomers to the region a bag of leaves from either the red bay or sassafras tree as a welcome gift. Both are used in cooking; the red bay in any recipe calling for bay leaves, and the sassafras to thicken gumbo, a coastal mainstay.

Activity: Check and see if there are any edible leaves on trees in your area and if they or their tree is threatened by insects.

13 We All Need Trees

Most are familiar with the birds and mammals that live in the trees, but there are many more, often unmentioned, arthropods and insects. Arthropods have been using trees much longer than we have, and we find chewers and sap suckers, scavengers and sun baskers, predators and parasites, tourists and shelter seekers, to name a few groups. More specifically you will find aphids, ants, plant bugs, leaf miners, mites, various gall-forming arthropods, bees and wasps, spiders, beetles, flies, and gnats.

Activity: Researchers sometimes spray an insecticide over an entire tree to survey its insects. But there is a safer technique you may want to try. Spread a sheet on the ground under a low-hanging branch and rap on the limb with a stick to dislodge its insect inhabitants, which will fall on the sheet. Be mindful a white sheet on the ground might also attract ticks. Use a field guide and the internet to identify the insects and try to figure out how the insects were using the tree.

14 Renewable or Not?

All schools should have an outdoor classroom and that is as good a place as any to discuss whether things are renewable or not. Students can actually see the soil being renewed through composting and planting nitrogen-fixing cover crops. Horticulturalist and Gestalt Gardener Felder Rushing suggests placing a number of items recyclable and non-recyclable items such as a banana peel, a piece of aluminum foil, a nail, an apple core with its seeds in a nylon stocking and putting it in a pumpkin. Bury this in a corner of the outdoor classroom. This is a good post Halloween activity and the pumpkin should be a used jack-o-lantern. Dig it up before school is out and examine the contents. You may not find the pumpkin, but if you carefully spread the contents of the stocking on newspaper you will find a variety of very small arthropods including springtails and mites that are helping renew the resources.

While we are discussing an activity for the outdoor classroom, there are several important renewable techniques worth mentioning. Scan through the Activity Guide to see which activities may involve growing plants or working with insects. As you are helping renew the resources you should have an old rotting log in the outdoor classroom to provide a habitat for a wide variety of insects and other arthropods that can be used for several years before it is returned to the soil. You can grow mushrooms in holes in the log and maybe even plant a tree in a hole and turn your log into what is called a "nurse log" in the temperate rain forest in Oregon because it nurses or supports the growth of the new tree. Be careful to protect the roots that will grow down and around the nurse log because these will eventually create the sides of a cavity where the nurse log was.

Saving the best seed or seeds from plants (vegetables and wildflowers) with noteworthy traits from year to year teaches important skills that are slowly eroding in this day when farmers have become dependent on seed companies' "specialized" seeds. Many seeds are bred or treated to be insect resistant and have to be purchased from the producers every year. However, seeds that have not been hybridized or genetically modified, called heirloom seeds, are maintained by organizations and available for you to purchase and grow so you can experience diverse flavors from the past and learn to save the best seeds and replant them. (See Activity 95 *Did You Notice?*)

Use seeds you intend to plant in the schoolyard instead of popcorn in Part B—Demonstrations 1 and 2, and then plant the seeds.

Variation on Demonstration 3—Global Candy Jar. If you have a large paved area, consider scaling it off with latitude and longitude lines from a world map and then sketch in chalk and later paint the outlines of continents on the grid. There are activities in every subject that could benefit from such an outdoor classroom element. For this activity consider using fruit that is locally available and that originated on as many continents as possible. You might send suggestions home for parents to contribute several of a favorite fruit from their family. Conduct the lesson as written. As an extension, identify and label the countries of origin of various non-native insect pests in the U.S.

15 A Few of My Favorite Things

If your favorite thing is plant or animal derived, there is an arthropod or insect connection. The short list includes any plants that were pollinated or used natural arthropod or insect control, or used beeswax, honey, cochineal red dyes (made from the bodies of scale insects), or shellac (secreted by insects).

Activity: Everybody enjoys a piñata! Piñatas made to look like various insects can be hung from the ceiling as permanent displays—but make one or two to smash! You will need a large mixing bowl, flour, water, all-purpose glue, hot glue gun and glue sticks, paint in various colors, pictures of the objects you are going to make, and wrapped candy to put in the piñata. You can also use a combination of balloons taped together, feathers, pipe cleaners, toothpicks, foam, plastic wrap, chicken wire, wooden sticks, plastic window insulation, crepe paper, construction paper, wrapped candy, tissue paper, and fabric scraps.

Rip up newspaper (you'll need a lot) into thin strips at least six to eight inches long, and 2 or so inches wide. Balloons make excellent molds for paper mache piñatas. All sizes and types of balloons can be used. Blow up balloons and tie them off.

There are several recipes for paper mache or Papier-mâché (French for chewed paper—do you think they got the idea from watching paper wasps?). A simple, tried-and-true method is to start with a few cups of flour, add a little water at a time (it will be very thick at first), and stop adding water when it feels like glue. Some directions also advise to include glue in the paste, but flour and water will do the trick.

Dip each strip of newspaper in the paste and squeeze off the excess paste with your fingers. Apply to the balloon form until it is completely covered. Put several coats on, allowing each layer to dry (a couple days) before adding another. If more than one balloon will make up the final piñata, glue them together after the first layer is dry. Once the body is fully formed and totally dry, pop the balloons, carefully cut a hole in the piñata, and add wrapped candies. Add one more layer of paper. When it is dry, you are ready to apply at least one coat of paint, and preferably more, to protect the piñata from moisture. Decorate as desired.

Of course a few of my favorite things include insects! Flies are so much fun to play with! I use a very thin silk strand, or even a piece of hair to make a tether for flies. I tie this around their neck and tape the other end to the table and watch them fly in circles.

16 Pass the Plants, Please—In the form of honey!

When I speak to senior citizen groups I often take a few “special” flavors of honey for them to sample. Almost every time I get to enjoy watching a seasoned face break into a big smile, and I know they are going to say, “Oh my, I haven’t tasted this since I was a child!” *This* is the real thing—the sweets our ancestors, since the beginning of time, sought and eventually maintained colonies of bees to have on hand. The two flavors seniors enjoy the most are sourwood and tulip poplar, or swamp gum!

Specialty honeys preserve the character of the plants the bees have communed with, not to mention the health benefits of locally produced honey on asthma and other respiratory ailments. These honeys are made by skilled beekeepers that put fresh hives near sourwood or tulip trees just as they are starting to bloom and then process the honey when the blooms start to wane. Sourwood trees are in short supply and succumbing to development. As an understory tree, conditions are not optimum every year for a good crop, so this honey can be considered rare and endangered. In fact, a good sourwood honey flow may occur only once in a decade.

Most children have only had the overprocessed, environmentally boring honey that comes in plastic “bear” bottles and is sold at most grocery stores. These children have missed what honey is all about.

During tastings, children always sneak back into line for another sample of their favorite honey, and I pretend to not notice. Honeys with their natural flavor intact will awaken an epicurean response that delights!

Activity: Treat your class to a honey tasting by giving each student one toothpick for each of the honeys they will be sampling. Demonstrate how to dip a toothpick in a jar of honey and continuously twirl the toothpick to prevent it from dripping before it reaches your mouth. This toothpick should then be discarded—no double dipping. Oh, you won't find these honeys at a typical grocery store. Watch for roadside stands and look for honeys that are labeled for the trees from which they are made. There are specialty honey stores that sell various honeys on the internet. Be aware some are adulterated, such as key lime and some orange blossom by finely grating the peel and adding that to the honeys! But some of these are quite delicious.

In recipes, honey can be used in place of sugar, but use only 3/4 of a cup of honey to 1 cup of sugar, since it is sweeter.

Recipe: The original energy drink, popular in the Appalachians Mountains, is called **switchel**. It is made by mixing a half cup of honey and a half cup of cider vinegar. Keep it in a jar and add four teaspoons to a dipper of water, or your water bottle, for a refreshing drink. Of course, you will need to remember to wash your water bottle.

17 People of the Forest—Bugs de jour

Historically and currently people of the forest have eaten insects. Western (European) society stands virtually alone in shunning nutritious insects in their diets. The Mississippi State University Biochemistry, Molecular Biology, Entomology and Plant Pathology Department is home to the first insect rearing workshop in the world, and in recent years there has been an increase in participants who are interested in raising insects for human consumption. Participants are typically sent by large insect-rearing firms that got their start raising insects for research.

As more of the world's people become fascinated with the developed world's diet they are eager to join its ranks, and frankly, not enough crop land exists to support everyone on earth eating hamburgers and steak on a regular basis. The larger the human ball at the end of the food chain, the more herbivores you need on the other end producing food and energy.

Protein is produced rather high on the food/energy pyramid and deficits in the near future are a possibility. The most feasible alternative may be entomophagy, or eating insects. The menu currently includes almost 1,500 known edible species. I have always enjoyed getting to know people from other places and cultures by eating their foods with them, so it seems natural to dine on bugs as a way to appreciate diverse cultures.

Recipe: Roast the crickets first—like lobsters, insects are definitely better if cooked live as the postmortem changes render them unpalatable. To prepare the crickets, put them in the refrigerator for a while. This won't kill them but it will slow them down. Meanwhile preheat the oven to 200^{o}F. Spread the cool crickets on a cookie sheet in a single layer and pop them into the oven. Bake for one to two hours or more until completely dry. Test by crushing a dried cricket with your fingers to see if it crunchy. If they do not seem completely dried out, roast them some more. However, be careful not to burn them! Let cool.

Now let's make **Nutty Chocolate Chirp Cookies**!

2 ½ cups flour
1 teaspoon baking soda
1 teaspoon salt
1 cup butter or margarine
¾ cup granulated sugar
¾ cup brown sugar
1 teaspoon vanilla
2 eggs
12 ounces semi-sweet chocolate chips
½ cup chopped pecans (keep them guessing)
1 cup of roasted crickets

Preheat the oven to 375°F. Combine the flour, baking soda, and salt. In another bowl, combine butter, white and brown sugar, and vanilla. Beat until creamy, then beat in eggs and gradually add the flour mixture. Stir in chocolate chips, crickets, and pecans. Drop by small spoonfuls onto ungreased cookie sheets. Bake for about 10 minutes. Makes about 5 dozen cookies.

Oh, I almost forgot! You might be interested to know that the FDA allows an average of 60 insect fragments in every 100 grams of chocolate and an average of 30 insect fragments in every 100 grams of peanut butter. Just started your diet, huh?

18 Tale of the Sun

As an extension to this activity *The Christmas Spider*, part of bug camp's history and tradition, has been included.

The Christmas Spider
By Breanna Lyle, Mississippi State University Bug Camper

It was Christmas Eve. The small house had been thoroughly cleaned, and the tree had been decorated. The children were nestled into bed, and were dreaming of the exciting morning that was to come. Even the little spider that lived in the house had moved to the attic so that everything would be just right when Santa Claus arrived to bring the children their presents.

The light from the fireplace was casting a beautiful light on the room, and the spiders were sitting quietly in the attic. Before long, he heard the sounds of the adults turning in for the night. He peered through the attic floor, but couldn't see the tree very well. Spiders have very poor eyesight, despite their many eyes. Oh, but the spider wanted to see the beautiful Christmas tree. He had never seen one before, and it seemed so beautiful.

He decided, after much thought, that he would go down and take a quick look. It wouldn't take long, and he'd be really careful. No one would ever even know he was there. Without making a sound, the small spider scuttled through a crack in the floor, and dropped down on his web next to the tree. Sure enough, the tree was as beautiful as he had imagined that it would be. Delicate ornaments hung from every branch, reflecting the light of the fireplace.

He wandered all over, looking at everything. He turned, ready to go back to the attic, when he noticed that the tree was covered with webs. He hadn't realized it, but as he was walking around he had been laying down a drag line. A drag line is a piece of web that spiders use to ensure that they won't fall down and get hurt.

The little spider was devastated. He sat there trying to figure out a way to fix the tree when a noise came from the chimney. The spider turned around and saw the form of Santa Claus standing next to the tree. The spider started crying. The tree had been so beautiful, and now Santa was seeing it covered with webs. The little spider thought that now the whole night was ruined.

To his surprise, though, Santa didn't look upset at all seeing the webs left by the little spider. He smiled and asked the spider "What's wrong, little one? Why do you seem so sad?" to which the spider replied, "I wanted to see the beautiful Christmas tree, but I ruined it with my webs. I'm sad because I ruined it." Santa laughed. With a wink, and a little magic, he touched the web left by the little spider. A light grew from the web, and it turned a lovely silver color. Instead of ruining the tree or hiding its beauty, the webs now made it even more beautiful!

From that night on, the little spider found a new passion, using his webs to make the Christmas trees even more beautiful. To this day, we still find the little spider's influence, in the form of tinsel, which we still wrap around our Christmas trees. Some people even leave small spider sculptures in their trees, in honor of the little spider.

About the Author: Breanna Lyle has been bug camping with us for a long time and has developed an interest in spider behavior. She keeps spiders alive to study their behavior and even uses them in spider workshops. She also enjoys writing poetry and short stories and plays bass guitar!

Activity: Try this solar energy observation and writing activity. It is fun to get up early and search for butterflies in the bushes and then watch them using their wings as solar collectors and warming up before the morning's first flight! The ability of insects to keep their body at an acceptable temperature is referred to as **thermoregulation**.

Can you write a story about butterflies that sunbathe in the morning?

19 Viewpoints on the Line

Harold Anderson, the Mississippi PLT Coordinator, uses a version of the following story when teaching *Viewpoints on the Line*. I used some material from Margaret B. Kreig's book *Green Medicine: The Search for Plants that Heal* (1964, Rand McNally) in the following case study**.**

DDT/Malaria Case Study

Sir Ronald Ross, who in 1897 determined mosquitoes were the vectors (carriers) of malaria, wrote "Malarial fever is important not only because of the misery it inflicts upon mankind, but also because of the serious opposition it has always given to the march of civilization….no wild deserts, no savage races, no geographical difficulties have proved so inimical to civilization as this disease." Malaria remains one of the major causes of morbidity and mortality primarily affecting third world countries. Cave paintings and fossil skulls that were opened in operations as early as the Neolithic period, possibly to let the headache demons escape, record what may have been an early treatment for malaria. The standard medical treatment became bloodletting and it persisted well into the nineteenth century.

The first stage of malaria consists of muscle soreness and backache, followed by chills and uncontrollable shaking. The next stage involves high fever, severe agonizing headaches, and vomiting. In the final stage the infected person experiences a drop in temperature, profuse sweating, and a burning delirium. Infected people may also experience anemia, weakness, and a swelling of the spleen. If the patient lives and even after their fever breaks, seizures return repeatedly on the infecting parasite's schedule.

The first important synthetic organic insecticide was DDT, discovered in 1939. The pesticide was considered a miracle because it killed a wide range of insects, did not seem to harm mammals, persisted on the sprayed surface over time, was not water soluble, and was inexpensive to apply.

For the first time in the history of the world it appeared a solution was at hand and insects would soon be pests of the past. Mosquitoes were finally on the wane, crop yields were up, and bed bugs were disappearing! Then Rachel Carson warned the world about the damage to the earth's fragile ecosystems being caused by DDT in her bellwether book *Silent Spring*, published in 1962. The "rain of chemicals" Carson described was already on scientists' radar, and an early version of integrated pest management called integrated control was being experimented with by the University of California, but Carson's efforts ignited an environmental movement.

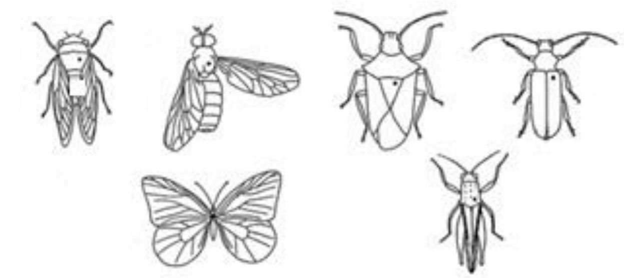
Carson's targeting of chlorinated hydrocarbons, including DDT, as responsible for killing non-targeted organisms, including birds, through direct and indirect toxicity was on the spot. The title *Silent Spring* was in reference to spring without birds… Manufacturers claimed that the residual amounts of DDT in the environment were too small to be significant. However, research revealed the reproduction and survival of a number of organisms were in danger, and the concept of biomagnification through the food chain was immediately understood by scientists. The newly formed U.S. Environmental Protection Agency quickly cancelled the registration of DDT in 1972, making it illegal to use. Many bird species have recovered since DDT's ban in the U.S. but evidence of its persistence, often in unexpected places, continues to be found.

Most people are surprised to learn that outside of the United States DDT is still in common use and that manufacturers in the U.S. continued to produce DDT for use in other countries for about a decade after its ban here! DDT is still manufactured in other countries.

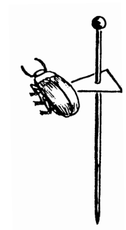
It is difficult for people in the U.S. to understand how insidious malaria is since its vectors were eliminated or suppressed before most of us alive today can remember. However, it persists today and is responsible for 300–500 million cases and 1–3 million deaths per year. Over 90% of the cases are in sub-Saharan Africa, where almost all deaths are among African children under 5 years of age. Increasing worldwide travel makes its spread a potential global epidemic for over 40% of the world's population in about 100 countries. Compounding this threat is mosquitoes' increasing resistance to currently used insecticides and the parasite causing malaria becoming resistant to the antimalarial drugs.

An international treaty signed by 176 nations to phase out the use of persistent organic pollutants allows exceptions for DDT's use in 25 countries with critical malaria problems. Of interest, the U.S. is not among the signatories.

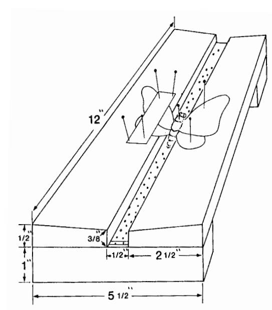
20 Environmental Exchange Box



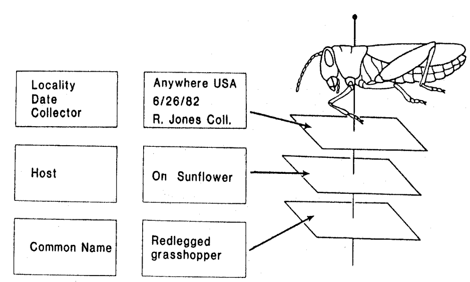
An insect collection with representatives of 10 or 12 local orders would make a great exchange box. See Activity 10 *Charting Diversity* for a guide to commonly collected orders. Insects can be placed in a plastic bag and stored in a freezer for a couple days to kill them. Just before you send your exchange box or when you receive one, you should put it in the freezer for a week to kill any dermestid beetles that may be munching away inside one of your insects!



Special pins are needed for this project. Insect pins come in a range of thicknesses, and #3 is a good general purpose size pin. Insect pins can be purchased from biological supply houses, university bookstores, or university entomology departments. Common straight pins like those used in sewing are too thick and too short, will rust, and may damage the insects. An illustration (top) is provided to show where a pin should be inserted in a dead insect. Very small insects should be mounted on a triangular piece of paper cut from an index card called a point. The insect can be glued to the point with a small drop of white glue.



Butterfly wings should be spread on a "spreading board" until dry, 3 or 4 days depending on humidity. A spreading board can be flat and made from a stack of corrugated cardboard pieces or a piece of foam insulation board. The front wings should be carefully pulled forward until the back edge of each wing is perpendicular to the butterfly or moth's body. Bring the hind wings forward so the front edge rests slightly below the forewing. Pieces of tracing paper can be used to hold the wings flat. Try not to touch the wings, and use forceps or tweezers to position the wings. Butterflies should be pinned as soon as they reach room temperature after you take them out of the freezer.



Finally, a series of small labels should be placed on the pin beneath the specimen. See the figure for information that should go on the label and where to position it. The top of the insect should be ¼ inch from the top of the pin. Insects should be arranged alphabetically by order in your collection.

Information and illustrations are from the *Mississippi 4-H Entomology Manual*.

Interrelationships

21 Adopt a Tree

Your tree has already been adopted! It has pollinators and diners and other insects that are just looking for a place to hide or hang out for a while. Watching the insects on your tree throughout a year will surprise you! You will hear the crickets and cicadas before you can find them and they will get quiet when you get too close. When your tree blooms the pollinators will not be worried about you; they have urgent business with the tree's flowers and will ignore you. Depending on your tree, the pollinators may be bees, wasps, butterflies, moths, or beetles. Make a list of the insects you find on your tree and which months they are active. Trees and plants with white flowers may be pollinated at night and typically save their precious fragrances for the evening.

A variety of conifers and deciduous trees attract bagworms, which have a delightful story to tell. When I need a bagworm for show and tell, I head for the junipers, where I often find them. Bagworm eggs hatch sometime around the end of May or the first of June, and the very small larva attaches a strand of silk to a limb and hangs down, looking for a place for its next level of development. Often wind transports it to a new tree. When it finds a suitable host, it begins to make a bag, incorporating needles, scales, or leaves from the host plant around itself. With only its head protruding, it starts eating, carrying its bag with it and enlarging it as it goes. By late August the larva is mature and attaches its bag to a limb with a little silk and develops into a pupa. The wingless female bagworm moth remains in the bag in which she pupates, mates through the bag opening, lays eggs, then drops to the ground and dies shortly thereafter. The eggs develop in the bag. The adult male moths, with fur-like hair on their bodies and transparent wings, appear in September. After mating, the adult males die. The picture shows the male and bag in which the female resides.

22 Trees as Habitats

The giant ichneumonid wasp is a parasitic wasp. The female has a very long (2 to 5 inches) needle-like ovipositor with a manganese- or zinc-coated tip that is often mistaken as a stinger. She senses the movement of larvae under the bark of trees and uses her three-part ovipositor to push through the bark and into a larva, where she lays an egg. Ichneumonids are parasitoids of other insects (meaning the developing wasp larvae feed on the insect host, eventually killing it), including the larvae or pupae of Coleoptera (beetles), Hymenoptera (bees, ants, and wasps), and Lepidoptera (butterflies and moths).

Sure signs that trees are habitat to pine or ambrosia beetles are the frass (excreta and plant material) tubes that stick out from the side of trees, and the dying needles in the top of the tree. See also Activity 62 *To Be a Tree*.

Activity: When walking in the forest watch for dying tree tops and the trunks of trees for these frass tubes and then examine them closely.

23 The Fallen Log—Wood Rot Fungi

A departure into another kingdom for this activity. Apologies to Animalia!

Rotting wood sounds bad, but when you remember this is nature's recycling program, you will realize it is only bad where we do not want it, e.g., in our homes. Walking through the woods you can observe fungi in action! Fungi are the major biodegraders of both cellulose and lignin in wood. Wood decay is the natural process that breaks down wood into carbon dioxide and water. There are two common types of rot you can easily recognize, white rot and brown rot caused by different fungi. Generally speaking, brown rot progresses at a faster rate, but white rot is more thorough.

White Rot Fungi—White rot fungi are easy to spot on firewood or the stumps of cut trees as shelf fungi. They are important decomposers of woody debris on the forest floor and common parasites that attacks the heartwood in living trees. White rot causes a bleaching, or whitening, of the wood. This is especially obvious when it bleaches darker heartwood. There are thousands of species that cause white rot. White rot fungi can degrade all cell wall components, and their unique ability to metabolize huge amounts of lignin (the non-carbohydrate glue that holds the cellulose fibers in wood together) has attracted the attention of forest chemists who hope to capitalize on this property for biofuel production.

Brown Rot Fungi—Brown rot progresses so rapidly that often before you know of damage, the characteristic loss of structural strength in infected limbs causes them to fall. Careful examination will reveal the wood is brown and sometimes cracked across the grain into characteristic "cubes." What is actually happening is the carbohydrates in the cell walls are being metabolized—the wood (carbohydrates that make up the cell walls) is gone and only the glue (lignin) skeleton remains. In advanced stages, crushing wood that has been infected can reduce it to powder. Brown rot fungi are common in downed timber and firewood, living trees, and even the wood framing in buildings. This makes brown rot fungi an economically significant concern. Brown rot is a serious problem in urban forestry because it can attack relatively young trees and large branches can unexpectedly fall from otherwise healthy-looking trees. Brown rot is often referred to as dry rot, but that is a misnomer since moisture is a prerequisite.

Insects found in an old rotten log include: ants, beetles (bark, bess or passalid, click, longhorn, powderpost, and anobiid), crickets, fly larvae (maggots), glow worms, cockroaches, and termites. Of course a lot of other community members join the insects in the log including fungi, bacteria, spiders and other arachnids such as daddy longlegs and mites, centipedes, millipedes, earthworms, slugs, slime molds, protists, and nematodes.

24 Nature's Recyclers

This activity is already about a couple of favorite arthropods of youth, sowbugs and roly polies, or pillbugs, formally referred to as woodlice (woodlouse singular). They are not insects or bugs, but terrestrial crustaceans and close kin to shrimp, lobsters, crabs, and crayfish in the Isopoda order. They can reproduce by parthenogenesis, and the young, carried in a pouch under the mother's belly, shed their skins as they grow. Both use a gill structure to breathe so you will find them in moist places such as under leaves. The roly polies' defensive response of rolling into a ball (called conglobation) also functions to reduce their water loss. The surface–to–volume ratio calculations used to describe the heat loss of a shrew compared to larger mammals in Activity 8 *The Forest of S.T. Shrew* above can be used to describe the water retention problems insects and other related arthropods face because of their small size. The pillbug is an interesting example as it can roll into a ball to conserve water.

Activities: There are a variety of activities you can do with sowbugs or pillbugs.

- There is a reason you typically do not find them in the sunlight, and you can do an activity to see if they prefer sunlight or the shade of a leaf.
- You can make an Isopoda corral with a fence-line of vegetable oil to contain them while you study them.
- You may choose to monitor their rate of breaking down litter since they are one of nature's recyclers.

- Place a pillbug in the center of a large piece of paper and trace a line behind it as it crawls, while timing it. Then use a piece of string to measure how many inches it crawled and calculate the inches it can crawl in a minute.
- Roly polies are easier to maintain in a terrarium than an ant farm! Tarantula owners sometimes maintain a colony in their tarantula cages because they eat feces, mold, and leftovers. Predators include frogs, toads, spiders and small mammals that may get some calcium from their exoskeletons! And they won't pee on you like a puppy, but they do pass gas (ammonia).
- Be sure to look at them under a microscope or with a hand lens (10 to 40x). The minute hairs and cones on the cuticle surface are sensory receptors. You can stick a piece of masking tape to their backs to hold them upside down for examination. When teased with a probe or forceps they may exude a thick glue they use to entangle predators.

25 Birds and Worms

The classic camouflage/environmental discovery involved the peppered moth (*Biston betularia*) in England and Ireland. Its caterpillar is a twig mimic varying from brown to green. Most adults, in earliest records, had light-colored wing patterns that blended in with the dominant tree lichens in their habitat. During England's Industrial Revolution, pollution from coal smoke caused many of the lichens to die out and trees were darkened by the soot from coal smoke. This made the light-colored moths easy pickings for birds, but enabled the darker colored moths to blend in, survive, prosper, and become the most common. Eventually, when air quality became a concern and smoke and soot levels decreased, the foliose lichens returned, the darker moths, no longer camouflaged, were more visible to birds, and the lighter colored moths once again prospered from their camouflage.

Two types of deceptive coloration are useful in avoiding predators, camouflage and mimicry. The classic example of mimicry involves the viceroy (top photo) and monarch (bottom photo) butterflies. The monarch contains toxic cardiac glycosides that it acquires through its diet of milkweed while a caterpillar. The viceroy has been thought to gain protection by its similar coloration, and birds' avoidance of anything that resembled the monarch is what is referred to as Batesian mimicry—a harmless organism gains protection by its mimicry of a toxic organism. However, the viceroy caterpillars dine on the leaves of willow and poplar species that produce bitter-tasting, herbivore repelling, noxious chemicals. In the early 1990s researchers discovered that birds eschewed both monarch and viceroy bodies when the wings had been removed, suggesting Müllerian mimicry, where two unrelated noxious organisms resemble each other and each mimic benefits! In recent studies it has been confirmed that when under attack by predators, the viceroy releases volatile phenolic glycosides. One of the beautiful things about science is that it is self- correcting, so Müllerian mimicry it is!

Adult grasshoppers commonly assume the color of local soils. What advantages might that impart to them?

Activity: Make a collection of pictures showing insects that use camouflage.

26 Dynamic Duos

Braconidae is a fine family of wasps that knowledgeable teachers welcome in their outdoor classrooms. These are *parasitoids* that usually kill their hosts. Those who try to raise nutritious vegetables under a fog of poisons may inadvertently be exterminating gardeners' friends along with their enemies. Teachers will also miss a fine opportunity to allow their students to see an excellent example of how nature works.

Gardeners are ever watchful for those large, 3- to 4-inch-long, bright green hornworms munching on leaves, stems, and even immature tomatoes. They are the larval stage of the hawk or sphinx moth, also known as the hummingbird moth. There are actually two closely related species, the tomato hornworm (*Manduca quinquemaculata*), which has a black horn on its rear end, and the tobacco hornworm (*Manduca sexta*), with a red horn. Both are the bane of gardeners! Pick these off the plants in your home garden and squish them to kill them, or drop them into a bowl of soapy water and compost them, but in the outdoor classroom you will want to leave a few to feed the wasps and use in a lesson. They are so well camouflaged you may find it easier to find them by looking for their frass (poop) and then up into the plant where they are hiding!

The hornworms undergo complete metamorphosis: egg, larva, pupa, and adult. The round, greenish-white eggs are laid on the underside of leaves and hatch in 4 or 5 days, so watch for the eggs, and monitor daily. After about 4 weeks of eating the leaves of your tomato plants, the larvae will head for the soil, where they will pupate and overwinter as dark brown pupae. In late spring the adults will emerge, mate, and lay eggs.

Now, back to our new friends the Braconidae. Different species, and over 15,000 have been described, of the small (usually less than ½ inch long) braconid wasps attack their hosts' egg, larval, pupal, or adult stage, where they develop as either internal or external parasites. Some of their favorite hosts include aphids, beetles, stink bugs and squash bugs! Different species specialize on different hosts. A favorite parasitoid of the tomato hornworm, the braconid wasp (*Cotesia congregatus*), considers tomato and tobacco hornworms the wasp's version of the pizza delivery person! The 1/8-inch-long female uses her ovipositor to lay eggs just below the hornworm's skin. When the eggs hatch, the larvae live on the hornworm's viscera—eating it alive! Eventually the larvae chew their way out to pupate and spin small oval cocoons, often mistaken for hornworm eggs, on the hornworm's back. Soon after the adult wasps emerge from the cocoons, the hornworm will die. So, when you see the hornworms covered with white-colored cocoons, leave the cocoons alone—they house our friends!

Why grow tomatoes in the outdoor classroom? The second most important reason is to feed the Braconidae! Oh, the most important reason is BLTs—'nuf said! Don't like acronyms? ***B****acon,* ***L****ettuce and home- or school-grown* ***T****omatoes make a highly desirable sandwich.*

27 Every Tree for Itself

Every Tree for Itself is a great starter for discussing insect attacks since traumatic events in students' lives, comparable to insect "attacks" on trees, can leave their marks. After several rounds of the activity you can select a student to play the role of an insect, let's say a bark beetle. The student touches the first tree it can get to and then moves through the forest of student trees, going from one tree to another that is close enough to touch without taking an extra step. Once invaded, a touched tree then plays the role of a new beetle looking for its tree. This will demonstrate the usefulness of thinning a stand (spacing student trees further apart) to reduce the spread of beetles.

Many insects call trees home. Ants, bees, beetles, moths, and wasps all make their homes in trees and often cause a lot of damage. Holes in the bark, oozing sap, frass tubes, and wilting leaves are a few of the symptoms you may notice. All bark beetles are attracted to trees damaged by wind storms, fire, overcrowding, or being hit by a vehicle, and many insects typically attack only after a plant has been weakened or killed by another stressor. Larvae and adults make tunnels in the branches, trunks, leaves, or roots of woody plants. Eggs of most borers are laid on or in the bark and the larvae chew into the plant. Most borers are beetle or moth larvae, but wasps and/or flies are also prevalent.

The southern pine beetle *(Dendroctonus frontalis*) is one of the most serious pests in the southeastern U.S. Its historical role has been as a scavenger of dying pines, expediting the return of minerals to the soil and opening meadows in pine stands that are beneficial for wildlife. Other areas of the country have their beetle pests, including the mountain pine beetle in the western U.S., which attacks and kills trees. Pitch on the tree's bark may be an indicator but the frass-packed S-shaped galleries underneath the bark are unquestionably the adult's tunnels. The tunneling destroys the phloem, eventually killing the trees. The first symptom you will notice is an even dieback from the top down as the leaves turn reddish brown. When the bark plates are loose and easy to pull off, the tree is dead. The beetles often do not become a problem unless they experience a population explosion or the pines are spaced too closely. Bark beetles' symbiotic relationship with various fungi enables them to feed on many trees since the fungi feed on the wood and the beetles on the fungi.

The black turpentine beetles (*Dendroctonus terebrans*) also bore into the phloem, producing vertical galleries with a "D" or fan shape. The pitch patches are white to reddish-brown and about the size of a half dollar (1.2 inches) in diameter. These beetles typically attack fresh stumps or the lower 10 feet of a tree's trunk.

Like other bark beetles the *Ips* engravers (*Ips* spp.) most often are attracted to trees after lightning strikes, root damage, or drought. Pitch masses on the bark and fading foliage are typical symptoms of the beetles' damage. Their frass-free egg galleries radiate out from an entrance hole (see picture of engraving). Blue-stain fungi, introduced by the *Ips* adults and spread by the larvae, disrupt the tree's water flow, resulting in its death. The first symptom is dieback of one side of the tree, as opposed to the even dying from the top down caused by the southern pine beetle.

Ambrosia beetle (Curculionidae family) females bore into twigs, branches, or trunks of healthy or stressed trees or freshly cut logs. Beetle attacks on living plants are often low on saplings and higher at wounds on larger trees. Numerous small holes in the bark and wilted foliage are indicators. The frass tubes resemble toothpicks sticking out from the trunk. A recently imported ambrosia beetle, accompanied by a symbiotic fungus that they cultivate and eat, is killing red bay and sassafras trees along the Gulf Coast. Eggs, larvae, and pupae can be found together in tunnels. See Activity 12 *Invasive Species*.

Long-horned beetles (Cerambycidae family) have unusually long antennae. The larvae bore cylindrical tunnels through tree bark and into the wood. Frass and sap, compressed behind the tunneling beetles, are sometimes pushed out of the tree, leaving visible evidence. Twig girdlers are interesting long-horned beetles that chew V-shaped grooves entirely around twigs or branches where they insert their eggs. Interestingly, their eggs are inserted into the bark on the girdled part of the branch away from the tree trunk. The girdled limbs eventually break and fall to the ground.

Metallic wood-boring beetles and their larvae, flatheaded borers (Buprestidae family) are often associated with stressed or wounded trees. The bullet-shaped adults are flattened and have short antennae. These beetles often sport metallic colors (blue, bronze, copper, or green). Their larvae are cream colored and legless with flattened body segments. The larvae tunnel beneath bark, making oval or flattened tunnels in the sapwood. Their winding galleries are typically packed with frass. The emerald ash borer, from Asia, is leaving a path of destruction reminiscent of Dutch elm disease and chestnut blight! It is killing green, black, and white ash trees. Symptoms include a thinning of upper branches, trunk sprouts, splits in the bark, and D-shaped exit holes.

The immature stages (caterpillars) of several kinds of moths tunnel into tree trunks. Large caterpillars called carpenterworms (Cossidae family) tunnel into many tree species where they feed under the bark before tunneling into the sapwood. Large piles of sawdust and frass are a clue to their attack. The mottled-winged adults emerge in the spring after a couple years under the bark.

Clearwing moths (Sesiidae family) are daytime flyers and often mistaken for wasps. These borers lay their eggs at the margins of insect holes, lawnmower nicks, on galls and other wounds. The newly hatched larvae bore into the phloem where they feed. Large patches of sap and ejected frass are indicators. Infestations can kill entire trees or just branches.

Carpenter bees (Anthophoridae family) have a very distinctive bore hole. They leave a perfectly round hole about 1/2 inch in diameter on the outside of the tree or on wood railings on buildings. The females bore into most softwoods, including pine, redwood, and cedar, to lay their eggs and literally produce colonies. They resemble bumble bees without hair on their otherwise shiny black abdomens. The males tend to be more aggressive but do not have stingers. Females have stingers but are typically not aggressive.

Carpenter ants (Formicidae family) bore into trees to make nests, often using holes that were already present. They characteristically follow the wood grain since it is softer. The ants do not eat the wood and push the debris out as they tunnel. They favor trees with higher water content.

Horntails (Siricidae family) are named for a terminal spike that projects from the abdomen of both sexes and is separate from the female wasp's ovipositor. The ovipositor is driven into the bark to lay an egg in weakened trees. The resulting whitish, 6-legged larva has powerful jaws and produces a long tunnel over a year or so before spinning a silken cocoon near the inner bark. Infected trees have been cut and used in construction, after which the adult horntails have emerged. See also Activity 62 *To Be a Tree*.

Activity: Introducing youth to tree pests is a great idea. We have had bug campers that have found pine beetles in their family's tree farms, so if you are doing a workshop around trees that are infected be sure to point them out during your programs.

28 Air Plants

Aphids are pretty fascinating and bizarre, and they may be stealing plants' thunder and identity! Like plants, aphids have been discovered to synthesize carotenoid pigments. These pigments are essential for maintaining healthy immune systems and making vitamins in many organisms, but most organisms must obtain these through their diets.

Do green "Martian" children photosynthesize and not have to eat their green vegetables? Well, aphids may. Entomologists in France have discovered aphids' carotenoids, which are responsible for aphid pigmentation, can absorb energy from the sun and transfer it to their cellular machinery that drives energy production.[1]

Research has indicated that green aphids have more ATP (adenosine triphosphate) than white ones. Orange aphids, which have intermediate amounts of carotenoids, were discovered to produce more ATP when moved into the sunlight, and production tapered off when they were removed!

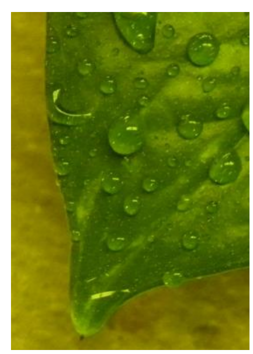
Nancy Moran, the insect geneticist at Yale University who discovered aphids had the genes for carotenoid production, pointed out that energy production is not a problem for them and speculates this capability may help them in times of environmental stress.

Now if the gene splicers can just splice that gene into our sequence, maybe we can quit eating green vegetables, although I cannot imagine who would want to quit eating greens!

[1] Lougheed, K. 2012, August 17. Photosynthesis-like process found in insects: Aphids may have a rudimentary sunlight-harvesting system. *Nature.* Available at http://www.nature.com/news/photosynthesis-like-process-found-in-insects-1.11214

29 Rain Reasons

Rainfall, sunlight, and temperature are not only important factors influencing where plant diversity is greatest but have similar influence on insect diversity and numbers. One study found over 480 tree species growing on a single hectare in a Brazilian rainforest as compared to 700 species on millions of hectares in the U.S. and Canada. Within Puerto Rico's wet, moist, and dry forests that range from sea level to 2,000 feet and experience a rainfall difference from more than 90 inches to less than 30 inches per year, there are a lot of different biomes to support a diverse assemblage of insects.



E. O. Wilson called the forest canopies "the last frontier" of biological research and this is certainly an apt description. Their extreme height has placed them out of reach until recent times, but already we are beginning to understand that as much as 70 to 90% of the life in the rainforest is in the tree canopies! No wonder Charles Darwin could not figure out why he saw fewer butterflies than he expected in the rainforest. He was unable to reach the ones in the tree canopy!

Many forest trees have adapted to life in an environment where rainfall is frequent. Leaves of many rainforest trees and other plants have "drip tips" that enable water to run off faster, thus preventing the growth of fungi or bacteria on their surface.

An interesting side note is that "crazy ants" (refer to the *Dry Forests* section of *Forest Types* for this PLT activity) are now well established on the Gulf Coast.

Activity: Collect insects in two forest types (e.g., pine and hardwood forests), or even a forest and a meadow to see how different environments support different insect communities.

30 Three Cheers for Trees

Start a tree inventory of the city or county you live in. Have students take pictures of all the trees in their neighborhoods and select the best specimens of each to make a tree directory or a guide to local trees. This should include a map with the location of each tree marked, along with the latitude and longitude for champion trees. To see if you have any champion trees in your community, find your state through the National Registry of Big Trees. Students can research the champion tree(s) and add what they learn to their tree directory. As they research each tree in the inventory, they can find what insects it is host to and include this information in the guide.

31 Plant a Tree—Plant a forest and attract insects

Consider turning your school into a native plant arboretum. Local foresters will enjoy helping find specimens to plant and in the future when Scouts or 4-Hers need to work on tree identification, they can use your school grounds! In selecting trees you may want to consider planting deciduous trees on the south side that will provide shade to cool the school during hot weather and shed their leaves during the winter to help warm the building. Planting evergreens on the north and northwest side will protect the school and students from cold arctic winds.

Activity: Oaks typically have weevils that attack their acorns. In turn, larvae of acorn moths (*Blastobasis glandulella*) feed inside the cavities made by the weevil larvae. Damage by these insects prevents germination of the acorns or their use as food for wildlife. Have your students collect 100 acorns, and cut them open to discover how many acorns, or what percentage since you are examining 100, escaped infestation by weevils or acorn moths and are available to feed squirrels or produce new trees.

Did you know that blue jays are responsible for the dissemination of oak trees? Blue jays select viable acorns that insects have not attacked and transport them as far as 6 miles, where they plant them in soil of the right consistency and moisture level. If forgotten by the birds, these acorns may sprout and produce new oaks.

32 A Forest of Many Uses

Two of my favorite trees are the sourwood, often called the honey tree (*Oxydendrum arboreum*), and tulip poplar (*Liriodendron tulipifera*) because bees make some of the most delicious honey from their flowers. If you can smell their flowers and taste their honey, you will understand the incredible job bees do in preserving the flavor of trees (see Activity 16 *Pass the Plants, Please*).

The tulip poplar is plagued by the sap-sucking tuliptree scale (*Toumeyella liriodendri*), an insect pest that is in turn controlled by lacewings and ladybird beetles (ladybugs). If you notice a mist or light rain under a tulip poplar, you may be interested in knowing the sticky, sugary “rain” is honeydew, or scale excrement! Fall webworm (*Hyphantria cunea*), hickory horned devil or regal moth (*Citheronia regalis*) larvae, and sphinx moth (*Sphinx* spp.) larvae feed on sourwood trees.

Activity: Find answers to these forest uses. *I have mentioned some of my favorites…*
What is a favorite food of yours that has come from a forest tree? *Black walnuts*
What is an important medicine that has come from a forest tree? *Quinine, from trees in the genus Cinchona*
What is your favorite forest animal, and on what tree is it dependent? *The hackberry butterfly and its host tree, the hackberry*

What is your favorite tree? *Osage orange, or Bois d'arc (Maclura pomifera). Experiment with it as an insect repellant*. *I also like sassafras. The leaves are used to thicken gumbo, and the roots are used to make root beer! The wood was used by early settlers to make beds since it repelled bed bugs.*

What kinds of wood are used in constructing your house, and what woods are used to make your furniture? *Black walnut, oak, juniper, and cherry are my favorite, and I enjoy using them to build furniture and other items for the house.*

Now go back and find out which insects are associated with each tree. *Black walnut curculio (black walnut), cynipid wasp (oak), bagworms (juniper), and spotted wing drosophila larvae (feed on cherries and are easy to collect for use in experiments).*

33 Forest Consequences

Have your class design an urban forest for your community. Students can decide where to plant deciduous and evergreen trees around municipal buildings and schools to make them more energy efficient (see Activity 31 *Plant a Tree* above) and other trees that may be useful or interesting. They could plant trees on both sides of various roads. Perhaps there should be an apple or pecan orchard where families can assist with maintenance and the fruit harvest. If there is a Maple St. and no maples, they need to plan on correcting that oversight. Consider planting a "council tree" outside the courthouse, a public building, or the school to use as an outdoor meeting place.

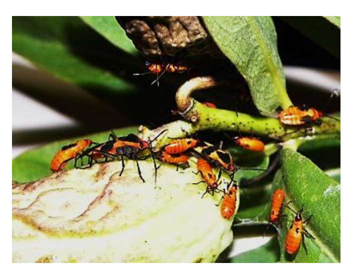
As they plan their urban forest, they should research potential insect pests of the trees, as well as climate conditions to choose trees most suitable for the local environment.

34 Who Works in this Forest?

Forest entomologists work in the forest. Go into a forest and see how many insects in different orders you can find. Break open an old rotting log and look for termites (Isoptera), beetles and their larvae (Coleoptera). Examine flowers for butterflies and moths (Lepidoptera); bees, wasps and ants (Hymenoptera); and horse flies and deer flies (Diptera). You may find stink bugs (Hemiptera) on plants, walkingsticks (Phasmatodea), or praying mantids (Mantodea). You might also find centipedes, millipedes, roly polies (pillbugs), mites, and springtails if you look closely enough. Approximately 100 different species of ants have been found in the Sam D. Hamilton Noxubee National Wildlife Refuge.

35 Loving It Too Much

Collecting insects and plants in national and state parks and wildlife refuges is typically forbidden. However, these places are known for their diverse wildlife and great opportunities to photograph insects as well as other wildlife. In some cases the wildlife is almost tame, enabling you to get spectacular pictures of them doing things seldom seen, such as this deer rubbing the velvet off its antlers.



In photographing insects you will need to learn about depth of field and macrophotography, and this is better done with your camera in hand. Often wildlife refuges and nature preserves host photography contests, and I encourage you to get involved. Someone there will be anxious to share their techniques with you! I can be found hanging out around the Sam D. Hamilton Noxubee National Wildlife Refuge and I almost always have my camera to snap a few pictures such as this milkweed bug and early nymphs.

36 Pollution Search

Mosquitoes can lay eggs in a tablespoon of water. Before the water evaporates, they could hatch and the female could bite you! Survey your schoolyard or neighborhood for objects or areas that hold water. It may be a discarded soda bottle or a cup from a fast food place, a white plastic grocery bag, an old tire, a saucer under a houseplant, or a low place in the yard where water only slowly drains. Check these places for an egg raft or mosquito wigglers so you will know them when you see them later.

Now organize neighborhood cleanup teams to walk through neighborhoods searching for and removing discarded trash where mosquitoes could breed. If you need a science fair project, you could devise a project to monitor mosquito bites in your neighborhood before and after the cleanup.

37 Reduce, Reuse, Recycle

If you decide to make an insect collection you will probably break a few specimens. Save them and you can use them for other activities. Butterfly wings can be arranged on a bookmark-sized piece of paper. Write a poem about butterflies on the paper then laminate the bookmark, or cover it with wide clear tape if a laminator is not available. You can even use a hot glue gun and create your own insects from other spare body parts.

Of course your garbage can is a great place to collect flies, and there are over 150,000 species of flies, gnats, and midges! Throw your spoiled fruit into the yard to attract flies, wasps, and butterflies.

Old bed sheets and broom sticks make great nets! And if someone discards sheer curtains, grab them to make nets as well. You can find a variety of designs for insect nets on the internet.

38 Every Drop Counts

Often, if I am camped in an area where I will be collecting insects away from others, I will carefully select places to urinate, and then check them regularly for butterflies. Butterflies need salt to reproduce and will soon find what you no longer need. Their behavior is known as puddling because they often gather at puddles.

39 Energy Sleuths

Sunlight also nourishes mosquitoes and fish. The leaves of broadleaf trees along stream banks absorb energy from the sun before falling into streams. This leaf litter, or detritus, then becomes the major food and energy source that supports aquatic, and later terrestrial, food webs. Aquatic fungi, bacteria, shredding invertebrates, protozoans, and microarthropods break these leaves down, benefiting from some of the "green" nutrients and stored solar energy and making the rest available to higher levels of the food chain. Increasingly larger invertebrates, including insects, eat these organisms before fish eat them. Eventually the fish may be caught by a hungry bird or human.

40 Then and Now

Invite an extension entomologist or agricultural specialist to visit your class and do a short talk on the history of insecticide use in your county. A war rages in the agricultural sections of the country between insects and farmers and has for a very long time! Mosquitoes have been a pest since before the North American continent was settled and persist as an ever-present nuisance and danger. Draining the wetlands is a practice that is highly discouraged today, but less than 100 years ago it was a successful technique for reducing mosquito populations and, consequently, mosquito-borne diseases such as malaria, yellow fever, and dengue. Now banned, DDT was once heralded as a miracle insecticide for knocking down mosquitoes and bed bugs, so there have been a lot of changes in how we have managed insect populations from then to now. See also Activity 19 *Viewpoints on the Line* and Activity 72 *Air We Breathe*.

Systems

41 How Plants Grow—Some grow and evolve with their pollinators

The yucca moth (Prodoxidae family) and yucca plant (Agavaceae family) have *co-evolved*, becoming completely dependent on each other. The yucca flower is shaped in such a fashion that only the female yucca moth is the right shape and size to pollinate it. The pregnant female yucca moth uses her palps to gather some pollen grains that she forms into a ball and tucks under her "chin" before flying to another yucca flower, where she lays her eggs in the side of the ovary. She then crawls to the top of the ovary, where she deposits some of her pollen on the stigma, insuring cross-pollination. The yucca moth caterpillar then feeds on the yucca seeds. If too many eggs are laid in a single flower's ovary the plant will abort the flower, so each moth leaves pheromones when she visits a flower. Other moths respect the scent and leave fewer eggs than they normally would or select another flower.

This is a great example of the interdependence of an insect and a plant where both benefit. If one becomes extinct, so will the other. A formal name for this is mutualism, and it appears the yucca and yucca moth association began over 40 million years ago.

42 Sunlight and Shades of Green

In Activity 28 *Air Plants*, we discovered that aphids produce carotenoids that are responsible for their pigmentation and can process sunlight for the energy needed to drive their cellular machinery. Well, it appears aphids got the genes responsible for this via gene swapping with fungi!

The green pigment in insects is often the result of chlorophyll. In the fourlined plant bug the stripes are initially yellow and change to green. After death, they revert to yellow. The green is due to chlorophyll in the diet of the leaf-eating insects. Like leaves that yellow in the fall as the chlorophyll breaks down, when the insect dies, the green pigment breaks down, allowing the yellow pigment to be more obvious. See *Adventures with Insects* by Richard Headstrom (1982, Dover, ISBN 0-486-21955-0) for more information.

Tobacco and tomato hornworm larvae eat leaves and the chlorophyll pigment is conserved, showing up in their green coloration. Some Lepidoptera and arachnid cocoons are also green.

43 Have Seeds, Will Travel—Have silk, will fly!

Insects and other arthropods are always on the move looking for food and avoiding becoming food, looking for water, searching for shelters or habitats or space. They have developed many fascinating ways of traveling, leaving no opportunity unexploited! Left alone they hop or jump, swim or float, crawl, fly, walk on water, drift on air currents, and in recent times they have been traveling by car, ship and on airlines! I will relate a few interesting insects and other arthropods and their ways of traveling.

- Bed bugs can only crawl and are dependent on humans to carry them home, to new hotels or to other exotic places.

- Ticks (arachnids related to spiders and scorpions) are very patient and they can wait for years for a ride and a blood meal. An adult tick can lay several thousand eggs on the ground, typically in moist areas with tall vegetation. After hatching, the larva crawls up the leg of a deer, dog, human, or other animal for each subsequent stage of development, where it enjoys blood meals. Ticks go through 4 life stages: egg, six-legged larva, eight-legged nymph, and adult. Ticks know how to find you or another suitable host, and often crawl up tall stems where they can wait for years for your sign, which may be exhaling carbon dioxide, or your body odor, body heat, moisture, or vibrations. Ticks cannot fly or jump but many assume a “questing” position where they hold onto the weed or leaf with their third and fourth pair of legs and reach for a host with their front pair.
- Pseudoscorpions are small arachnids with 4 pairs of legs and pedipalps that terminate with pincers. They resemble ticks with pincers. Pseudoscorpions are often found in other animals’ nests or hitchhiking on moths or other animals.
- Many moth caterpillars lay down a silk or life-line as they search for food. They can also use this line to find their way home. When the small, hairy, buoyant gypsy moth larva crawls to the edge of a tree’s crown and drops from a strand of silk, strong winds can break the strand and the remaining section attached to the larva acts as a parachute, sometimes transporting the larva for several miles. The gypsy moth was introduced to the U.S. from Europe in 1869 and has since become a major pest of oaks and many other tree species. It has been regarded as one of the most insidious pests of shade and forest trees in the eastern U.S.

44 Water Wonders—There are bugs in the watershed!

Evaporation. Household insects, such as cockroaches, can be managed by evaporation. Sprinkle diatomaceous earth in places where the sharp, angular pieces of silica that were diatom shells can scratch the soft connecting tissue between the insects’ exoskeleton parts when they crawl over it. These scratches will scrape away the wax and enable water to evaporate from the insect, thus it will die of dehydration. During Greek and Roman times road dust was added to stores of grain to protect the stores from insects.

Transpiration. Transpiration cools the plant leaf and surrounding air, creating an air-conditioned microhabitat for some small insects. Transpiration occurs through insects’ cuticles at elevated temperatures when the waxy coating softens.

Condensation. Small arthropods like springtails can sometimes be found where moisture is condensing on windows or other surfaces.

Precipitation. Insects have a waxy coating on their exoskeleton that gives them some protection from the rain. However, when it is about to rain they seek shelter under leaves or other places. Bees return from the field.

Snow fleas are springtails, which normally feed on leaf litter, that have worked their way to the surface of snow by crawling up blades of grass or tree trunks to frolic a while in the sun!

Caddisfly (order Trichoptera) larvae inhabit flowing streams, rivers, and sometimes ponds. They are one of the water wonders because their larvae construct protective cases of silk decorated with sand, pebbles, or twigs. Occasionally they use precious stones in their cases. Some stack twigs log cabin style as they build. The cases are open on both ends, and water is drawn in the posterior end, carrying oxygen the larvae extract with their gills from the artificial streams that flow through their cases. Net-making larvae use a variety of net designs to snare algae and animal food and as a retreat. Some caddisfly larvae produce multiple strands of silk simultaneously and make nets with the smallest opening of any net found in nature. The larvae secure their cases to a substrate and pupate. When the adults emerge they swim to the surface, cast off their pupal skins, spread their wings, and fly off to find a mate. Most adults do not feed.

45 Web of Life

Peering into the woods at night with a bright spotlight you will see dozens of eyes peering back at you! The vast majority of these are spiders! There may be between 30,000 and 1,000,000 spiders in an acre of woods. A spider web that is at least 100 million years old is preserved in Early Cretaceous amber from Sussex, England, so spiders have been snaring prey for a very long time. Not all spiders build webs. Some pounce on their prey from a concealed location like the trap door spider. Others, such as the wolf spider, run their prey down. Young spiders of several species crawl to the top of high trees and begin paying out a long strand, or balloon, of silk. When it is long enough, the winds pull the spider from the tree top and sometimes carry it for hundreds of miles. The various types of spider webs include: spiral orbs (primarily Araneidae family) built by the golden silk spider and the spiny back; tangled webs or cobwebs (Theridiidae family) made by black widows; funnel webs (Aglenidae family) constructed by grass spiders; tubular webs (Atypidae family) made by the purse web spiders; and sheet webs created by the bowl and doily weavers (Linyphiidae family) and brown recluses (Sicariidae family).

The golden silk orb weaver's web (top photo) is a made from a beautiful golden silk and this large spider is gentle enough that we allow children to handle them. The spiny back orb weaver produces a huge web with intermittent thick sections of silk in the various strands that enable mammals and birds to see it and avoid walking through it (bottom photo).

Activity: It is fascinating to throw insects into spiders' webs and watch the spiders securing their prey. Tube web spiders can be coaxed out for a look during the afternoons or evenings by gently touching their web with a stick.

46 Schoolyard Safari

Most of the animals children will see in the schoolyard will be insects, and you can refer to the descriptions of insect orders in Activity 10 *Charting Diversity* above to determine which orders they spot. Often when we want to measure the diversity of insect populations we examine the number of orders present. So, how many insect orders can you collect or photograph? Since each insect also needs food, water, and shelter, which of these are the insects finding in the schoolyard?

47 Are Vacant Lots Vacant?

Not only plants of all kinds are found in a vacant lot; it is also inhabited by many insects and arthropods.

Activity: Using an aspirator (see instructions below), collect ants from a square-foot plot. ***Suck on the straw protected by gauze*** while holding the other straw close to ants, one at a time. You can probably catch 50 or so before emptying the bottle some distance from where you are counting ants. You may want to wear gloves since some ants' bites can be painful. Take measurements to calculate the square footage of the lot then estimate how many ants are in the "vacant" lot.

Make an aspirator from a pill bottle and two straws with bendable elbows. Punch or drill two holes in the bottle cap into which you will insert the short ends of the straws. Make a filter for one straw by placing a piece of gauze over one hole in the cap before pushing the straw through the lid. If desired, attach aquarium tubing to this straw to extend your reach. Push the straws into the bottle only as far as necessary for them to stay securely. Note: Gauze mesh must be smaller than the insects you collect!

48 Field, Forest and Stream—Insect Surveys

Team 6 in their survey will discover the insects in a field, forest, and stream make up the greatest biodiversity. Which environment has the most insects?

Now divide the insects found in each setting by order using the descriptions in Activity 10 *Charting Diversity* above. As measured by the number of orders present, which environment contains the most diverse insect life?

49 Tropical Treehouse

The great diversity of insects in tropical forests has been pondered by scientists since Darwin's voyage, and then we discovered the insects of the tree canopies!

Only in recent times has the diversity of insect communities 200 feet above the forest floor in tropical tree canopies, where green leaves, fruits, and sunshine are abundant, been investigated. Many of these insects are never found on the ground. The first studies were done using insecticidal fog machines that poisoned all of the insects in tree canopies so many could be collected on the ground for study. This revealed complex communities living in the tree tops that really have to be visited and observed to advance our understanding of them. Today, getting to them requires technical climbing equipment, walkways in the sky, towers and cranes, and even dirigibles, and we are just beginning to understand the ecological canopy communities that contain herbivores, predators, fungivores, and scavengers.

An entomological take on the Jungle Tunes Variation. In 1991 I was in central Mexico on the Pacific coast for the Eclipse of the Century, a total eclipse of the sun of unusually long duration—7 minutes of totality or darkness at noon. We used a tape recorder to record our observations. After the eclipse we noticed an interesting piece of incidental data we inadvertently collected. As noon and the darkness of the eclipse approached, there was a steady increase in the frequency of a slapping sound that tapered back to its original levels as the eclipse waned. Near the peak of the bell curve relationship I gave the deciphering clue as to what the slapping sounds were when I commented, "Dang, the mosquitoes are getting bad!"

50 400-Acre Wood

A diverse community is a healthy community. Look back through the insect orders in Activity 10 *Charting Diversity* and research where insects in each order can be found. Now develop a management plan for how you will provide habitat for as many orders as possible in your 400-acre wood. Such strategies as creating a meadow in the center of the woods are good for most wildlife, including insects. See Activity 23 *The Fallen Log* to see how many insects you can provide habitat for by leaving some fallen logs in the woods! Snags or standing trees also provide habitat for a lot of insects and birds as well.

51 Make Your Own Paper

Using some of the pulp produced in the PLT activity wrap a thin layer over each of about a dozen hexagonal pencils. Cover the entire unsharpened end about ¾ of an inch up the pencil. Then bundle all of these pencils together and secure with rubber bands until the paper is dry. Gently remove the pencils and compare your nest to a real paper wasp nest. See Activity 93 *Paper Civilizations* below for a photograph of a wasp nest.

52 A Look at Aluminum

Using tin snips and wearing gloves, cut the top and bottom off of an aluminum soda can. Outline a butterfly with all four wings using a marker on the inside of the can. Cut out the butterfly shape and carefully use pliers to fold the edge of the metal can under to prevent cuts from its sharp edges. Now balance the butterfly on a single finger to determine its center of mass. Using a nail and a hammer, drive a hole through the butterfly at this point and suspend it from a string. Make several butterflies and suspend them from sticks, creating a mobile. Use this same technique to cut butterflies for Activity 1 *The Shape of Things*.

53 On the Move

Nonindigenous species have arrived in the United States via a variety of carriers. Some years ago when passengers arrived in Australia men in white suits would walk through the plane spraying an insecticide to kill any insect that may have hitchhiked a ride with the passengers.

Google the phrase, "How do nonindigenous insects arrive in the United States," and make a list of the intentionally and accidentally introduced species, how they arrived, and where they came from.

Visit http://msucares.com/pubs/publications/p2286.pdf and you will find a book of nonindigenous species activities for youth I produced with Sea Grant funding while I was a Sea Grant professor.

54 I'd Like to Visit a Place Where…

Make an insect guide to a local park or recreation area, describing where various insects or representatives of insect orders can be found.

55 Planning the Ideal Community

Research beneficial insects for the garden and plants that discourage harmful insects, then design a garden-insect community. You will also need to decide what plants to include that will attract the good insects. What cultural practices can you adopt that will encourage the beneficial insects and/or discourage the pest species?

56 We Can Work It Out

When people decide how to use a piece of land they are often not very well informed about its history. The light pollution in the northeast United States is so great that moths, which are out at night, have difficulty finding mates. The grasshoppers and butterflies that returned every year to the hill near my childhood home disappeared when the hill was graded down and apartments were built, destroying their habitat.

The regular summer appearance and serenade of the annual cicada portends a summer courtship. Children enjoy watching the emerging adults crawl up blades of grass or tree trunks where they shed their skin and their wings expand before their eyes. Soon after their wings are fully developed, they find a mate. Scanning the trees along a hedge row you can watch nature take its course and even witness the female using her knife-like ovipositor to insert eggs in twigs. When nymphs hatch from the eggs, they burrow into the ground and feed on sap from plant roots as they grow, shedding several skins until they are ready to emerge as adults. Incidentally, the empty skin makes a great nature broach that easily attaches to a shirt or cap.

The exciting cicadas are the periodical cicadas, with red eyes, that emerge after 13 or 17 years underground. Everyone should see a periodical cicada emergence. Unfortunately before we completely understand their ways and cycles they have begun to disappear. I am afraid development and uninformed land use may be in part responsible. There may be other animal populations adversely affected by new land uses, such as fish, mussel, and aquatic insect populations when streams are rechanneled.

What groups should be involved in solving these problems?

57 Democracy in Action

As the enrichment topic, find out what the mosquito sprayers are using in your community. What other insects does the insecticide they are using kill? Are honey bees affected? Aquatic insects? Is the spray at the levels being used effective on mosquitoes?

Design an experiment to determine if the spray is effective. Place caged mosquitoes in the path of the sprayer and a control group at a safe distance. Could you design a more effective mosquito abatement plan, e.g., neighborhood patrols that would eliminate standing water (see Activity 36 *Pollution Search*), or placing Bt (***Bacillus thuringiensis***—a naturally occurring bacterial disease of insects that is the active ingredient in some insecticides) mosquito dunks in water that cannot be drained? What would you need to do to get the local government to consider your plan?

58 There Ought to Be a Law

Insects produce an unimaginably huge number of offspring, and when just one has a unique ability or genetic anomaly to deal with an insecticide, its offspring may also have that ability. In this situation, the benefits of the pesticide are lost (i.e., the insects have developed insecticide resistance).

Our best management practice for an agricultural pest is an environmentally sensitive combination of common sense practices designed around knowledge of the pest's life cycle and interactions with the environment. Known as integrated pest management (IPM), this strategy entails not just a single action but a series of steps. 1) Decide when action is warranted. I have a friend who calls the exterminator when <u>one</u> roach is found in the house, a time when action may not be warranted. Farmers have to weigh the cost of control against potential loss. 2) Monitor and accurately identify the pests, which helps insure pesticides are not used unnecessarily. 3) Prevention is much better than rushing to use pesticides and allowing insect resistance to develop. If crop rotation, companion planting, selecting pest-resistant varieties, planting pest-free root stock, or another cultural practice works, you have saved your most valuable asset for another day. 4) Implement the least risky pest controls when monitoring reveals that prevention has failed. These controls include physical removal or trapping of pests, or the use of targeted chemicals such as pheromones to disrupt mating. 5) Apply pesticides to target areas where the pests have been found if monitoring indicates the need. 6) Broadcast spraying of non-specific pesticides is the last resort.

Recently Dr. Sebastião Barbosa, former Senior Integrated Pest Management Officer at the Food and Agriculture Organization, Rome, Italy, gave a talk in the Biochemistry, Molecular Biology, Entomology, and Plant Pathology Department at Mississippi State University on agricultural insect pest management on the world scene, discussing the major advances that resulted from IPM. Dr. Barbosa lamented that IPM is now more popular in developing countries than in the more affluent nations. As countries develop, farmers and others tend to skip the first steps and use broadcast spraying, yet the consequences from this abbreviated practice *are why IPM was developed*. Continuing to develop more insidious pesticides is too expensive economically and environmentally when the urgency outweighs the desperately needed time trials to ascertain their secondary effects on people and the environment, as well as the time required for their breakdown and secondary products resulting from their decomposition.

There ought to be a law requiring the use of IPM.

59 Power of Print

Local newspapers are the last bastion of printed newspapers and they are desperately looking for material that will keep subscribers happy. Local television stations are finding reporters to be too expensive to make extensive use of, so there is a void that can be filled by youth writers and reporters. Instead of focusing on just controversial issues, consider writing informational articles about how to solve regional problems. TV reporters can be youth with vision for a better way to do something, and video cameras today are everywhere! So share your novel solution to a local problem—write it up for the newspaper or make a TV-style report and submit it to the station. If you regularly create pieces people find useful, the paper or station will gladly continue to publish them!

60 Publicize It!

This activity reminded me immediately of Sir Robert Dudley and Sir James Cavendish landing on the beach of Cuba where they saw a large number of lights moving through the woods. Immediately suspecting a forthcoming attack by the Spaniards they hastened back to their ships and went on to settle Jamaica. The lights they saw were luminous click beetles (genus *Pyrophorus*), whose lights are much brighter than that of fireflies. Had this been publicized, the English might have stayed in Cuba and changed the course of history!

Structure and Scale

61 The Closer You Look

While looking at trees, take a closer look in the leaf litter around trees for some centipedes and millipedes. They are found all over the world and share similar habitats—dark, damp areas such as shady woods, under the bark of dead trees, in rotting leaves, and under stones. A fossil myriapod has been dated at 428 million years old, making it the first known land animal.

Centipedes are predators with venomous claws and a flattened body. Centipedes move rapidly with one pair of legs per segment. They can bite and cause reactions in humans similar to reactions to insect bites, so it is best to handle them with forceps. The female lays eggs and curls around them until they hatch.

Millipedes are herbivorous, with a rounded body and two pairs of legs per segment. (Even with the millipedes' extra pair of legs per segment, centipedes outpace them.) Millipedes are shredders in the forest ecosystem and begin the process that reduces a significant amount of leaves to soil. They also use defensive chemicals and at least one order emits cyanide gas. This was discovered in the late 1800s when a collector placed several insects in a jar with a millipede while on a collecting trip. The insects were killed by the cyanide. A South American monkey (capuchin—long known for its use of tools and as the organ grinder) has been found that rubs the oily exoskeleton of a millipede species on its face as an insect repellant.

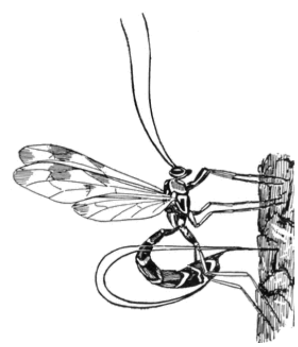
Activity: As a demonstration, hold a millipede loosely in a paper towel and shake it, then note the pleasant almond smell. This odor is toxic to beetles, shrews, and other predators. Entomologists often use cyanide to kill insects and have noted that millipedes are not killed by cyanide gas.

Incidentally, one species of millipede is bioluminescent (see Activity 60 *Publicize It!* above).

62 To Be a Tree

Bug campers have enjoyed making insect costumes from newspaper and acting out insect roles—both destructive and beneficial. Even parasitoids can be portrayed.

Give the students plenty of newspaper, masking tape, string, and balloons. I prefer to use the 2 inch x 60 inch balloons clowns use on street corners. Such a balloon can be made to curl like a moth's proboscis by wrapping it around your finger while you inflate it. After it deflates, it will maintain a curled appearance when reinflated.



Students acting out a female ichneumonid wasp searching for a horntail wasp larva an inch below the bark surface by tapping on the wood with her antennae and then drilling a hole directly into the larva to lay an egg is entertaining! The ichneumonid wasp lifts her abdomen so that her slender, sharp, three-part ovipositor is vertical and the two guides push the third into the trunk to lay an egg on the horntail larva. When the egg hatches, the ichneumonid larva feeds on the horntail larva before pupating inside the gallery. When mature, the adult ichneumonid wasp chews its way out and the cycle starts anew! See also Activity 22 *Trees as Habitats*.

63 Tree Factory

A great extension associated with the trees' inability to keep insects out would make a good second component of Variation 5. Bark beetles, ambrosia beetles, various wasps, moths, and other insects have close associations with trees. Some, e.g., the pollinators, are beneficial to the tree, but many others are harmful. Younger children could act out the role of pollinators (you might want to add flowers to the trees when you construct it if using pollinators in your extension), and older students could act out the role of the ichneumonid and horntail wasps described in Activity 62 *To Be a Tree*.

64 Looking at Leaves

In the extension for Activity 11 *Can It Be Real?* is a picture of a field of pitcher plants. It is always interesting to ask students what part of the plant is the pitcher, and "stem" seems to get the most consideration. Adults' most common incorrect answer is "flower." The correct answer is "leaf." When you think about it, the pitchers are outstanding examples of leaves as the plant part responsible for producing essential nutrients, including photosynthetic products and the scavenged nitrogen, which is especially needed as carnivorous plants grow in nitrogen-poor soil.

Entomologists use pitfall traps, cups buried in the ground containing a little soapy water, to collect crawling insects. The soap breaks the surface tension and the captured insects drown quickly. Pitcher plants are possibly natures' most sophisticated pitfall trap. Insects are attracted to pitcher plants by an odor I have not detected. As the insects investigate, they crawl over the lip of the pitcher and immediately realize they have made a fatal mistake. The inside of the pitcher is very slippery and they fall inside. Those that can get some traction discover the minute hairs inside the pitcher that all point down. The only direction the insects can go is down, where enzymes are waiting to dissolve them and extract their nitrogen for the plant's use.

Activity: Slit open a pitcher plant and hold it inside up on a table. Slide a finger from the top of the pitcher plant down and then back up, noticing a little resistance while sliding your finger up. You are feeling the resistance of the downward-pointing hairs.

See the electron microscope picture of ant exoskeleton parts that have been completely disassembled and that are devoid of contents inside a pitcher in Activity 11 above (picture on right). Looking carefully you can see a few of the hairs that have passively packed the ants into the bottom of the pitcher as the pitchers blew in the wind while the ants struggled.

A number of insects such as small ants have adaptations that enable them to crawl over the hairs in the pitcher, swim in the enzyme broth without consequence, and steal a meal from the plant! There are even pitcher plant moths whose caterpillar is completely at home in the pitcher. This photograph shows a spider web across the opening to the pitcher where a spider has learned the hunting is good!

65 Bursting Buds

A good entomological accompaniment to this PLT activity is to raise painted lady butterflies (Nymphalidae family) from caterpillars to adults and then stage a release in the spring. Painted ladies are the same species all over the country and the thinking is that it is not harmful to release them wherever you live.

66 Germinating Giants

The Queen Alexandra's birdwing in the rainforest of Papua New Guinea is the world's largest butterfly, with a wingspan of 12 inches. Collect a few butterflies and pin them down on a piece of cardboard. Gently pull their front wings forward (toward their head) until the back edge of both wings is perpendicular to the body. Measure the wings from tip to tip and compare to the Queen Alexandra's 1-foot span. As an alternative, you can check a few car radiators for butterflies. These will be crispy and you will have to break the wings off the body and arrange them as described above to measure them. The largest butterfly in the U.S. is the giant swallowtail with a wingspan of 4 to 6 inches. See Activity 67 *How Big Is Your Tree* for other measurements you can take on your butterflies.

67 How Big Is Your Tree?

Who can catch the largest butterfly and measure its wing span? How much area does a butterfly's wings cover. Place a set of forewings and hind wings of a butterfly on a sheet of graph paper and outline them with a pencil. You only need to use the two wings on one side of the butterfly because you can multiply the area by two for the total area covered. Now count all of the squares on the graph paper that are completely covered and those that are more than half covered. Multiply the sum of these by the area of a square on the graph paper. For example if two of your butterflies' wings cover 4 squares and each square is 1 inch by 1 inch, then 1 inch x 1 inch x 4 = 4 square inches. Since the butterfly has 4 wings, you need to double the area covered by the two wings: 2 x 4 square inches = 8 square inches. See Activity 66 *Germinating Giants* for other measurements you can take on your butterflies.

68 Name that Tree—Name that Insect

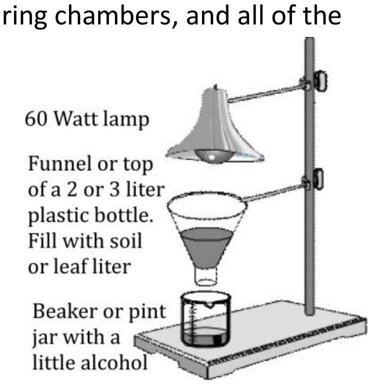
You can still find insects new to science. Now they will probably be small, but every week people are finding moths that are new to science. Between 3,000 and 4,000 new species are discovered every year, and that is just moths. A colleague of mine has found between 90 and 100 species of moths that are new to science in his backyard. You can attract moths to your backyard using a black light and a sheet. See Activity 47 *Are Vacant Lots Vacant?* for instructions for making aspirators and Appendix B for information about making kill jars. For helpful tips on black lighting techniques, visit http://mississippientomologicalmuseum.org.msstate.edu/collecting.preparation.methods/Blacklight.traps.htm

To identify the moths from your night collecting expeditions, you might find this moth photographers group website useful: mothphotographersgroup.msstate.edu/MainMenu.shtml. Their website is actually managed by the entomology museum at Mississippi State University. If you find a unique specimen, you can also get your photographs published on this site.

69 Forest for the Trees

Managing an ant farm seems a natural entomological extension. There are so many things you could do. For tree farms, there is a wealth of options to consider and strategies to monitor and manage, e.g., best management practices and thinning the stands. Ant farms are equally complex. You must think about food and water, ventilation, finding a queen for your colony, insect rearing chambers, and all of the specialized needs of the ants you are raising.

70 Soil Stories



The Berlese funnel is useful in extracting small arthropods and other soil organisms such as bristletails, springtails, mites, ants, spiders, snails, millipedes, centipedes, pillbugs, earthworms, termites, and slugs from forest leaf litter or soil. Comparisons can be made of the number of organisms found in different environments, such as near a fallen log, on the trail, in old leaf litter, and in different kinds of leaf litter. While collecting, place the leaf litter in a plastic bag and record as much information about the site as possible: light intensity, proximity to plants and rotten logs, soil pH, temperature, and moisture content.

Assemble the apparatus as illustrated. A ring stand may not be essential. The lamp can be suspended from the ceiling or clamped onto a shelf, and the funnel can sit in the top of the jar or beaker.

Collect leaf litter and place it in the funnel (the larger, the better). Put alcohol or soapy water in the beaker. Leave the lamp on overnight to drive the organisms in the litter toward the bottom. The funnel will direct the organisms into the beaker and the alcohol will preserve them for future study. The lamp should be as close as possible to the litter, but still at a safe distance. Maintain the funnel at or near room temperature for three to four days.

A detailed comparison can be conducted using precise techniques, such as comparing the organisms found in a 6-inch-square plot at two different depths (maybe 6 inches and 12 inches). Or you could compare organisms in a hardwood forest and a pine plantation or field. You will need a dissecting microscope to see many of the organisms collected. Expect to see a lot of mites, springtails, and nematodes—and much more!

71 Watch on Wetlands

There are just so many interesting observations you can make in the wetlands!

Larval stoneflies (order Plecoptera) live in cool flowing streams. When oxygen levels are low they do pushups to increase the water flow over their gills, thus giving them access to more oxygen.

Water striders (order Hemiptera) do amazing things on the surface of water, from communicating by causing ripples to hunting down and capturing prey to mating! They owe their ability to walk and jump on water to waxy secretions on their legs, hairs that trap tiny air bubbles, and water's surface tension. If the surface tension is reduced by adding soap to the water, the water strider will sink. It can be removed from the water, rinsed off, and allowed to dry on paper towel.

Backswimmers (order Hemiptera) swim upside down just below the surface of the water using their hind legs as oars! With their well-developed wings they can fly as well. Backswimmers trap enough air in pockets at the tips of their abdomens to last for up to 6 hours. Commonly found in slow-moving water and swimming pools, they can bite, but it is not usually as painful as a bee sting.

Giant water bugs (order Hemiptera) are among our largest insects and have two short, snorkel-like breathing tubes at the tip of their abdomens they stick through the water's surface to breathe. They also carry bubbles of air with them under their wings when they dive that constitute what is called a "physical gill." As they use oxygen from the bubble it is replenished by oxygen in the water. The water bug stretches the bubble by flexing its abdomen, stirring the water to bring oxygenated water in contact with the bubble. There is a great video showing this process at http://thedragonflywoman.com/2012/01/29/abedus-breathing/. They are also known as toe biters because of the painful bite they can inflict on swimmers. Giant water bugs are a top invertebrate predator in wetlands and are found in vegetation along the margins of ponds and lakes. They have well-developed wings and can often be seen at night flying under the lights in parking lots. These large beetles are eaten as a delicacy in Thailand and China.

Waterscorpions (order Hemiptera) have a long breathing tube that extends from their abdomen. The tube's waxy lining repels water, enabling them to negate the effect of surface tension and push their breathing tube through the water's surface.

Water scavenger beetles (order Coleoptera) often have a conspicuous keel or ridge resembling a sewing needle between their legs that they may use for defense or to assist in swimming. They surface head first and gather an air bubble under their elytra, or wing covers, before diving back underwater. This bubble is part of its physical gill. The oxygen in the bubble is replenished from the water as it is used. Nitrogen dissolves into the water, reducing the bubble's size so the beetle periodically must return to the surface for more nitrogen and oxygen. Water scavenger beetles are easy to keep in aquariums and will feed on the lichens on a stick.

Mosquito rafts (order Diptera) can be found while you are wandering around in the wetlands, and anywhere water stands for that matter. Be on the lookout for mosquito egg rafts. Many mosquitoes, including those in the genus *Culex*, lay their eggs over a period of time, gluing them together in floating rafts of 100 to 300 eggs. The 1/4-inch by 1/8-inch rafts look like a piece of detritus floating on the water. The females prefer sites that are protected from the wind by weeds or other structures. Many other mosquitoes lay their eggs singly, and they are much more difficult to find.

72 Air We Breathe

Pesticides are a fact of life. Throughout history we have competed with pests for food, been annoyed by them in our homes and at picnics, and died from diseases they carry! Insect-borne diseases, including malaria, have been a fact of life since prehistoric times. Malaria is as prevalent today as it was before DDT knocked it back for a while. The earliest record of insects in human society dates to 12,000 BC. The Sumerians 4,500 years ago were using sulfur as an insecticide. The Chinese 3,000 years ago were using mercury and arsenical compounds to control body lice. Two thousand years ago during the Chou Dynasty in China, the flowers of the pyrethrum daisy were used to control body lice and fleas. Pesticides represent humans' most recent and important achievement in a historic war with insects and other pests. They have enabled humans to survive, prosper, and reach unprecedented numbers on the planet, for an organism at the top of the food chain! But pesticides come with a Faustian bargain. The devil *is* in the details! Losses today from pests and diseases range from 10 to 90%, averaging 35 to 40% for all food and fiber crops, even with centuries of research and development!

Pesticides are a very appropriate subject to think about when we are learning about the air we breathe. We have often demonstrated the efficacy of various insecticides by applying some (by spraying or contact) in covered petri dishes containing cockroaches. Of course if you are conducting an experiment you need to carefully adjust how much you use in the very small environment of a petri dish.

All school gardens should experiment with a natural insecticide by planting chrysanthemums (*Chrysanthemum* spp.). Most chrysanthemums will work. Planting them on one side of a vegetable plot will enable students to see if there are fewer insects on one side of the garden or the other. The petals of the flowers can be ground to a dust and sprinkled over plants where insects have become a pest to evaluate its effectiveness.

This is also a great activity to use to introduce reading labels on pesticides and learning to measure the area a quantity is "labeled" to be used on. Look at various sprays and the insects they are effective against, such as wasp and hornet spray. Will this insecticide work on yellowjackets?

73 Waste Watchers

It is interesting to watch ants finding and devouring dead insects, birds, etc. Consider allowing a student to make a time-lapse movie, and post it on YouTube. Energy and nutrients are conserved in nature!

74 People, Places, Things—Insects, Places, and Things

It is fun to watch honey bees in an observational hive as they communicate directions to blooming flowers to other bees. If there is such a hive in your area, you should make an attempt to get all children to it for a visit. Inside the hive, you can point out that the space between the glass and frames, called the "bee space," is carefully controlled to be just the right size to prevent bees attaching comb to the glass. Discovering this space requirement was a major advance in helping bees to maintain an "organized" hive and in beekeeping. You should also follow the bees from the hive to the plants they are pollinating and back. And finally there is something *all* will enjoy—tasting honey! If you are lucky enough to know where a tulip poplar or sourwood tree is and have some tulip poplar or sourwood honey, everyone is in for a treat! See also Activity 16 *Pass the Plants, Please* and Activity 32 *A Forest of Many Uses* above.

75 Tipi Talk

Ant and termite mounds and wasp nests, like tipis, give some great clues to the needs and ingenuity of their inhabitants. Scraping the top off an ant hill when the weather is dry and again just before a rain will reveal how the ants move their larvae to protect them. Before a rain, they move the larvae to the top in case rainwater floods the lower chambers. On cool days, they also move their larvae near the top, but on very hot days they are moved lower, where they remain warm but not too hot.

Termites have been conditioning the air in their mounds since prehistory! The thick walls provide heat insulation during the day and radiate warmth during the night. A series of chambers and tunnels keeps the temperature constant in the mound throughout the day, and termites open and close openings as we would adjust a thermostat.

Paper wasps bring water from puddles to spray on their paper nests during hot weather, which cools their larvae by evaporative cooling.

Patterns of Change

76 Tree Cookies

Make a collection of leaves or other items that show insect damage or interactions with plants. For some you may need to enlist a biologist, naturalist, or entomologist to help explain what you have found. Hickory leaves are great for showing a lot of pests. See the examples below.

 Fall webworms on juniper trees.	 Mantid ootheca (egg case).	 Waxy filaments that conceal the bodies of psyllid nymphs.	 Spittle made by spittlebug for a nymph to hide inside.	 Leafminer larvae grow while eating the inside of the leaf.

77 Trees in Trouble

Nature is replete with incredible strategies to renew itself. Nature provides the opportunity for new trees to begin growing by the use of drought, lightning, and windstorms that starve trees, set them on fire, or blow them down. After such catastrophic events the endemic bark beetles respond to the smell of stressed trees like a dinner bell. The tree's crown may display the first noticeable sign as its needles turn yellow, then red, and finally brown. Careful inspection will reveal the small pitch tubes on the trunk where the beetles bored through the bark. Pulling off a piece of the bark may reveal characteristically shaped galleries underneath. The beetle larvae spend most of their time under the bark, where they get their food and develop. The so-called blue stain fungus that the beetles bring with them produces fungal gardens on the wood and the beetles dine on the fungus. This fungus also plugs the tree's sap-producing cells, protecting the beetles from the tree's defense and stopping the flow of water and nutrients, thus killing the tree. As you have likely surmised, the fungus stains the wood a bluish color, as seen in the bowl a friend turned from a pine that died as a result of the beetles' gardening efforts.

As soon as a pine is dead the beetles (e.g., southern pine beetle) depart for healthy trees (*Ips* beetles can stay longer depending on moisture and availability of phloem tissue). Now, instead of cutting these trees you may want to consider leaving them standing for a while, since dead pine trees become hosts for clerids (checkered beetles) and woodpeckers that prey on the pine beetles. Later, the tree will fall and a host of other insects and arthropods will call the fallen log home. Or a wood turner can make several beautiful bowls from a blue-stained tree! See also Activity 27 *Every Tree for Itself* above.

78 Signs of Fall

You would expect insects, the most diverse organisms on the planet, to have a variety of cold weather survival techniques, and they do! Honey bees are a great example of community living. They cluster in their hives and vibrate or shiver using their thoracic muscles to generate heat during the winter. Older bees make a shell around the cluster thus providing insulation. As they drop off when they die, other older bees move out to take their places. You can see bumble bees flexing their thoracic muscles, shivering, when the temperature drops to around 55°F. Fire ants and termites hunker down below the frost line to wait winter out. Many insects, such as the woollybear, burrow under leaves as a caterpillar; praying mantids overwinter as eggs; some moths, e.g., the Saturniidae (silkworm family), overwinter as pupae. Wasp and yellowjacket queens survive the winter in tree crevices or attics. Mourning cloak butterflies overwinter in tree holes or under loose bark as adults and are often the first out in the spring. Ladybird beetles (ladybugs) hibernate during the winter, often in our homes.

But of particular interest is insects' use of antifreeze, actually glycerol. Insects begin producing glycerol in the fall and it enables insects' bodies to fall below the freezing temperature of water without damage from expanding ice! The glycerol levels begin dropping as spring approaches.

Activity: My absolute favorite sign of fall is the migration of the yellow sulphur butterflies (Pieridae family). They migrate to the southeast in the fall and return to the northwest during spring. They are easier to spot than the monarchs and you can literally do transect surveys of their migration while traveling. If in the fall you are traveling on a north-south highway, count the number of sulphurs crossing the road from east to west and west to east. You will notice a much greater number crossing from west to east. Likewise traveling on an east-west highway, count those crossing from north to south and south to north, and you will notice more headed to the south. You can measure the reverse in spring.

Watch for the appearance of the woollybear caterpillars (Arctiidae family) in the fall and note the date on your calendar. Keeping records of when you make such counts or seasonal observations may enable you to watch changing patterns as we experience climate change.

In the South we refer to other members of our own species from more northern latitudes as snow birds when they migrate south for the winter.

79 Tree Lifecycle

Insect Life Cycles—Metamorphosis
Insects have developed incredible life cycles that enable them to inhabit different environments and even exploit different foods in different stages of development within the same environment. No evidence of metamorphosis (change in form) has been found in the earliest fossil records, but between 280 and 300 million years ago a life cycle change reduced the competition for food between young and older insects, enabling the coexistence of greater numbers of each species in the same place.[2] Metamorphosis has been so successful that 65% of all animals on earth may be metamorphosing insects!

There is much variety in the growth and development of insects and with this come differences in thought on how to categorize insects by life cycles. Insects have two general ways of changing shape known as simple metamorphosis and complete metamorphosis. Complete metamorphosis may have evolved from simple metamorphosis.

Simple metamorphosis involves insects with three life stages (egg, nymph, and adult). There is no resting stage in simple metamorphosis. Insects that undergo simple metamorphosis hatch as miniature versions of their adult forms (nymphs) and gradually develop wings and genitals as they molt (shed the rigid exoskeletons they have outgrown). Insects (and their orders) that undergo simple metamorphosis include: grasshoppers and crickets (Orthoptera); termites (Isoptera); booklice and psocids (Psocoptera); aphids, scales, whiteflies, psyllids, cicadas, leafhoppers, and true bugs (Hemiptera); earwigs (Dermaptera); cockroaches (Blattodea); praying mantids (Mantodea); stick insects (Phasmatodea); webspinners (Embiidina); lice (Phthiraptera); zorapterans (Zoraptera); rock crawlers (Grylloblattodea), and gladiators (Mantophasmatodea).

Three additional orders, mayflies (Ephemeroptera), stoneflies (Plecoptera), and dragonflies and damselflies (Odonata) undergo simple metamorphosis, progressing from egg to naiad to adult. In this case the aquatic, gill-breathing naiads differ substantially from adults in appearance and habitat. In this progression, insects increase in size through several molts until the adult emerges. Many references report around 10% of insect species undergo simple metamorphosis.

Complete metamorphosis involves 4 distinct stages, changing from egg to larva (caterpillar, grub or maggot), then to an inactive pupal stage (cocoon-like) before emerging as an adult.   Approximately 80% of insects undergo complete metamorphosis, including beetles (Coleoptera); moths and butterflies (Lepidoptera); bees, ants, wasps, and sawflies (Hymenoptera); antlions, lacewings, and dobsonflies (Neuroptera); thrips (Thysanoptera); scorpionflies (Mecoptera); caddisflies (Trichoptera); fleas (Siphonaptera); and flies (Diptera).

The bristletails (Archeognatha), silverfish (Thysanura), springtails (Collembola), and insects in other orders with wingless adult forms do not go through typical metamorphosis processes.

Insects' life cycles can affect the life cycles of trees. For example, during their life cycles, weevils or other insects bore into acorns as part of an insect-tree interaction that affects dissemination and germination of the oaks (see Activity 31 *Plant a Tree*). Twig-girdling insects have a life cycle that involves pruning tree twigs. As trees weaken with age, many more insects begin to call them home. When the trunk finally falls, even more come to visit, dine, and lay eggs! See Activity 27 *Every Tree for Itself.*

[2] Jabr, F. 2012, August 10. How did insect metamorphosis evolve? *Scientific American*. Available at http://www.scientificamerican.com/article.cfm?id=insect-metamorphosis-evolution

80 Nothing Succeeds Like Succession

Research the plants that accompany forest succession and make a list of insects associated with them. Much is made about the returning plants, but as soon as the fire is out the ants are active, and when the weeds begin growing, the grasshoppers are back. It is most useful to watch an area after a windstorm or forest fire opens a meadow in the woods. The insects are all over it!

81 Living With Fire

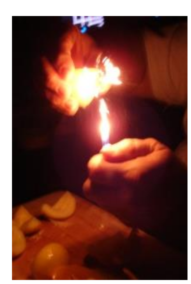
Pyrophilous or fire-loving insects, including beetles and bugs, depend on forest fires to reproduce. These insects have visual and olfactory adaptations to alert them to a fire's presence. They have special sensors for smoke on their antennae and infrared radiation sensory organs on their thorax or abdomen. The males often remain perched just outside forest fire areas awaiting the females' return. As soon as the females return, breeding commences and they lay eggs under the bark of burnt trees.

82 Resource-Go-Round

Baseball was a lot more fun before the introduction of aluminum bats. The label on ash bats is exactly where you want to hit the ball since it is the strongest part of the bat and thus minimizes the chance the bat will break. When I grew up this was important knowledge! This is one reason I encourage everyone to collect as many emerald ash borers as time permits. The emerald ash borer is an invasive species in North America and highly destructive to ash trees. So if you like baseball, and who doesn't, kill a boxful of emerald ash borers!

83 A Peek at Packaging

Plants have been defending themselves from insects for over 400 million years and only a handful of the more than 250,000 plant species have been tested for their insecticidal properties. Many trees package their fruit to protect it from insects. The orange, for example, has insecticidal oil in its rind that gives it some protection from insects. These are quintessential renewable resources and they protect their products!



Activities: You can squeeze a piece of orange rind and the insecticidal oil will squirt out. Hold the rind such that the oil will be squirted over a candle for a miniature fireworks display as the oil ignites! Design an experiment to study the repellant properties of the oil against various insects. Some good insects to start with are *Drosophila* fruit flies that show up if you leave your bananas out too long.
Willow and a lot of other trees' bark and leaves come packaged with salicin, the

chemical that relieves headaches, reduces fever, and relaxes muscles. Now, trees do not produce salicin out of the goodness of their heartwood, they use it as an insecticide to protect themselves. Its effect on insects is the same as it is on us, only they are smaller so the effect is greater! Go ahead—dissolve an aspirin tablet in water, spray it on insects, and watch their reactions.

84 The Global Climate

Ticks are activated by carbon dioxide, as the following anecdote demonstrates. After a long morning canoeing with my students in Barkley Lake adjacent to the Land Between the Lakes in Kentucky, we stopped on a remote island for lunch. After eating we gave the students time to relax and when we started rousing them, I noticed one student's head and neck were covered in ticks. Obviously this island had not had mammal visitors in some time, and the ticks were activated by the CO_2 in the student's breath! Fortunately none of the ticks had latched on, and my student was not disturbed by the event.

Activity: I mentioned in Activity 13 *We All Need Trees* that a white sheet on the ground might attract ticks. You can see just how important carbon dioxide can be in the atmosphere if you place a chunk of dry ice in a coffee can with holes in its bottom and hold it such that the vapors, which are heavier than air, will flow down the sheet. Compare a dragged white sheet with one you have carbon dioxide vapor flowing onto to see which collects the most ticks.

Note: This is not a realistic simulation of a danger of too much carbon dioxide in our atmosphere. However, it is a simulation of an effect of increased carbon dioxide levels on ticks. If our atmosphere had this much carbon dioxide in it, we would be in big trouble!

85 In the Driver's Seat

Beetles' exoskeletons give them a huge mechanical advantage and they can pull many times their own weight. Collect a bessbug (Coleoptera, Passalidae family) or rhinoceros beetle (Scarabaeidae family) and tie a string between its head and thorax. Attach this to a piece of cardboard resting on 2 round pencils. The beetle will be able to pull this very easily, so start stacking pennies, one at a time, on the cardboard until the beetle can barely pull the load. Now weigh the cardboard, pencils, and pennies to determine how much weight the insect can pull. You will be amazed!

A 2013 VW Beetle weighs 2,939 pounds (1,333 kg). Divide the weight one beetle can pull into the weight of the VW Beetle to see how many insects it would take to pull the car.

86 Our Changing World

Pick out an easy-to-spot butterfly, such as the bright yellow sulphur. Now, in the fall and spring watch carefully in your yard for its departure and arrival, respectively. Note the dates of the last and first one you see. Get your family and friends to help watch for their arrival, record the date on your calendar, and keep the calendar at the end of the year. Their migration is tied to the climate, and when you see changes in their arrival and departure dates you *may* be seeing the influence of climate change. You will need to repeat these observations for a number of years to establish a trend you could attribute to climate change. See also Activity 78 *Signs of Fall*.

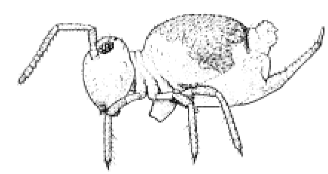
87 Earth Manners

Take the students on a short hike and look at the insects. On your hike take some pictures of the insects you see so you can identify them when you get back to the classroom. Do some research and find out what they eat and where they live. Consider keeping one insect for a few hours while you observe it. Sketch a picture of it and label all of the parts. Use a magnifying glass to look for details to include in your sketch. Then set your insect free in an appropriate habitat.

You can point out what an insect is and what it is not. Insects have 6 legs and three body parts (head, thorax, and abdomen). I often draw one on the board or a flip chart, asking the students if it has wings or not, one or two pairs (one pair makes it a fly), jumping or walking legs, etc. Sometimes I give it a name, maybe their teacher's if I am a guest in the room. Incorporate anything you know about insects, as well as the following quick facts: the veins on the wings are sometimes used for identification; their compound eye is more sensitive to motion than to the image of a tree or person; the spots (holes) along their sides are spiracles that are used for breathing. See also Activity 10 *Charting Diversity* above.

88 Life on the Edge

A springtail (order Collembola) has a forked tail-like structure, or furcula, it keeps tucked under its abdomen. It is held in place by a clasp, or tenaculum, and when released, catapults the 1/5-inch springtail 3 to 4 inches into the air! Can you calculate relatively how high this would be for a human? Floating springtails can even jump on water!



Springtails have great potential as bioindicators. They play a role in the soil ecosystem, are widely distributed and easy to sample, are resistive to low levels of pollution, and yield reproducible responses. Their permeable cuticle enables them to respond to a wide range of pollutants, and they may also be useful in evaluating the impact of climate change and fire on ecosystem diversity. They have been used as pH indicators to describe changes in forest soils after liming or fertilization. The organization Quality Deer Management suggests a large number of springtails in the soil is a good indicator of prime habitat for deer.

89 Trees for Many Reasons

The acacia, also known as thorn tree, is home to an ant species that bores holes in the thorns and sets up housekeeping! In Africa, giraffes that eat the acacia foliage can hear the ant holes in the thorns whistling as the wind blows through the trees, enabling them to avoid leaves near the thorns in which the ants are living. Giraffes hate having ants on their noses!

While living on the Gulf Coast we periodically got calls around Halloween with the caller reporting a prankster had covered their oak trees with some type of web. We knew what it was without going out for a look! Nymphs of barklice (*Archipsocus nomas*) look a little like hand grenades running around like cows in groups eating lichens and fungi on the tree trunk. The adults produce wonderful nets that cover branches, or on the coast, whole trees! The nets are harmless and quite enjoyable. I encourage parents and teachers to cut a slit in the net and show their children the “tree cattle” scrambling about, eating.

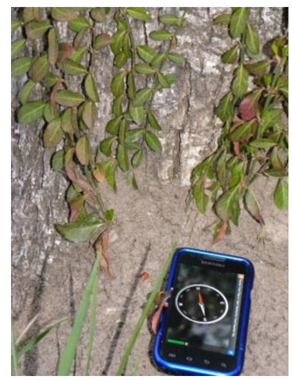
Another call I always enjoy getting starts with, “Lichens are wandering up and down the branches on my tree,” or “the lichens on my tree have come alive and are walking around!” These are actually lacewing larvae and they are entertaining to watch, especially if you know lichens are not supposed to walk. These larvae are our friends because they eat a lot of aphids! Sometimes the lacewing larvae will glue aphid cases to their backs, with the lichens as camouflage.

Activity: I always thought there were so many different trees to support the large insect community! If the Lorax speaks for the trees, who speaks for the insects? Can you use one of the stories above to write a Dr. Seuss–like story?

90 Native Ways

We once lived close to nature and the people of that time understood more native ways than most do today. That being said, I will note some examples of "ways" that are interesting and/or still useful.

The first that comes to mind are the huge termite mounds/nests seen on Caribbean islands, in Africa, and in Australia. The termite mounds have thick walls and sophisticated ventilation systems. The cliff dwellers in the American southwest built adobe buildings under cliffs, a practice that took advantage of the thick south-facing walls. These thick walls keep the interiors cool during the day and during the evenings the walls that absorbed heat all day keep the inhabitants warm. The termites have been using solar heat in mounds for geologic periods!



Ants often build their nests on the south side of trees or other obstructions to take advantage of the heat. The photograph shows a compass (an app on my cell phone) sitting on top of a fire ant mound on the south side of a pecan tree. I have three south-facing nests in my yard. Similarly, fall webworms orient their nests southeast to take advantage of the morning sun.

Glowing click beetles were used by natives in Cuba and other places in ceremonies and even to light paths into the woods at night (see Activity 60 *Publicize It!* above). Today, we understand how to combine luciferin with adenosine triphosphate (ATP) to produce a cool light.

Could spider or caddisfly webs have been the inspiration for fish nets?

On the dark side, wood ants have been using chemical warfare for a very long time, squirting formic acid at their enemies.

91 In the Good Old Days—there were some really giant insects!

Earth's early atmosphere contained around 30% oxygen as compared to around 21% today. The increased oxygen concentration fueled larger insects' metabolisms and supported their larger bodies, and fires were likely more spontaneous. Oxygen levels peaked during the Permian, as did giant insects. The elevated oxygen levels would have benefited all stages of insect development. Incidentally, adult insects can control their oxygen intake by opening and closing holes in their bodies called spiracles.

The largest wings of insects today are the Queen Alexandra birdwing butterfly and the atlas moth that can have a wingspan 12 inches across! The extinct *Meganeura* dragonfly had a wingspan of over 2 feet! And before leaving the Permian period, it should be noted that birds were quickly evolving and probably enjoying the large, delicious flying insects!

92 A Look at Lifestyles

The organization and structure of social insect colonies including ants, bees, wasps, and termites have amazed humans for all times and been much studied. Their cooperation has enabled them to become dominant life forms on earth. We can probably learn a lot from social insects, however they genetically crossed the Rubicon in ancient times. Many social insects are **haplodiploid**—drones or male bees, for example, are **haploid** (having half of a full set of chromosomes) and the queens and females are **diploid** (having two sets of chromosomes, one from the mother and one from the father).

The queen can control whether she lays a fertilized egg or not. A fertilized egg becomes a female and an unfertilized egg becomes a male—and that is where a lot of bad jokes start! Now back on track. The quality of the food fed to the female larva determines whether she will be a worker or a queen.

A few of the biological anomalies include:

- In ants, some of the workers do not even have ovaries and some can lay male eggs.
- Most bees and wasps are not social.
- Termites are social, and a colony contains diploid male and female workers as well as a king and queen.

93 Paper Civilizations

The paper wasps, yellowjackets, and hornets (Vespidae family) were making paper long before the Egyptians made paper from papyrus (4000 B.C.) and Tsai Lun, the Chinese inventor, made paper from bark, hemp, and other fibers (around 105 A.D.). If you watch a paper wasp for a while before going for the wasp and hornet spray, you will notice her visiting trees, your deck, or a fence post and pulling off small pieces of wood. She chews this wood, mixing it with a secretion from her labial gland to form a gray paper she shapes into groups of hexagonal cells that will soon have eggs deposited in them. Before we started building houses, where wasps find plenty of nooks and crannies, they were finding great places to build their nests in underground burrows, in trees and shrubs, and under ledges in cliff faces.

See Activity 51 *Make Your Own Paper* above to build wasp nests.

94 By the Rivers of Babylon

Fresh water is an essential need, and as humans spread around the planet they followed rivers and settled along them. Hikers in wilderness areas are always on the lookout for flowing streams to camp by, and when they spot a damselfly it is a sign that flowing water is near.

Fire ants form rafts when flood water inundates their territory, and the queens and larvae are kept high and dry. Ants have a couple characteristics that are exploited when forming a raft. Their outer covering, or cuticle, has a waxy layer that is hydrophobic and repels water. The roughness of the cuticle enables them to trap and hold a bubble of air when submerged, which adds to their buoyancy. When a group falls into water, they grab onto each other using claws and jaws as well as sticky secretions from pads on their legs. Since they collectively repel water, they take advantage of water's surface tension and can float for a long time or distance in a river. You can use a stick to push a raft down into the water and you will be amazed at how well they repel the water. Release them and they pop back to the surface like a cork. Soap, you will remember, breaks surface tension, so pouring some onto the water adjacent to the raft will cause it to sink and the ants to drown.

95 Did You Notice?

There is a healthy interest in locally produced food where you know the farmers and they live in your community. Organically grown food is also becoming popular and consumers are slowly beginning to understand that a few blemishes on fruit and vegetables caused by insects are okay.

The extensive use of hybrid plants and genetically modified organisms (GMO) has caused a resurgence of interest in heirloom varieties. The fear is that GMOs may cause digestive problems, increased cancer, allergies, infertility, and the loss of native stocks. Research is underway to determine the safety of GMOs for human consumption. Seed Savers Exchange is a non-profit organization that has been saving and sharing heirloom seeds since 1975. They have been collecting and selling samples of rare garden seeds to other gardeners so people can experience varieties of plants that our ancestors enjoyed that are no longer available in grocery stores. Thanks to Seed Savers and heirloom seed growers, if we get too far out on a limb, heirloom seeds are still available.

Activity. Plant heirloom and hybrid varieties of tomatoes and evaluate each for flavor, presence of insect pests and plant diseases, fruit size and number, and damage to fruit and foliage by insects. Does the difference in flavor, if any, outweigh any observed shortfalls?

There are thousands of different apple trees and this author hopes farmers will start growing uncommon apples so that as we travel around the country we can enjoy local varieties!

96 Improve Your Place

Entomologists and naturalists have known for a long time that a rich habitat replete with a wide variety of insects often reduces the necessity of chemical controls. When you have a diverse dynamic population, crop and human pests are, to a large degree, controlled by their natural predators. However, you may need some help. You can plant chrysanthemums around your garden to discourage pest insects, drain standing water to reduce mosquito populations, install birdfeeders or purple martin gourds to help with mosquitoes.

Of course a wonderful way to improve your place is to plant a butterfly garden, and the best way to start this is to find an experienced butterfly gardener in your area and ask for their help. They will likely share tips, cuttings, eggs, caterpillars, and even pupae. Adult butterflies typically return to the area where they emerge if you provide a good larval host. A mature female can be caged on a larval host plant for a few days, but be sure to provide her with sugar water to maintain her energy level. Be aware that many birds feed on butterflies and/or caterpillars, so bird feeders and bird houses should be on the other side of the house or school from the butterfly garden.

Essential elements for butterfly gardening include open areas (sunshine), access to bare soil (preferably damp or a mud puddle), shelter where they can get out of the wind, and camouflage. Thick hedges and larger larval host plants might suffice. Almost all the butterflies listed will nectar on butterfly bush, lantana, and zinnias, but remember you also need larval plants for a steady supply of food and to observe their entire life cycle. Many common butterflies feed on herbs. Swallowtail caterpillars feed on caraway, dill, parsley, and fennel, so plant extra for them. Butterflies in the southeastern U.S. are included in the table below as a guide.

Butterflies, Larval Host Plants, and Nectar Plants

Butterfly	Larval Host Plants	Nectar Plants
Buckeye	Snapdragon, verbena	Composites, dogbane
Cloudless sulphur	Senna, partridge pea	Lantana, hibiscus, daisies
Comma	Violet	Rotting fruit, butterfly bush
Eastern black swallowtail	Dill, fennel, parsley	Milkweed, thistle
Gray hairstreak	Clover, vetch, oak	White clover, milkweed
Gulf fritillary	Passion flower (maypop)	Lantana, composites
Hackberry butterfly	Hackberry	Rotting fruit, carrion
Monarch	Milkweed (*Asclepias* spp.)	Butterfly bush, lantana
Painted lady	Daisy, thistle, hollyhock	Thistle, dandelion
Pipevine swallowtail	Dutchman's pipe	Thistle, butterfly bush
Queen	Milkweed (*Asclepias* spp.)	Milkweed, daisies
Question mark	Nettles, hops	Rotting fruit, carrion
Red admiral	Nettles, hops	Rotting fruit, daisies
Red-spotted purple	Willow, poplar, cherry	Rotting fruit, carrion
Spicebush swallowtail	Spicebush, sassafras, bay	Milkweed, thistle
Viceroy	Willow, plum, cherry	Rotting fruit, carrion

Appendix A: Learning Station

Set up a learning station as soon as students have learned how to collect insects and leave it open all year. Supply students with spreading boards as required and keep them on hand. A wood worker can cut spreading boards from 2-inch foam insulation that comes in 4-foot x 8-foot sheets using a dado blade to cut different size channels to accommodate insect bodies. The spreading boards students are using will require the most space and a set of shelves may be needed to store them.

Hang a large piece of foam insulation on the wall behind the pinning table. Students should maintain a classroom insect collection on this board with insects arranged by orders. This will help them learn the orders. The pinning table will be the "business" area of the learning station and a good place to keep the field guides.

Enlist the help of parents with sewing and woodworking skills to help make nets and even insect boxes that the students can purchase, if they want one. Look on the internet for instructions. Often making a few dollars is a great incentive for parents to get involved.

Appendix B: Supplies and a Few Notes

- Insect nets—easy and cheap for a woodworker and someone who sews to make
- Foam spreading boards
- Insect pins—these will be your greatest expense. Pins cost around $5 per pack of 100 and I can go through that many in a single pinning session. Most of these can be reused many times. You will want to have students put their names on their packs of pins and let you keep them locked in a desk drawer until they need them.
- Forceps
- Magnet on a stick—to collect dropped pins
- Black light and white sheet for night collecting (optional)
- Supplies and directions for making **kill jars**:
    - glass pint and half-pint jars with tight-fitting lids
    - sawdust
    - plaster of Paris
    - duct tape to wrap jar bottom (prevents breakage when dropped and aids in cleanup when jar does break)
    - masking tape and red permanent marker—make a label that says "DANGER POISON" to stick on the outside of the jar
    - non-acetone fingernail polish remover (ethyl acetate)

  Add ¼ inch of dry sawdust to a pint jar. Place a round piece of paper towel cut to the inside size of the jar over the sawdust and tap down before slowly adding ½ inch of plaster of Paris mixed according to directions. Let harden for 4 or 5 days without the lid. Add a teaspoon of ethyl acetate and a crumpled paper towel (butterflies and moths will work their way between the folds and not thrash and damage their wings). You can use this jar for everything; however it takes beetles longer to die in ethyl acetate vapors than in an alcohol jar and they will damage butterflies and moths crawling over them. Recharge the jar with more ethyl acetate when you notice that insects take longer to die. When pinning insects, empty the ethyl acetate jar over a paper towel and immediately put the top back on.

  Alcohol jar: Add about 2 inches of 70% isopropyl alcohol to the half-pint jars for collecting beetles, wasps, flies, and hard-bodied insects. Insects in alcohol can be removed using forceps or strained through an aquarium-sized fish net.
- Collecting bags to hold kill jars—try getting the local hardware store to donate nail aprons to hold jars for collecting
- Aspirators—see Activity 47 *Are Vacant Lots Vacant* for instructions
- Aquatic dip net—a D-ring net works best (as opposed to a net with a round opening). Try using an aquarium net or a colander if you can't find a dip net.
- Dissecting scope and/or loupes
- Honey and toothpicks

Appendix C: Recommended Books

Borror and DeLong's Introduction to the Study of Insects (7th Edition), by C. A. Triplehorn and N. F. Johnson. Brooks/Cole, 2005 (ISBN 13:978-0-03-096835-8) was the definitive resource used for producing this manual.

The Life of Insects, by V. B. Wigglesworth. Mentor Books, 1964. This is probably the most comprehensive book for serious young entomologists.

To Know a Fly, by Vincent G. Dethier, Holden-Day Inc. 1962. Library of Congress Card Catalog Number: 62-21838 This is a great book for young scientists, made more so since they can still experiment with insects for science fair projects!

The 4-H Entomology manual for your state will provide handy insect collecting and preserving tips, as well as lists of insects in your region.

Recommended Field Guides

Butterflies and Moths: A Guide to the More Common American Species (Golden Guide), by Robert T. Mitchell and Herbert S. Zim. St. Martin's Press, 2002. ISBN 1-58238-136-4

Caterpillars of Eastern North America: A Guide to Identification and Natural History (Princeton Field Guides), by David L. Wagner. Princeton University Press, 2005. ISBN 0-691-12144-3

Dragonflies through Binoculars: A Field Guide to Dragonflies of North America, by Sidney W. Dunkle. Oxford University Press, 2000. ISBN 0-19-511268-7

A Field Guide to Eastern Butterflies (Peterson Field Guides), by Paul A. Opler. Houghton Mifflin, 1998. ISBN 0-395-90453-4

A Field Guide to the Beetles of North America (Peterson Field Guides), by Richard E. White. Houghton Mifflin, 1983. ISBN 0-395-91089-7

A Field Guide to the Insects: America north of Mexico (Peterson Field Guides), by Donald J. Borror and Richard E. White. Houghton Mifflin, 1970. ISBN 0-395-91170-2

Handbook for Butterfly Watchers, by Robert Michael Pyle. Houghton Mifflin, 1992. ISBN 0-395-61629-8

Insects: A Guide to Familiar American Insects (Golden Guide), by Herbert S. Zim and Clarence Cottam, revised by Jonathan P. Latimer, Karen Stray Nolting, and David Wagner. St. Martin's Press, 2002. ISBN 1-58238-129-1

Kaufman Field Guide to Butterflies of North America, Jim P. Brock and Kenn Kaufman. Houghton Mifflin, 2003. ISBN 0-618-76826-2

Kaufman Field Guide to Insects of North America, by Eric R. Eaton and Kenn Kaufman. Houghton Mifflin, 2007. ISBN 0-618-15310-1

Peterson First Guides to Insects of North America, by Christopher Leahy. Houghton Mifflin, 1987. ISBN 0-395-35640-7

The Songs of Insects (with photos and sound recordings by the authors), by Lang Elliott and Wil Hershberger. Houghton Mifflin, 2006. ISBN 0-618-66397-5

Spiders and Their Kin (Golden Guide), by Herbert W. Levi and Lorna R. Levi, revised by the authors, Jonathan P. Latimer, and Karen Stray Nolting. St. Martin's Press, 2002. ISBN 1-58238-156-9

Tracks & Sign of Insects and Other Invertebrates: A Guide to North American Species, by Charley Eiseman and Noah Charney. Stackpole Books, 2010. ISBN 0-8117-3624-5

Appendix D: Topical or Thematic Entomological Extensions & Activities for Use with PLT

Sequence of Activities for a Logical Entomological/PLT Arrangement

What follows is a sequence of PLT activities in a logical order that will allow you to teach an insect unit by incorporating entomological extensions. The suggested progression will lead students from investigating their environment, including the arthropods and insects, to understanding the life cycles of plants (trees) and insects.

PLT Activity	Entomological Extension
9 *Planet Diversity* Students pretend to be visitors on earth and describe life they find in a plot of land	Discover diverse arthropod life in a small area
6 *Picture This* Look at pictures of the diversity of life	Learn a little about the classification and diversity of the most abundant organisms, invertebrates
10 *Charting Diversity* Explore diversity and plant and animal adaptations	Learn to use wings and antennae to identify the most available wildlife, insects
20 *Environmental Exchange Box* Trade boxes of local environmental items with others in another region	Create a 10- or 12-order collection of common insects from your area to trade
79 *Tree Lifecycle* Trees have life cycles and stages of their lives	Learn about insect life stages, or metamorphosis

Sequence of Activities to Address an Entomological Problem: The Decline in Monarch Populations

You can use the entomological extensions & activities for use with PLT in a different way while teaching a thematic unit of your own. The following example deals with the declining numbers of monarch butterflies migrating successfully to Mexico. It also describes how youth can become involved and possibly make a difference.

Monarchs' Problems

Monarchs are special. They are the only tropical butterfly that makes such an ambitious 3,000 mile migration and the round trip requires multiple generations! It is still a mystery how butterflies arrive in the same wintering grounds several generations after their grandparents left them!

This year, 2013, marked an alarming decline of 51 percent in the number of monarchs wintering in Mexico. Monarchs breed in the United States and Canada during the summers and overwinter in Mexico. This is the third consecutive year of declines and the lowest level in recorded history. The population is estimated to be only 1/15 of its 1997 level. A variety of factors are contributing to this decline, including illegal logging in the monarch preserves of Mexico, changing climate conditions, and agricultural practices. Mexico has significantly reduced illegal logging in the preserves but amending the agricultural practices in the United States and Canada may prove more difficult. The use of herbicides in agricultural fields and on roadsides that kills milkweed, the larval host plant, is a serious problem. Mowing the roadsides before seeds are mature is also reducing the availability of milkweed. If we want the monarchs to survive, we must take action.

Get your students invested in the monarchs' dilemma by incorporating the following entomological extensions in your unit. The extensions, as listed, follow a logical order.

Entomological/PLT Activities

7 Habitat Pen Pals

Adopt a monarch butterfly and learn about its migration and problems.

41 How Plants Grow

Milkweed along highways is being mowed before it has time for the seeds to set and farmers are poisoning it in their fields. As a result monarchs are having trouble finding their host plant. Learn to identify milkweed so you can point it out to as many people as possible and enlist their help in protecting it for the monarchs. There are different species so become familiar with all in your area.

53 On the Move

Students will map the route monarch butterflies take on their several-generation migration and compare this to a trip they may take.
To monitor real-time monarch migration and report sightings use the Monarch Butterfly Journey North website http://www.learner.org/jnorth/monarch/
To learn how to help scientists track migration by tagging monarchs, see:
http://monarchwatch.org/tagmig/tag.htm

78 Signs of Fall

Students will learn the monarchs' departure for Mexico is a sign of fall and do a little research to determine if it is caused by the falling temperatures, shorter days, or food becoming scarce.

88 Life on the Edge

Monarchs are on the edge with habitat destruction in Mexico, the U.S., and Canada. Students will research the causes of decline and decide which is happening in their community before designing a campaign on behalf of the monarch.

5 Poet-Tree

Write poems about monarch migration and publish them in a local newspaper during migration seasons.

59 Power of Print

Produce a barrage of articles, editorials, and poems about monarchs before migration seasons and publish them in the local paper daily or weekly during migration season. You may want to report on spots where you have found milkweed growing so people can go watch the monarchs. Older students may want to explore both sides of the issues involving the monarchs' decline.

60 Publicize It
Consider binding all of the stories and poems your students have written about the monarchs in a book and publish it. Be sure to describe some of the experiments and activities you have engaged in, including tracking and tagging. The following items may give you some ideas as well.

1 The Shape of Things
Experiment with color added to the cutout shapes of monarch butterflies and see if they are attracted to your outdoor classroom.

31 Plant a Tree
Plant local milkweed in the outdoor classroom and it will return year after year.

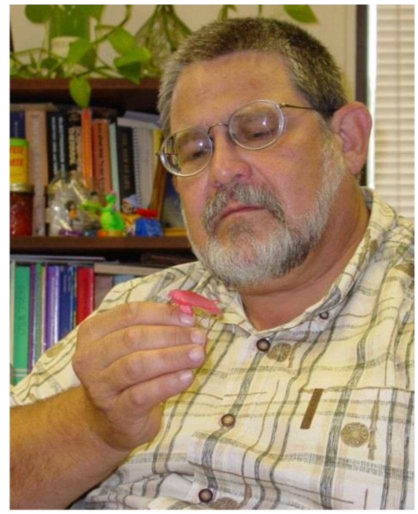
43 Have Seeds, Will Travel
Monarch seeds are attached to a strand of silk that blows in the wind. Consider starting a Plant Milkweed for the Monarchs campaign. Learn to grow milkweed seedlings and supply them to people who are willing to tuck a few into their garden and sustain them over the years.

47 Are Vacant Lots Vacant?
Get permission to plant milkweed in vacant lots.

Index of Topics by Activity Number[3]

[3]App = Appendix

About the Author



Dr. Guyton is an Extension Entomologist in the Biochemistry, Molecular Biology, Entomology and Plant Pathology Department at Mississippi State University. He runs the oldest residential Bug and Plant Summer Camp in the world and each summer leads youths, teachers, environmental educators, and parents into the amazing world of insects and their companions including plants. This fast-paced interdisciplinary academic camp starts early and runs late into the night as 10 year olds to grandparents investigate our environment from an entomological perspective. Camp has produced around 10 entomologists with advanced degrees. Dr. Guyton was a science educator while at Murray State University in Kentucky and participated in writing the science portion of first state mandated curriculum framework. While working on the framework, he aligned the PLT Activity Guide to illustrate how such programs could continue to support the curriculum.