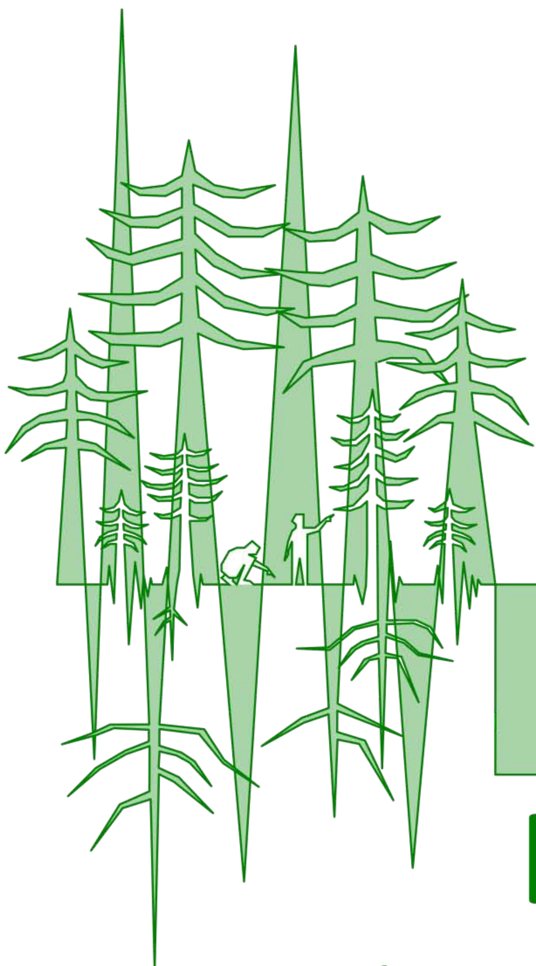
EDIS FOR286



What Is a Healthy Forest?

A Supplement to Florida Project Learning Tree

Sarah L. Hicks
Martha C. Monroe
Geetha S. Iyer
Jason A. Smith

School of Forest Resources and Conservation, University of Florida
Developed with the Florida Division of Forestry, Department of Agriculture and Consumer Services

How to cite this document:
Hicks, S. L.; M. C. Monroe; G. S. Iyer; and J. A. Smith. 2011. What Is a Healthy Forest? A Supplement to Florida Project Learning Tree. Florida Cooperative Extension Publications FOR286. Gainesville FL: University of Florida

This document is FOR286, School of Forest Resources and Conservation, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Original Publication Date: July 2011 Reviewed: August 2014

Visit the EDIS website: http://edis.ifas.ufl.edu
Visit the Florida Project Learning Tree website: http://sfrc.ufl.edu/plt
For more forest health education materials, visit: http://sfrc.ufl.edu/extension/ee/foresthealth.html
For more information on forest health, visit these sites:
School of Forest Resources and Conservation, University of Florida: http://sfrc.ufl.edu/extension/forest_health
Florida Division of Forestry: http://www.fl-dof.com/forest_management/fh_index.html

What Is a Healthy Forest?

A Supplement to Florida Project Learning Tree

Sarah L. Hicks, Martha C. Monroe, Geetha S. Iyer, and Jason A. Smith

School of Forest Resources and Conservation
University of Florida

2011

EDIS FOR286

Developed with the Florida Division of Forestry, Department of Agriculture and Consumer Services
With funds from USDA Forest Service
In conjunction with Florida Project Learning Tree

Acknowledgments

This material is a product of the foresight and wisdom of Edward Barnard, Ph.D., forest pathologist at the Florida Division of Forestry. His work with the public, and especially teachers, over the course of his career convinced him that we could improve how teachers and youth understand forest health. It is through his guidance that we have expanded the traditional notions of the threats to forest health to include not only pests and pathogens but also development, invasive exotic organisms, fire suppression, and forest fragmentation.

This project would not have been possible without funding from the Florida Division of Forestry (DOF), United States Department of Agriculture Forest Service, and the School of Forest Resources and Conservation (SFRC) of the Institute of Food and Agricultural Sciences, University of Florida (UF/IFAS). The curriculum development team is especially grateful to the extensive content and editorial input provided by faculty and experts from both UF and the DOF. Particular thanks go to Edward Barnard, Linda Cronin-Jones, Jeffery Eickwort, Albert Mayfield, Brian Myers, Jennifer Seitz, Don Spence, Jessica Tomasello Ireland, Dave Treadway, and Andrea van Loan for their insights and guidance in shaping this handbook.

We owe thanks to several teachers and extension agents for their insights, support, feedback, and enthusiasm during various stages of the product's development. They provided helpful notes, critical questions, and fabulous suggestions as they reviewed and pilot tested draft versions of this material. They deserve special mention for their dedication to quality education.

Randy Boyd, Lake Gibson High School, Lakeland, FL	Lisa Prescott, Lakeland Christian School, Lakeland, FL
Rebecca Harris, Orange County Extension, UF/IFAS	Katie Schlotterbeck, St. Michael's Lutheran School, Ft. Myers, FL
Patricia Jackson, South Seminole Middle School, Casselberry, FL	Vanessa Spero-Swingle, Brevard County Extension, UF/IFAS
Sherri Kraeft, Wakulla County Extension, UF/IFAS	Shaun Stewart, Florida Division of Forestry
Carmella O'Steen, Alachua County School District	Paul Webb, Frostproof Middle~Senior High School, Frostproof, FL

We would also like to acknowledge the following educators for their assistance during the project's needs assessment, providing input into content and types of materials that would be most helpful to educators.

Hadrian Alegarbes	Rayanne D'Auria	Megan Grey	Angela Mizzi	Deana Sharp-Williams
Areon Atkinson	Judy Der	Sean Green	Tia Needer	Cheryl Stephens
Jenn Bartley	Shawna Evgridge	Luiza Holtzberg	Monica Nelson	Sharon Stewart
Marie Boyette	Haven Felker	Ebni Howard	Lia Orlando	Cheryl Tamargo
Kyle Carlton	Cheryl Fernandez	Jill Huesman	Sarah Pardue	Carlton Taylor
Ginger Chapman	Susan Ferrell	Randy Kegler	Sara Peoples	Jennifer Tenenblatt
Rewa Chisholm	Erica Field	Yvonne Kirkland	Stephanie Phillips	Ahira Torres
Jody Corder	Jackie Fletcher	Stan Kosmoski	Megan Redecker	Kevin Wells
Sara Cultra	Amy Fordyce	Carolyn Kreite	Pam Roman	Robert Wilder
Jessica Cummings	Marie Fussell	Haylee Marshburn	Kelly Rowley-Seghi	

Thanks also go to the UF team: SFRC PLT Coordinator Nancy Peterson; Kelly Biedenweg, Amanda Burnett, Lara Colley, John Fort, Lindsey McConnell, Annie Oxarart, Annelena Porto, and Deb Wojcik for their feedback on various drafts of the materials; and Eleanor Sommer, for creative, constructive, and exhaustive editorial advice.

Lastly, we are extremely grateful to all the youth who helped us pilot test these activities by so willingly participating in them.

The Authors

Table of Contents

Introduction

The forests of Florida are diverse and indispensable. From the cypress swamps and longleaf sandhills along the Blackwater River to the mangroves that hug the Florida Bay, they form a network of temperate to subtropical ecosystems that shelter animals as small as bark beetles and as large as black bears.

Forests support humans in both tangible and intangible ways. Apart from being sources of aesthetic beauty and regional pride, forests provide economic resources in sectors ranging from timber and fiber production to recreation and tourism. Timber alone is a multibillion dollar industry in the South. In addition to the monetary value of these products, forests are also valued for their ecosystem services. They hold together soil and filter water, photosynthesize and produce oxygen, recycle nutrients and store carbon, and serve as a gene bank for countless organisms that may otherwise be lost.

Photo: Ricky Layson, Ricky Layson Photography, Bugwood.org

Figure 1. A Florida icon: The longleaf pine forest ecosystem.

There have been losses already. The longleaf pine forest ecosystem, once a defining characteristic of the South, has shrunk from more than 92 million acres in pre-settlement times to less than 3 million acres today (Figure 1). Heavy deforestation in the pre-1900s reshaped the land to serve agricultural, industrial, and other human needs. Despite this, southeastern forests still represent at least 30 percent of all forested land in the United States. Land conversion to timber production has been a key factor in maintaining forest cover, and since the 1980s forested land in the region has shown signs of slow but continued growth.

However, the human population in the South, which represents about 35 percent of the total population of the United States, is also growing. Thus, our conflicting demands for both land to live on and land for forest goods and services is increasing. Forests and trees are renewable resources, but are limited by the land we reserve for them. Since humans depend on forests for continued survival, it is incumbent upon us to monitor their health, encourage their growth, and manage them in a sustainable manner. With these goals, the question that arises is, "Who among us is knowledgeable and responsible for sustainable and healthy forest management?" There are two ways to answer this.

On the one hand, we may look to those who own and control forests for an answer. Forests may be owned and managed by public entities, private businesses, individuals, or families. In the South, more than 80 percent of forests are privately owned. This means that while everyone essentially has a stake in the health of forests, residents of the South are particularly engaged, because in many cases the forests here are a source of livelihood.

On the other hand, who benefits from the services that healthy forests provide? Here, the answer is much broader. Many sectors of the population can benefit from the health of forests. Forest health is a relevant issue for foresters, researchers, farmers, timber growers, hunters, hikers, urban citizens, educators, and children. Teaching youth about the significance of forests is especially critical—they are future decision makers and stewards of the planet's natural resources. Educating youth about forest health is a first step in equipping them to make informed decisions about the future of this valuable resource.

What Is Forest Health?

A healthy forest is an intricately balanced system of interacting parts. Climate influences environment, environment shapes plant growth, plants provide food for numerous other organisms, and humans intersect with this system by harvesting, planting, fragmenting, reshaping, analyzing, using, and appreciating forests for a variety of purposes.

As a result, defining forest health can be confusing because it is a subjective categorization. For those who take the utilitarian perspective, a healthy forest is a producer of tangible goods, and an unhealthy forest is one that fails to be economically valuable. On the other hand, for those with an ecosystems perspective, health is measured by quantifying different variables, such as biodiversity, a forest's capacity to provide ecosystem services, and its ability to bounce back from disruptions and disturbances. Since a forest's sustainability is the ultimate goal, some combination of the

utilitarian and ecological perspectives may be used to understand forest health.
The Society of American Forests describes forest health as "the perceived condition of a forest derived from concerns about such factors as its age, structure, composition, function, vigor, presence of unusual levels of insects or disease, and resilience to disturbance."

Historically, concerns about forest health overwhelmingly focused on the eradication of undesirable pests and disease-causing pathogens, such as insects and fungi, or environmental disruptions such as fire, which could weaken or kill trees. However, damage, decay, and destruction are essential components of healthy forests. Insects that feed upon trees are fed upon, in turn, by other animals. Fungi that rot away trees replenish the soil with nutrients that would otherwise be locked away in wood. In fire-dependent ecosystems, fires clear the undergrowth and make room for new trees to grow. So the death of individual trees in the forest is not always cause for alarm—in many cases, it is integral to the continued health of the entire ecosystem.

Death and decay are treated differently in more controlled ecosystems, such as plantations, parks, and urban settings. For those who depend upon certain trees for products or aesthetic value, the priority placed upon healthy individual trees may define their perspective of overall forest health (Figure 2).

Photo: Chris Evans, River to River CWMA, Bugwood.org

Figure 2. Healthy urban forests: Not a place for rotting trees.

But there are some unambiguous threats to forest health. Non-native or exotic pests and pathogens are problematic in any ecosystem. These organisms have the ability to eliminate species and permanently alter ecosystems. For example, in the early 1900s, American chestnuts covered 25 percent of eastern forests, but within a few decades, 3.5 billion of those trees, more than 80 percent of the existing population, were dead from a fungal pathogen that caused chestnut blight. The disease resulted in a loss of $82.5 million in 1912. In 2002, a similarly worrying fungal-insect cohort causing laurel wilt landed in Georgia. This disease is systematically killing redbay trees in the Southeast and threatens the avocado industry of South Florida.

Non-native insects such as the Asian longhorned beetle, emerald ash borer, and hemlock wooly adelgid are also wreaking havoc in the United States. The emerald ash borer has killed 15 million ash trees in the Midwest and is now found in Tennessee. The hemlock wooly adelgid, which has killed 80 percent of the hemlocks in Shenandoah National Park, has the capacity to completely remove hemlock trees from the continent. The immense voids created by these insects and disease pathogens might be filled by invasive and exotic plants. Kudzu, Chinese tallow, climbing ferns, cogon grass, and Chinese privet top the list of invasive plants that are changing the ecosystems of the Southeast.

All together, there have been an estimated 50,000 species of plants, microbes, and animals introduced into the country, of which 400 insects and 24 pathogens have established themselves in forests. The total damage in monetary terms is staggering. At least $97 billion dollars was lost or spent on damage caused by 79 species between 1906 and 1991. Millions of dollars are spent every year on control efforts. The permeability of geographic boundaries has resulted in accidental, misinformed, and occasionally deliberate transfer and naturalization of pests and pathogens, which hitch rides on building material, fruit crates, trucks, and ships associated with national and international trade. Even the transport of contaminated firewood from one place to another facilitates the movement of invasive species. Native ecosystems are defenseless against invasive exotics because they have not had the time to evolve protective strategies.

The situation appears even bleaker if abiotic threats to forests are also considered. Forest fragmentation by roads and development; land loss due to urban encroachment; improper fire management regimes; air pollution from ozone, sulfur dioxide, and nitrous oxides; runoff from concentrated animal feeding operations (CAFOs); and climate change are all factors that can weaken trees and forests. There are also ethical dimensions surrounding these threats to forest health. The demand for larger residential areas puts a greater strain on existing forests to provide all the goods and services we require.

Many of the problems associated with unhealthy forests originate from human actions through mismanagement or misconceptions. This can be a source of hope, because while we may be complicit in these problems, we may accelerate solutions through increased awareness, knowledge, and a change of behaviors. Educating young people about the significance of healthy forests and the consequences of management activities is essential. Research and management are essential components of maintaining or restoring forest health, but so is an informed public. Monitoring imported goods for pathogens, managing forests through prompt harvesting and prescribed fire routines, encouraging native vegetation, creating better buffers against abiotic pollutants, and producing less and conserving more are important concepts to be understood and practiced to ensure the continued health of forests.

Teaching about Forest Health

Our conversations with educators before developing this material revealed that while agricultural education teachers, AP biology teachers, and other environmental education practitioners understood the importance of forest health and wanted to teach their students about it, they were not equipped to do so given their existing curricula. Educators who did cover forest health taught about forest insect pest and tree disease identification. They also addressed the role of fire in forests. Aspects that were missing from their curricula included the following:

- The beneficial roles of insect pests and tree disease pathogens in a forest.
- Management-related forest health issues.
- The impacts of exotic and invasive species.
- Forest fragmentation and urban encroachment.

Further conversations with students and teachers during the development of this material suggest that some of the important concepts are intuitive and natural for learners, and others are quite new. We offer the following insights to help educators listen for misconceptions and develop accurate understanding in their learners.

1. Ecosystems are an easy way to launch into the study of forest health. People typically think that a healthy forest is also a healthy ecosystem, and this is a good foundation on which to start a forest health unit. What may be less intuitive is that urban forests and plantations are also ecosystems that contain similar types of biotic and abiotic influences and relationships as natural forests, albeit with heavy anthropogenic influences. One advantage of using an ecosystem approach to forest health is that learners may be better able to generalize indicators of forest health and apply them to a variety of forests rather than believing that each forest is healthy for unique reasons. Exposure to ecosystem concepts in school can help students develop this perspective.

2. Many people mistakenly consider mammals and birds a defining feature of forest health. This may be because they are more familiar with animals than trees (Figure 3). While animal diversity is important, it is not the only important component of forest health, and some animals (or too many of a specific kind) can be a destructive force as well as a positive element.

Photo: Larry Korhnak

Figure 3. Can you name all the living things in this picture? Most of us would point out the raccoon, but few would include the oak it is perched on. Fewer still might notice the patches of lichen growing on the oak bark. Yet all these organisms are part of a healthy forest.

3. Invasive exotic species are common in the Southeast and students are likely to be aware of their influence on natural ecosystems. Some species are better known than others, of course, but drawing attention to the generic strategies and influences of non-native species helps students make more robust future connections to ecosystem health.

4. Younger students typically prefer a world with clearly defined good and evil, even in forests. Young learners, therefore, may be challenged to understand that threats to forest health have both positive and negative implications. For example, insects have multiple functions in the forest. Positive roles include pollination, decomposition, and prey for other organisms, and negative roles include defoliation, vectoring of tree disease, and associated tree decline.

5. Insects, fungi, and other microorganisms are ubiquitous in forests, yet ignored as key components. This is perhaps because they are small (Figure 4) and are rarely featured on television specials, unlike larger animals. Fungi in particular are poorly understood by people of every age. Few correctly identify them as potential pathogens in forests, and their life cycles remain obscure. Yet fungi, bacteria, and other micro-organisms are essential to forest health, and this handbook attempts to give these organisms greater exposure.

Photo: Joseph O'Brien, USDA Forest Service, Bugwood.org

Figure 4. Misunderstood miniatures: This bird's nest fungus, found on the forest floor, is usually invisible but for its pencil head-sized fruiting bodies, yet it is an important decomposer of plant litter.

6. Students who have been exposed to natural or managed forests or farms may have an awareness of forest management strategies that is not always possible to duplicate in coursework. Urban students may benefit from a field trip to several types of forests to better understand the concerns and potential solutions to forest health challenges. Facilitating small group discussions and using students' experiences in class discussions enables students to share their knowledge with each other.

7. It may be tempting to use human health examples to teach about forest health, but the analogy does not transfer well. Tree health may be explained using examples from students' own lives—they are familiar with being sick, and trees can have diseases too. Tree diseases are usually caused by fungi and bacteria, while our diseases tend to be from viruses and bacteria. Likewise, broken bones heal, as do structural wounds on trees, but through different growth mechanisms. However, the analogy loses elegance when up-scaling from individual trees to the population. Forest health can be improved when weak and stressed trees die, and dead trees play an important role in returning nutrients to the forest ecosystem. But a friend or relative's illness or death is not easily recast into a statement about how this helps the human population overall.

Using This Material

This handbook is a supplement to Project Learning Tree's Pre K–8 Environmental Education Activity Guide. The PLT Guide is a national environmental education resource with 96 engaging activities that help educators introduce trees, forests, and environmental issues to youth. The goal of this supplement is to convey basic concepts of forest health, which of course should build upon a knowledge of trees and forests. This supplement to the national PLT Guide focuses on Florida forest insects and pathogens, Florida forest ecosystems, and Florida forest management strategies. You can find out more about Florida's PLT program by visiting http://sfrc.ufl.edu/plt.

A survey of educators and a review of the Next Generation Sunshine State Standards suggested that this material can complement the science curriculum for grades 5 and 7. We have selected three basic concepts to help these students understand forest health, and each concept forms one section in this supplement.

Section 1: Forests are ecosystems that are composed of interacting parts. These parts include plants, animals, fungi, bacteria, and abiotic components, such as soil, water, fire, and climate. In this section we identify ten PLT activities that can help educators introduce forest ecosystems, and we have designed modifications to three PLT activities to help convey concepts that focus specifically on forest ecosystems. We also developed two new activities to round out this section.

Section 2: Forest insects and tree disease pathogens play important roles in forest health. At low levels, they can improve forest health by removing weakened trees from the system. Anthropogenic factors have the potential to trigger population explosions in insects and disease pathogens that can significantly damage forest health and pose challenges for forest managers. A variety of PLT activities discuss forest animals; we identified seven such activities and have provided Florida-specific information about insects and pathogens in the modifications provided here. A new game was also developed about an important forest health concept, the disease triangle.

Section 3: Forest management includes a set of tools we can use to protect, maintain, and restore forest health. Six PLT activities are recommended resources to introduce concepts about forest management, and three additional activities have been modified in this supplement to help educators focus on the health issues associated with management strategies. An additional two activities were created to supplement the PLT activities in this section.

This supplemental guide will be most helpful to educators when used with the PLT Guide as the referenced activities *are not* duplicated in these pages. Educators can obtain a PLT Guide by participating in a workshop or enrolling in an online training course. Information about both opportunities is available through the Florida Project Learning Tree office at the School of Forest Resources and Conservation (SFRC) at the University of Florida and at http://sfrc.ufl.edu/plt.

The new activities are correlated to state science standards and provide background information, step-by-step directions to implement the activity, extension and assessment suggestions, and student handout pages when appropriate. The *modified* PLT activities are not correlated to the state standards in this document because the intent of the original activity did not significantly change. Correlations for the entire PLT Guide can be found on the Florida PLT website previously mentioned.

Several of the activities and modifications suggest that educators access additional resources, photographs, and visual presentations. Many of these are available at SFRC's Extension website for educators at: http://sfrc.ufl.edu/extension/ee/foresthealth.html, including links to videos, fact sheets, and other sites that will help educators discover a host of resources.

Specific materials created to complement this guide include the following:

- ***Beyond the Trees: A Systems Approach to Understanding Forest Health in the Southeastern United States***
  Beyond the Trees is a set of six lesson plans for high school educators to convey forest health concepts using a systems thinking framework. The activities share similarities with the new activities developed for this handbook and may be used to augment the concepts learned here.
- **Pocket Identification Guide to Forest Pests and Tree Diseases of the Southeastern United States**
  The *Pocket ID Guide* is a deck of flash cards with photographs and identification information of common and important insect pests, tree diseases, and miscellaneous other forest stressors. These flash cards may be used as activity supplements or as a teacher resource.
- Visual presentations and photographs are available on the SFRC Extension website for educators: http://sfrc.ufl.edu/extension/ee/foresthealth.html.

There is an electronic version of this supplemental PLT handbook at the SFRC Extension website listed previously. These resources should enable you to build a unit that fits your teaching style, your students, and your forest ecosystem.

Conclusion

Forest health is an exciting and thought-provoking topic for biology, agriculture, current issues, and environmental science classes. Issues range from basic concepts to historic successes and calamities, and from unanswered questions to current debates. Forest health challenges affect urban and rural residents, private landowners, and public properties. Some issues are natural, while others are caused or magnified by people. Forest health is a topic that includes variety and complexity while inviting multiple opinions and new discoveries.

There is no question that forests provide important ecological services and economic resources to those who live in the Southeast. Similarly, there is no doubt that the health of our forests is contingent on the decisions we make to manage and enhance Florida landscapes. The activities in this supplement, along with the original PLT Guide, help students rise to the challenges of managing forests for human use as well as ecosystem health, now and in the future.

Section 1

Forests as Ecosystems

Productive, resilient forests are healthy ecosystems. The activities in this section use this basic fact to focus learners on understanding forest health in the context of ecosystem function. Forests are intricate webs of interacting living and nonliving components and each part can have an effect on the system's overall health. Conversely, the health of a forest can measurably affect individual biotic and abiotic ecosystem features.

Since forests are complex systems, a holistic view is crucial. Thus, forest health is best addressed at the ecosystem level and not by only looking at a small patch of trees. Trees span the continuum from seedling to decomposing log. They are continually aging and their health may be compromised by, for example, insect attacks, fungal disease, or lightning strikes. Although it is not intuitive, unhealthy individual trees provide nourishment, shelter, and habitat for various other forest organisms and are essential to the overall health of the forest. In other words, parts of the ecosystem will be in varying states of fitness, and the good health of the entire ecosystem depends on some parts being in poor shape.

The Project Learning Tree K–8 Activity Guide includes a number of activities that help students explore forest ecosystems. You may wish to incorporate the following PLT activities into your unit on forest health:

Activity 22	Trees as Habitats
Activity 23	The Fallen Log
Activity 29	Rain Reasons
Activity 46	Schoolyard Safari
Activity 47	Are Vacant Lots Vacant?
Activity 48	Field, Forest, and Stream
Activity 70	Soil Stories
Activity 79	Tree Lifecycle
Activity 80	Nothing Succeeds Like Succession
Activity 81	Living with Fire

Three PLT activities were modified for this Section because they can readily help students learn additional aspects of forest ecology. The difference between generalists and specialists is an important consideration when ascertaining how an ecosystem might be impacted by changes in one population; this extension was added to Activity 45, Web of Life (page 16). In our modification of Activity 8, The Forest of S. T. Shrew (page 19), students are encouraged to write a story about a Florida forest, complete with real plants and animals. And in Nature's Recyclers (PLT Activity 24, page 20), additional discussion questions enable students to appreciate the importance of decomposition in a healthy forest.

To help round out this exploration of forest ecosystems as a foundation of forest health, two new activities were created. *It's a Forest* (page 2) begins this module by helping learners define a forest. How many trees are needed? Do all tall plants count as trees? There may be more nearby groups of trees and plants that count as forests than your students realize!

And finally, *Inside the World of Forest* (page 7) helps students talk about the relationships within a forest ecosystem with specific animals and plants that are typically found in Florida. The descriptions in this activity also can be used for the stories in S. T. Shrew and letters in Habitat Pen Pals. In addition, the *Pocket ID Guide* created to complement this handbook includes flash cards that can supplement these activities.

Some reports suggest that students are more familiar with tropical rain forests than the forests in their own communities. We hope these activities help educators and learners become more familiar with the forests in and around their homes and are able to see them as complex, interacting systems.

New Activity 1

It's a Forest!

Lesson Summary

In this activity students take a close look at forests. They learn that forests are defined according to various criteria, including size of trees and type of use. They are asked to think about these definitions and see if they'd like to add anything more to round out the definition of a forest.

Students also explore how different ideas of forests can create different ideas of forest health. This basic introduction to the forest as an ecosystem as well as a resource that humans use creates a framework for understanding the rest of the activities in this handbook—how we deal with issues such as forest diversity, the impact of invasive exotics, or forest management issues depends first on how we perceive and define a forest.

Background

How Do You Define a Forest?

For most people, the word "forest" conjures up an image of many trees. But how many? Does a group of a hundred constitute a forest, or a thousand? Would twenty be sufficient? Must the trees be scattered at random across the landscape or could they be lined up in rows? Would they all have to be of one species, or several? One age class, or all ages? Could the trees fringing a city park or those in someone's backyard be considered part of a forest? Would an orange grove qualify as one?

At first, it may seem easy to define a forest, but in trying to answer any of the previous questions, it becomes clear that forests vary in size, ***composition***, and function. Moreover, people's perceptions of and uses for various trees also influence their idea of what a forest is. In asking someone to describe a forest, they might be quite likely to draw from personal experiences. An ecologist might talk about the ***ecosystem*** she is studying; a timber grower might consider his plantation of pines to be a fine example of a forest; a young boy might speak with awe of the trees in his neighborhood park. In all these cases, it is not just the physical aspects of the forest that are important, but also their inherent value to the ***stakeholders*** involved.

Sunshine State Standards

SC.5.L.17.1: Compare and contrast adaptations displayed by animals and plants that enable them to survive in different environments such as life cycles variations, animal behaviors and physical characteristics.

SC.7.E.6.6: Identify the impact that humans have had on Earth, such as deforestation, urbanization, desertification, erosion, air and water quality, changing the flow of water.

Materials

For each student

2 pictures of forests, to be collected by the student at home.

For the teacher

Computer and projector to display visual presentation.

Time Considerations

Part A: 10 minutes
Part B: 40 minutes

Behavioral Objectives

Students should be able to do the following:

- Define a forest.
- Classify forests using various criteria.

There are in fact many definitions of forests, some of which may emphasize biological aspects of the ecosystem while others take on a more utilitarian focus. On a basic level, forests are ecosystems dominated by trees. The Food and Agricultural Organization (FAO) of the United Nations is much more specific: a forest is land with tree canopy cover of at least 10 percent, covering an area of more than .5 hectares where trees are able to reach a height of at least 5 meters. This means that a forest needs to cover an area slightly larger than half of a football field with trees at least 15 feet tall. If you think about the size of many neighborhood, city, and county parks, you may discover that many of these places could be considered forests! Even pine plantations count.

Despite its specificity, the FAO definition of forests lacks in several important details. Forests are more than just trees. Shrubs and understory plants, rotten logs, ***decomposers***, birds, reptiles, and mammals are also part of most forest ecosystems. Humans belong to the system as well, for example, hikers, hunters, researchers, and recreationalists. There are also roads and buildings that intersect with forests, products are extracted from within, and species that are introduced to the system.

Types of Forests

Forests may be categorized by ecosystem properties such as climate, topography, and biotic composition, but they may also be described in terms of their use. All forests provide ***ecosystem services*** such as clean air, fresh water, ***nutrient cycling***, soil maintenance, and gene bank reservation for a variety of organisms.

Natural forests are usually conservation areas for wildlife, ecosystem services, and recreation. They provide green landscapes for many people to enjoy, and some may be harvested for products, regenerating naturally from standing seed sources.

Plantations are forests that are specifically planted to make products people use, such as paper, timber, fuel, or pecans. These forests tend to be planted in rows for easy access. They are usually privately owned and managed for efficient production, and usually contain less biodiversity than natural forests.

Urban forests are those planted or left in developed areas (Figure 5). These forests are designed with human benefits in mind. They increase the aesthetic value of urban areas. They also improve environmental quality through such functions as reducing the urban ***heat island*** effect by casting shade over buildings and roads, and decreasing the need for stormwater ponds as they transpire water out of the ground.

Photo: Larry Korhnak

Figure 5. Is this a forest? Development eats into natural forests, but stands of trees are often left standing. Urban forests provide much needed shade, and people enjoy them too.

Ecosystem health: How forest type influences management

It is clear that forests are important and indispensible resources, regardless of their proximity to humans or the degree to which they are used in daily life. As such, managing for the health of forests is an important concern not just for forest managers, but for people in general. Daily decisions about water use on a lawn, where to build a new road, whether to release an overgrown ***exotic*** pet into the wild, fertilizer use, or prescribed fire management are all factors that could have consequences to the health of a forest, as will be seen in various activities in this supplement.

In this activity, take the opportunity to tell to students that while forests share many commonalities, their differences pose specific challenges to people trying to manage them. The type of forest influences how "health" is defined. For example, a dead tree in a natural forest is good for woodpeckers, but in an urban forest it is a hazard to people and cars. The choice of whether to plant or remove an exotic ***invasive*** tree from an urban forest has consequences for neighboring plantations or natural forests, and so on. Understanding what forests are is a starting point for learning about how they function and what can be done to improve their health.

Getting Ready

- Read the *Background* and *Doing the Activity* sections to familiarize yourself with the material.
- Familiarize yourself with the visual presentation supplement for this activity, available on the *Healthy Forests* CD and website. You may modify the presentation as necessary for use with your class.
- Prepare the supplies outlined in the *Materials* section.
  - Computer and projector to display visual presentation.
  - 2 pictures of forests, to be collected by each student before class. These pictures may be family photographs or images printed from magazines or the Internet. Ask the students to note the country and continent of the forest, if they know it.

Doing the Activity

Part A: Introduction
10 mins

1. Engage students in an introductory discussion using the following questions.

a. What do you think is a forest?

b. What characteristics must an area have to be a forest?

c. What elements, living and nonliving, are important in a forest?

d. What might make forests different from each other? What could be the same?

e. Do all forests have the same plants?

2. Ask each student to write down his or her own definition of a forest.

Part B: Classifying Forests
40 minutes

3. Divide the students into groups of three or four. Ask students to share the forest photos or images they brought from home with their group. Each group should examine all of its pictures.

4. Write the following questions on the blackboard for groups to consider:
- What are the similar features of the forest pictures in your group?
- What are the differences between the forest pictures?
- What parts of the world were these pictures taken from?

Ask one member of each group to take notes of the group's answers or individuals could record their own answers.

5. Have groups volunteer to share answers to each of the three questions. You may prompt them to share more by asking questions such as the following: Did any of the groups identify similarities or differences that other groups also noted? Were there any exceptional or surprising findings? Did all the forests come from the same parts of the world? What was the oddest-looking forest anyone found, and why was it so odd? Were any of the pictures of forests close to home? Which picture represented a forest that was far away?

After hearing the class members' answers to these questions, clarify where forests are found. Interviews with middle school students suggest that many children believe forests grow only in the tropics. Forests, however, can be found all over the world, from Russia to Alaska and Canada to Australia. Be sure students are clear that forests are not just rainforests; familiar trees such as pines and oaks can make up forests as well.

Image adapted from the Global Forest Resources Assessment 2010

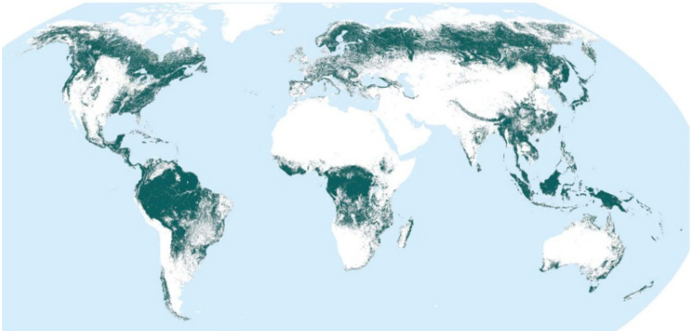


Figure 6. The world's forests: Forested land (>10 percent tree cover, as defined by the Food and Agriculture Organization of the United Nations) is shown here in dark teal.

If you would like to familiarize students with geography, consider pinning a map to a wall and asking students to place thumbtacks or stickers in places where their forests are located. You may use a map showing world forest distribution such as in Figure 6.

6. Next ask students to categorize their group's pictures in some way. This can be according to tree size, amount of understory, types of trees, or any other criteria they may come up with. Point out to students that they may use the similarities and differences they identified previously to help them categorize their forests, or use a new system of classification. Ask each group to share its organization system with the class.

7. Inform students that scientists use all sorts of factors to classify forests, including climate, latitude, and dominant tree species. Another way to classify forests is by use. Write the following on the blackboard:

- Natural forests
- Plantation forests
- Urban forests

Use the *Background* section to briefly introduce students to these three kinds of forests and ask groups to think about what each of the forests in their pictures may be used for. Ask them to define their pictures as natural, plantation, or urban forests. Are there any forests that students have trouble defining? Engage students in a discussion of why some forests may be hard to define. It could be that they are used for multiple purposes, or it may be that students previously would not have considered such an area to be a forest.

8. Ask several students to volunteer examples of natural, plantation, and urban forests they found within their pictures. Are there examples of all three? It is possible that students may only have collected "traditional" forests—those that look like natural forests. If so, ask students why they might not have thought a plantation or urban forest was a legitimate example of a forest ecosystem.

Share with the students the Food and Agriculture Organization (FAO) definition of a forest found in the *Background* section. Be sure to explain that there are many definitions of a forest; this is just one interpretation.
You should help students visualize the measurements used in the FAO definition. You can compare five meters to about the height of two and a half doorways stacked on top of each other.

9. Show students the pictures in the visual presentation that accompanies this activity (see *Resources and References*). The pictures include areas that are forests and areas that are not forests according to the FAO definition. Look for teacher notations below each frame indicating whether it is classified as a forest according to FAO.

Ask students to recall the FAO definition of a forest as well as the classification system used earlier in class. As you show them each picture, ask students to decide which ones are forests and how each of them might be classified. The following questions can help students think about each picture.

- Does this picture contain trees?
- Are the trees as tall as or taller than the height of a one-story house?
- Do you think this area is as large as half a football field?
- Has anyone seen a forest like this in Florida?
- Are forests always large? Can forests be small?
- Are forests only natural areas?
- Can we find forests in cities?
- Are forests in cities planted by people? What other forests may be planted by people?
- Can forests change over time? Why might a forest change?
- Do you agree with FAO's definition of a forest? What would you change?
- Has your definition of a forest changed at all since you looked for pictures at home?
- Do you think our definition of a forest is a good definition? What's missing? How do you think this definition could be improved?

10. Wrap up the discussion by asking students what they think a healthy forest might look like? What would it need to contain? Challenge them to think about what healthy versus unhealthy means in natural, plantation, and urban forests. The answers are sometimes not the same, based on the priorities for use in each of the three. Managing a plantation is different from managing an urban or natural forest.

Assessment

Using students' answers to *Doing the Activity*, check that they can do the following:

- Define a forest.
  Seen in students' responses to step 2.
- Classify forests using various criteria.
  Seen in students' responses to steps 6–9.
  Note that this is not an individual assessment.

Extension Ideas

- Ask students to individually research a forest ecosystem found in Florida: pine flatwoods, sandhill pine, bottomland hardwood, swamp, and upland hardwood are some common forest ecosystems in Florida. See *Resources and References* for more teacher and student-geared details on each of these systems. You may ask the students to write their answers in a report or present to the class. Where is this forest found? What does it look like? What kinds of animals may live there? What makes it a forest?

- Take a field trip to a nearby forest. Discuss with students what makes the area a forest. What kinds of animals live in there? Was the forest naturally planted or planted by people? Do any of the trees have adaptations for their environment? Ask students bring a journal to write observations of what they see.

Resources and References

- The University of Florida's SFRC Extension website for educators includes complementary material for this activity, in the form of a visual presentation.
  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

- Florida Project Learning Tree provides useful related resources for advanced students in its module, *Global Connections: Forests of the World*. Look for the following:
  - Maps illustrating global forest distribution ("Forests of the World") and the world's ecological zones ("Forests of the World Ecological Zones Map").
  - *Activity 2: What is a Forest*, which includes student worksheets as well as a visual presentation for educators.

  Visit http://www.plt.org/cms/pages/21_21_17.html

- More helpful maps and charts on world forest distribution and forest type may be found at the Food and Agriculture Organization of the United Nations website for Global Forest Resources Assessment. The latest Forest Resources Assessment, FRA 2010, includes maps and figures on extent of forest resources, forest biological diversity, socio-economic functions of forest resources, and many more.
  Visit http://www.fao.org/forestry/fra/62219/en/

- Information for educators on Florida forest ecosystems as well as fun stories about these systems written for younger audiences may be found at the University of Florida's SFRC Extension website for the Florida 4-H Forest Ecology Contest.
  Visit http://sfrc.ufl.edu/extension/4h/index.shtm

Photo: Larry Korhnak

New Activity 2

Inside the World of Forests

Sunshine State Standards

SC.5.L.17.1: Compare and contrast adaptations displayed by animals and plants that enable them to survive in different environments such as life cycles variations, animal behaviors and physical characteristics.
SC.7.L.17.1: Explain and illustrate the roles of and relationships among producers, consumers, and decomposers in the process of energy transfer in a food web.
SC.7.L.17.2: Compare and contrast the relationships among organisms such as mutualism, predation, parasitism, competition, and commensalism.

Materials

For each student
1 notebook or journal.
1 writing utensil.
1 sheet of newsprint.
2 or 3 markers or colored pencils.

For the teacher
1 copy of the *Student Page* section (4 pages).
1 pair of scissors.
1 roll of tape or other means of fastening posters to walls.
1 pack of sticky notes.

Time Considerations

Part A: 30 minutes
Part B: 60 minutes

Behavioral Objectives

Students should be able to do the following:

- Make observations of living and nonliving forest elements.
- Analyze observations to define a forest ecosystem.
- Describe five living and two nonliving components of forest ecosystems.
- Identify two connections between living and nonliving components of a forest ecosystem.

Lesson Summary

This activity helps students explore the connections between and among living and nonliving components of a healthy natural forest ecosystem. Students discover that biota are intimately connected with abiotic components of the environment and that there are various interdependent relationships between living organisms as they feed upon, shelter among, and compete with each other. They learn how to define an ecosystem using a forest as an example. They also learn that a healthy ecosystem functions because of the presence, strength, and quality of interrelationships among biota and their environments.

The activity makes use of nature exploration and observation to introduce students to these forest elements. Students go on a scavenger hunt in the forest, and later in the classroom they compare notes and observations to come up with a definition of a forest ecosystem. Students then enact an ecosystem using sounds, motions, and facts about forest elements. They later discuss the relationships observed between organisms and their environment and the quality of the forest as a result of these connections.

Background

The Elements of an Ecosystem

Florida holds many diverse and unique ecosystems. Each ***ecosystem*** is a physical area incorporating living organisms, nonliving features such as rocks, soil, and dead organic matter, and the natural cycles of water, carbon, and nutrients. Ecosystem function is determined by the interplay between the three elements—the ***biotic***, the ***abiotic***, and the ***nutrient cycles*** that transfer nutrients between the two.

Ecosystems are characterized by their biota and it is sometimes seems that the biotic elements are the most important. However, abiotic features of an environment lay the foundation on which biota flourish—topography, local climate, soil characteristics, and water availability favor specific organisms adapted to thrive in particular environments. Likewise the processes responsible for cycling air, water, and other nutrients within the ecosystem also determines the ***composition*** and quality of biotic features found there.

The mangrove forests of the Florida Everglades, for example, provide one illustration of all three ecosystem components in action. Red mangrove trees form the base of this ecosystem. The trees are adapted to grow in shallow, brackish water along the coast, and have finger-like prop roots to anchor them into the sediment as well as aid in providing oxygen to submerged roots. The prop roots serve as important habitat for juvenile fish and help reduce soil erosion. Decomposition of plant material under the prop roots contributes to the production of new soil, and releases nutrients that may be taken up by the plants and animals of that ecosystem. The tides, soil, plants, and animals create this unique system.

Trophic Levels in an Ecosystem

Although the species of organisms may differ from location to location, most forests are home to many of the same categories of living things. Nearly all forests contain canopy trees, understory trees and shrubs, groundcover plant species, insects, birds, mammals, fungi, and microbial decomposers. Each category of organism performs an indispensible function in the forest. In essence, each category occupies a ***niche*** in the ecosystem and exchanges or provides vital resources that all other components of the ecosystem depend upon. For example, trees form the base of the food web in a forest ecosystem.

As a result, ***trophic levels***, or production and consumption levels, are an important concept in a forest ecosystem. Organisms occupying each trophic level provide food and energy for those at higher levels. ***Primary producers*** include plants, which make their own food through photosynthesis, and some bacteria, which use chemical synthesis. Trees are the most important, and most visible, primary producers in a forest (see *Extension to PLT Activity 42: Sunlight and Shades of Green* [page 52] for more on this concept).

Primary consumers are organisms that eat primary producers to make energy. Those that feed on plants are also called ***herbivores*** (see *Extension to PLT Activity 25: Birds and Worms* [page 22] for more on this concept). ***Secondary consumers*** are organisms that typically eat other consumers. Some examples include bobcats, owls, praying mantises, rats, and snakes. They may be ***carnivores***, eating only other animals, or ***omnivores***, eating a combination of plant, animal, and fungal matter.

Finally, **decomposers** are organisms that eat dead or decaying organisms. In a forest, as with most ecosystems, decomposers can be some of the most numerous of organisms—numbering in the trillions. But decomposers often go unnoticed. Most of them, such as bacteria and fungi, are microscopic. Many of them live secretive lives—carrion beetles, bark beetles, fly maggots, and earthworms may be found within a decomposing animal, underground, or within leaf litter or logs. Yet decomposers unquestionably perform one of the most important roles in the ecosystem, that of releasing nutrients locked up in plant and animal matter and cycling it back into the ecosystem (see *Extension to PLT Activity 24: Nature's Recyclers* [page 20] for more on this concept).

Each trophic levels helps to support the food web in a forest ecosystem. If all of the organisms within a trophic level are extirpated, the food web is drastically changed and may become unbalanced. Therefore, the interdependence of organisms within each trophic level is important to maintain a healthy forest ecosystem. If only one element is removed, however, the forest may continue unphased. A healthy forest is resilient and can withstand some degree of change (see *Extension to PLT Activity 45: Web of Life* [page 16] for more on this concept).

Ecosystem health: A function of biotic relationships

Trophic levels illustrate consumption relationships, but an ecosystem's biota interact in many other ways. Some of the most commonly illustrated ***symbiotic relationships*** between organisms are ***competition***, ***parasitism***, ***mutualism***, and ***commensalism*** (see *Extension to PLT Activity 26: Dynamic Duos* [page 43] for examples of the latter three such relationships in Florida). These relationships may not always relate to the obtaining of food, and may focus on other needs, such as a place to live, type of shelter, or an aid to reproduction. The strength and complexity of these connections between organisms often reflects the general health of the ecosystem as well.

Competition is a relationship in which two or more organisms in the same environment vie for the same resources. In this type of relationship, both organisms are negatively impacted. For example, when two trees are planted close to one another, they may compete for sunlight, water, and nutrients. Therefore, each tree obtains fewer resources than if they were farther apart.

Parasitism is a relationship in which one organism gains from the relationship while the other is negatively affected. Mistletoe, for example, is a tree ***parasite*** that steals nutrients and water from its ***hosts***, giving nothing in return.

Mutualism is a relationship in which both organisms involved benefit from the interaction. During pollination, for example, hawk moths and hummingbirds obtain a sugary, energy-rich meal of nectar from flowers while becoming pollen couriers aiding in the plant's reproduction.

Finally, *commensalism* is a relationship in which one organism benefits while the other is unaffected. An orchid growing on a tall cypress tree is a perfect example of commensalism. The orchid is an ***epiphyte***, using another plant as an anchor upon which to grow. From its high vantage point on the cypress, it can access sunlight as well as water and nutrients trickling off branches in the canopy. The cypress tree is not harmed in this relationship but does not gain any benefit either.

In addition to these symbiotic relationships, many others exist. Although only one relationship was illustrated for each of the previous examples, a single organism typically maintains many symbiotic relationships with surrounding biota. The complexity of these relationships demonstrates the intricacy of a healthy, self-sustaining ecosystem. The health of a forest is not dependent on the success of an individual organism. Individual plants, mammals, birds, and insects are constantly sprouting, growing, migrating, or dying in the forest. They each belong to a larger population that may shrink or swell depending on seasonal variations in nutrient availability, predation pressure, and other such factors. Losing one individual animal or plant that is part of a larger population will not affect the forest ecosystem as a whole—it happens every day! However, a significant change in a population can cause an effect. A population is dependent on and can impact the overall health of the forest ecosystem in a variety of ways.

For example, if a ***disease***-causing fungus enters a forest and kills off all the oak trees, this might result in a cascading series of effects—the organisms that feed on the acorns from the oak trees might starve, change what they eat, or migrate to other forests; other tree species would fill the niche left by the oak trees; epiphytes, insects, and fungi dependent upon oaks for their survival would have lost a habitat, and if these organisms preferentially inhabited oaks, they could decline. To understand ***forest health*** is to recognize the various interconnections between species and their environment, and to learn how to anticipate the consequences, good and bad, of changes made to an ecosystem.

Getting Ready

- Read the *Background*, *Doing the Activity*, and *Student Page* sections to familiarize yourself with the material.
- Prepare the supplies outlined in the *Materials* section.
  - For each student:
    - 1 notebook or journal.
    - 1 writing utensil.
    - 1 sheet of newsprint or other large paper.
    - 2 or 3 markers or colored pencils.
  - For the teacher:
    - 1 copy of the *Student Page* section (4 pages).
    - 1 pair of scissors.
    - 1 roll of tape or other means of fastening posters to walls.
    - 1 pack of sticky notes.
- Cut the *Student Page* section into the 32 ecosystem component cards. If you have fewer than 32 students, discard a few cards; for more than 32 students, make extra copies of some cards or have students share. See *Resources and References* for pictures corresponding to the cards.
- Select a local natural area to visit with students for *Doing the* Activity, Part A. You might pre-visit a local park, preserve, refuge, or other natural area near your school to see that it is appropriate for the activity. Consider how much travel time is needed to visit the site as a class and the logistics of getting there.

Doing the Activity

Part A: Scavenger Hunt in the Forest
30 minutes

Take it outside

1. Take students to a wooded area near your school. Students should bring notebooks and writing instruments. Tell students they will be going on a forest scavenger hunt. During this hunt, ask students to search the area for evidence of five animals, five plants, and three nonliving things, and make notes or sketches about each—what it is, where it was found, what it looks like, why it caught their eye. If they think any of the items on their list might have some relationship to something else on the list, ask them to make a note of that as well—for instance, if they make put down “soil” and “maple tree” then one connection between the two would be that the tree grows in the soil.

Traces of an animal in the area, such as prints, feathers, or feeding marks on leaves and twigs, may be used as evidence. Samples of plants, such as seeds, pieces of ***bark***, or fallen leaves, may be collected in some natural areas and forbidden in others—draw students’ attention to park rules about collecting. Forewarn students not to touch poison ivy, poison oak, and any other stinging, thorny, or toxic plants in the area. It may be advisable to provide gloves and plastic bags to students keen on collecting samples to take back to class, but notes and sketches should be sufficient. Students may pair up while searching, but each should make independent notes and sketches.

2. When you return to the classroom, pair up students (not the same pairs as in the forest) and ask each pair to share and exchange their observations and notes. Distribute large sheets of newsprint and markers and ask them to work together to come up with an answer to the question, "What makes up an ecosystem?" They should diagram what they think an ecosystem looks like, either listing or drawing ecosystem elements. Below their diagram, ask them to write their definition or description of an ecosystem.

Encourage students to include living and nonliving components in their definition. Have them use their scavenger hunt notes, but also suggest that they can record additional things they noticed in the forest.

3. When students are finished, collect the diagrams and tape them to the classroom walls. Allow students to walk around and examine each other's work. After students have had a chance to see what their classmates have come up with, ask each pair to explain their diagram and definition to the class.

4. Discuss with students what makes an ecosystem, based on everyone's notes and observations. Write down key terms or components on the board. Once the class has come to an agreement on a definition of an ecosystem, write it on the board. Explain that forests are ecosystems made up of interacting biotic and abiotic elements.

Although students were asked to find plants, animals, and nonliving things in the forest, these categories do not include all that one might find in an ecosystem. Ask if any students observed toadstools or mushrooms, the fruiting structures of some fungi. Most fungi are invisible most of the time, but forests are full of them! What else might students not have noticed? You may start a discussion on the overlooked or invisible components of a forest ecosystem—bacteria, fungi, nematodes, pollen and fungal ***spores*** in the air, nutrients in the soil, and so on.

Part B: Acting Out a Forest
60 minutes

5. Distribute the forest ecosystem component cards. Explain that each student will represent a component in a 100-acre forest in Florida.

Have students form a circle. They will be sharing the information on their card with the rest of the class, first by reading the card aloud, then acting out the role with sounds or motions. Each card is numbered from 1 to 32. Ask students to come into the circle in order starting from number 1. Each student, as they enter the circle, may interact with any of the previously introduced components. Encourage students to make descriptive noises and motions, moving, hiding among, and engaging with other members within the circle.

6. After everyone has read and acted out a card, ask students to share their thoughts about the different relationships they've seen between living and nonliving components of forests.

7. As a class, try to improve on the original class definition of an ecosystem. Use this discussion to introduce some important concepts of forest ecosystems using the *Background* section as a guide. For instance, point out the importance of the connections between biota, abiotic components, and nutrient cycles. Also address various relationships between biota, such as herbivory or commensalism.

8. Work as a class to categorize the forest ecosystem components. It may be helpful to ask each student to write the name of their component on a sticky note. Clearly define parts of the chalk board for nonliving and each living trophic level (primary producers, primary consumers, secondary consumers, decomposers) and challenge students to place their ecosystem component sticky note under the correct category.

9. Ask students to identify the types of interactions exhibited in the forest ecosystem. Use this as an opportunity to reapply the concepts of parasitism, mutualism, competition, and so on. Explain that these interactions occur in other ecosystems as well. Ask students to brainstorm what species would perform each role in other ecosystems, such as a lake, a grassland, or a desert.

10. Discuss the concept of ecosystem health. What do students think are the important components of a healthy forest ecosystem? Can a forest do without one of these components?

Healthy forests include living organisms and nonliving *components that interact with each other. The components of an ecosystem are dependent upon each other, so if an entire component disappears, others will have to compensate. They may need to find new sources of shelter, nutrients, or water.* ***Generalist*** *species that can use a variety of resources may not be affected much by changes to the ecosystem.* ***Specialist*** *species that rely upon a single source of nutrients or a specific habitat may die out as well, adding to the cascade of ecosystem changes (see* Extension to PLT Activity 45: Web of Life *[page 16] for more on this concept).*

11. Discuss with students the importance of scale in a forest. Will the forest miss an animal if it dies? Will the forest miss a population of animals if they all die out? Is there a difference between the death of one tree in a forest, perhaps because it could not obtain enough water due to competition, or an entire stand of trees dying because of drought? Does it matter if the drought is natural or caused by people draining water from the area?

Be sure that students understand the difference between an individual organism dying versus an entire population, or a pocket of an ecosystem experiencing a dip in nutrient availability versus the entire forest losing a nutrient source. The magnitude of the impact and its consequences is very different in each case—ecosystems are constantly experiencing micro-scale changes in nutrient levels and organisms, but it is the broad-scale fluxes, such as the disappearance of an entire species, that can have significant consequences.

12. Ask students to look at the board where the ecosystem component sticky notes are posted. Instruct students to draw a picture showing the relationship between five of the living organisms and two nonliving components from the forest ecosystem using pictures, labels, and connecting arrows. Challenge the students to write a paragraph elaborating on the system they just illustrated. The following questions may guide students as they write their paragraphs:

- Describe each component as living or nonliving, common or rare.
- If living, does this component have a large population?
- If nonliving, is this component found everywhere, or only in some places?
- What kind of living organism is it—a primary producer, primary consumer, secondary consumer, or decomposer?
- What type of nonliving component is it? How do the living organisms depend on this nonliving component?
- How are the elements of the forest connected to each other?
- Are there any elements of the forest connected to each other element?

Assessment

Using students' answers to various steps in *Doing the Activity*, check that they can do the following:

- Make observations of living and nonliving forest elements.
  Seen in students' notebook entries in step 1.
- Analyze observations to define a forest ecosystem.
  Seen in students' diagrams in step 2.
  Note that this is not an individual assessment.
- Describe five living and two nonliving components of forest ecosystems.
  Answered in students' responses to step 12.
- Identify two connections between living and nonliving components of a forest ecosystem.
  Seen in students' diagrams from step 12.

Extension Ideas

- Watch a movie about an ecosystem not yet explored. Ask students to identify relationships between living and nonliving elements in the film. You can ask students to research some of the organisms and make their own component cards for the ecosystem in the movie.

- Ask each student to research more information about their ecosystem component cards, and prepare a short presentation to the class. Encourage students to be creative and share interesting facts with the class about their research topic.

Resources and References

- The University of Florida's SFRC Extension website for educators includes pictures of the organisms introduced in this activity. You may wish to combine these pictures with the ecosystem component cards in the *Student Page* section.
  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

- UF IFAS Extension's Solutions for Your Life includes information on various Florida ecosystems in 'Ecosystems & Species.'
  Visit http://solutionsforyourlife.ufl.edu/environment/ecosystems_and_species.html


Photo: Tony Pernas, USDI National Park Service, Bugwood.org

Inside the World of Forests

Instructions

Make copies and cut out the thirty two ecosystem components on the following pages. Each student should receive one card. If you have more students than cards, allow some students to share a card, or make a few extra copies.

1. Sun

I am the sun. I shine light into the forest, helping plants produce food through photosynthesis. This food helps the plants grow leaves, fruits, seeds, and nuts, which are important food sources for the insects, birds, and mammals that call this forest home.

2. Live oak

I represent one of many species of oak and one of 60 live oak trees in this forest. I can reach heights of 85 feet tall. My large branches stretch out from my trunk and grow low to the ground. I prefer moist woods or coastal sandy soils. I produce hundreds of sweet, tasty acorns that deer and squirrels love to eat.

3. Eastern fox squirrel

I represent one of several species of squirrels, and one of 40 eastern fox squirrels in this forest. I am dark grey or black with white markings across my eyes and tail tip. I eat fruits, nuts, and seeds. I bury acorns in hiding places but sometimes forget about them. These forgotten acorns can sprout into new oaks. I love pine cones. I eat them like you eat corn on the cob!

4. Slash pine

I represent one of hundreds of pine trees that grow into the forest canopy. I am a tall tree that enjoys wet soils and swampy areas. I can grow up to 115 feet tall and like lots of sunlight. Eastern fox squirrels love to eat the seeds from my pinecones. The fox squirrels actually help spread my seeds through this forest.

5. Live oak seedling

I represent one of hundreds of live oak seedlings growing in this forest. Mammals and birds spread acorns from older live oak trees around the forest. I like sunlight and moist areas. I wait in the shade for one of the older trees to die and fall over. Then I might grow up into the canopy where the old tree once stood.

6. White-tailed deer

I represent one of many species of mammals and one of 7 white-tailed deer living in this forest. I eat acorns and fruits from plants such as live oaks and sparkleberry. In the winter I eat twigs and branches. I can run very fast and travel many miles throughout the forest, so I must eat a lot to give me energy. Some people hunt me for food and sport.

7. Lightning

I am the discharge of electricity from a thundercloud. I hit forests during storms, usually in the summer months. I send a bolt of electricity down through the atmosphere toward the Earth's surface. If I hit a tree, I can crack its trunk, set it on fire, or damage its phloem, preventing it from carrying food and water to and from its leaves and roots. I can cause a tree to die.

8. Decaying log

I was once a huge tree that got hit by lightning five years ago. My phloem was damaged and I died. My body provided a home and food to southern pine beetles. When my roots rotted, I fell to the ground, making a new home for many insects, worms, fungi, and nematodes. These creatures break down my wood and add nutrients to the soil for new trees to grow. I am now one of 25 logs still visible on the ground in this forest.

9. Earthworm

I am one of millions of earthworms in the soil of this forest. I am a decomposer, eating plant debris such as dead leaves and twigs. As I digest food, I break it down and mix it with secretions from my intestine before releasing it into the soil. This adds important nutrients to the soil, which helps plants and trees to grow. Birds dig around in the soil and enjoy me as a yummy snack!

10. Soil

I am found under the leaf litter layer of the forest floor. I am made of rock and sand minerals, and the remains of dead plants and animals that have been eaten by insects and earthworms. Although I am not alive, I contain nutrients that help plants grow. I also provide habitat for many species of insects and reptiles, and decomposers such as earthworms, fungi, and bacteria.

11. Nematode

I am a species of microscopic roundworm. My relatives cover the planet in many different environments, but I prefer the soil in this forest. Here, I am one of hundreds of millions—nematodes usually outnumber plant and animal species in every ecosystem, and many of us can be quite destructive! I burrow into roots using a piercing mouthpart, damaging them and making it harder for plants to take in nutrients. I also feed on other microscopic organisms such as bacteria and fungi.

12. Honey mushroom

I am one of millions of fungi found in the forest. I have a net-like body of threads that I can send through soil to grow into roots and tree stumps. When I grow under the bark of trees I produce thickened nets of hairs that glow in the dark! When I grow in a sick or injured tree, I can cause it to rot and die. I make honey-colored mushrooms that release tiny, seed-like spores for reproduction. Eastern fox squirrels like to munch on my mushrooms.

13. Southern pine beetle

I am one of millions of southern pine beetles in this forest. I tunnel into sick and dying pine trees and feed on their phloem. I carry a fungus that can grow through wood. The fungus blocks the transport of water and nutrients in a tree, killing it in the process. By killing old, sick, or dying trees, I make room for new ones to grow. I reproduce and spread through a forest quickly. Woodpeckers and even some insects love to eat me!

14. Pileated woodpecker

I represent one of 10 pileated woodpeckers in this forest. I am one of the largest woodpeckers in North America. I have a loud, repetitive, drumming call, "kuk, kuk, kuk." I peck at trees with my large beak and dig big, rectangular holes in tree bark to find insects. These holes attract other birds that come to feast on insects for dinner. I excavate holes for nests in large, tall dead trees and branches.

15. Spanish moss

I am one of thousands of Spanish moss plants found in the forest. But did you know that I'm not really a moss? In fact, I'm related to the pineapple. I grow on oaks, but I do not steal nutrients from them. I make my own food through photosynthesis. Scales on my leafy strands absorb water and nutrients. I produce seeds that are spread by birds and wind. Many birds use me for nesting material because my leaves are like tangled wool, and very comfy.

16. Pine warbler

I am one of 50 pine warblers found in this forest. I have a bright yellow belly and white lines on my wings. I live in pine forests and search along branches and under tree bark to for insects to eat. I use Spanish moss to build my nest high in the tree canopy.

17. Wind

I am the wind. I travel through the branches, leaves, and stems of plants in the forest. I carry pollen and seeds from plants throughout the forest to new places where they can grow. When I am a very strong wind, I can cause trees or plants to blow over and die. These dead plants decompose and become part of the soil.

18. Japanese climbing fern

I am one of thousands of non-native, invasive Japanese climbing fern plants in this forest. I am from Asia, and I am making myself at home here in Florida! I grow rapidly over shrubs and trees, shading out the sun. Although my leaves and vines die in a freeze, I can re-sprout in the spring. The wind carries seed-like spores from my leaves.

19. Wild grape

Also known as "muscadine grape," I am one of many vine species and one of hundreds of wild grape plants in this forest. I grow on the ground, in shrubs, and up into trees—my vines can be 100 feet long! My grapes are eaten by white-tailed deer and birds. When animals eat my fruit, they spread my seeds, letting them sprout throughout the forest.

20. Standing dead tree

I am one of 15 standing dead trees, also called "snags," in the forest. I provide important habitat for many animals—especially insects, lizards, and woodpeckers. Birds like the red-shouldered hawk use me as a hunting perch. As I slowly fall apart, I provide food for decomposers. This returns nutrients to the soil below me, helping other plants grow.

21. Red-shouldered hawk

I represent one of several species of raptors and one of 4 red-shouldered hawks that hunt in this forest. My call, "kee-aah," can be heard echoing in the forest. I perch high in the canopy and swoop down to the forest floor to catch prey. My favorite foods are small mammals such as squirrels and mice, small birds, lizards, and frogs.

22. Southern black racer

I am one of several snake species found in this forest. I am slim and shiny, ranging from 2 to 5 feet long. I am not venomous, but I am fast—that is why I am called "racer." I slither on the ground and up trees for prey such as insects, small reptiles, amphibians, and small mammals. I help control rodent and insect populations.

23. Southeastern pocket gopher

I am one of 7 pocket gophers in this forest. I eat plant roots, and carry the food in the "pockets" of my cheek pouches. I live underground in deep, sandy soil, and I dig tunnels up to 145 feet long. Many reptiles and amphibians, including the mole skink, live in my tunnels. As I make tunnels I push sand and soil to the surface, providing nutrients to plants. You may sometimes see the sand piles I make along roads and paths.

24. Mole skink

I am one of hundreds of skinks found in this forest. I am a small, skinny, brown lizard with an orange-red tail. I am called a mole skink because, like moles, I burrow in the ground. Unlike other lizards, I do not climb trees. I am very secretive and rarely seen because I like to hide under logs and leaf litter. I feed on small insects and spiders. Yikes, the black racer snake likes to eat me!

25. Sparkleberry

I am one of many understory plant species and one of hundreds of sparkleberry plants in this forest. I grow to about 12 feet tall. In the spring, I make white flowers with nectar that attracts pollinating honey bees. In the summer, I produce dark purple berries that animals enjoy eating. When animals digest my berries, the seeds pass through their systems and can sprout into young trees.

26. Honey bee

I am one of millions of honey bees in this forest. My family lives in a colony. My mother, the queen bee, has more than 30,000 daughter worker bees, and a few thousand sons! My sisters and I collect flower nectar to make honey. The flowers we visit dust our bodies with pollen which brushes off onto the next flowers we visit, pollinating them so they can produce seeds.

27. Blazing star

I am one of thousands of wildflowers in this forest. I grow in sunny spots where there is an opening in the forest canopy. I have a tall stem and in the late summer and fall, I produce beautiful, feathery pink or purple flowers. My seeds are a favorite food of many songbirds, and these birds and the wind disperse my seeds throughout the forest. The monarch butterfly enjoys drinking the nectar from my flowers.

28. Monarch butterfly

I am one of 50 monarchs found in this forest. My big wings are striped orange and black and I use them to migrate to Mexico in the winter. My wing colors are a warning—if a bird eats one of my family, it'll never touch another orange-and-black flying insect again to avoid the bitter taste! I drink nectar from flowering plants and lay eggs on the undersides of leaves. Caterpillars hatch from these eggs and munch on the leaves. Mature caterpillars form chrysalises and emerge as beautiful adults like me.

29. Oak tussock moth caterpillar

In the spring, I am one of millions of caterpillars that hatch from eggs in this forest. I have two antennae-like hair stalks on my head and a fluffy tail. If I'm picked up, I can hurt you. I develop a stinging toxin in my hairs so birds will leave me alone. I eat with many other caterpillars and together we can eat all of the leaves from an oak tree! After I feed for several weeks, I spin a cocoon and change from a caterpillar to a moth.

30. Mistletoe

I am one of several parasitic plant species and one of hundreds of mistletoe plants in this forest. Birds and mammals enjoy eating my fruit. The seeds within my fruits are very sticky and easily transported through the forest by animals and rain. When a seed lands on a tree, it grows a rootlike structure into the tree's phloem and xylem. Although I can use photosynthesis to make food, I use this rootlike structure to steal nutrients and water from a tree. This is quite a nuisance to the tree—the more mistletoes it has on it, the less food it gets for itself.

31. Rain cloud

I am a cloud that rains on the forest. My rainwater sustains all life here. It goes deep into the soil, and also into streams and ponds that are a part of the forest. The streams and ponds provide a source of water and habitat for many insect, reptile, bird, and mammal species. The water in the soil is essential for plants to grow.

32. Resurrection fern

I am one of many types of air plants and one of hundreds of resurrection ferns that grow on tree branches in this forest. I attach myself to large live oaks and get nutrients and water as they trickle down the tree's bark. When there is not enough water, I curl up and turn brown. When it rains I uncurl, turn green, and resurrect! Many insects use my leaves and stems as a home.

Extension to PLT Activity 45

Web of Life

Lesson Summary

The original *Web of Life* teaches students about the importance of interdependence between plants and animals in an ecosystem. It also introduces students to the concept of a system, a set of interrelated parts that influence each other, and importance of system dynamics, where the complexity of a system relates to its stability.

This extension to *Web of Life* helps students understand that the connections between predator and prey are not necessarily linear. Depending on whether an organism is a generalist or specialist, it may or may not be affected by food web changes in its ecosystem.

Materials

1 watch.
10–15 pages of paper in each of four different colors.
1 pair of scissors.

Time Considerations

60 minutes

Background

As noted in the *Background* section of the original activity, it is clear by the feeding relationships in the forest that all organisms are connected to each other in some way. A food chain represents a simple, linear relationship. A food web is complex, but more accurately depicts the diverse ways in which organisms may be bound. In the food web modeled in the original activity, complexity is related to stability—the more bonds that link the various organisms, the more robust is the ***ecosystem's*** ability to rebound after ***disturbances***. Likewise, the more kinds of food an organism eats, the better able it is to survive when food sources are scarce. A ***generalist*** diet is therefore a resourceful adaptation. On the other hand, organisms with ***specialist*** diets eat only one or two types of food. They are much more sensitive to changes in prey density or health and their populations may fluctuate wildly or even decline when their sole source of food disappears or is otherwise compromised.

A case in point is the palamedes swallowtail (*Papilio palamedes*). This butterfly's range extends along the Atlantic coast down to central Mexico. Its green caterpillars feed exclusively on leaves from redbay and a few related trees in the Lauraceae family. An ***invasive exotic*** fungus introduced to the southeastern United States in 2002 decimated redbays in the region. As a result, the palamedes swallowtail population in the Southeast is severely threatened, as its caterpillars may eventually not have have a food source.

A closely related butterfly species, the tiger swallowtail (*Papilio glaucus*) has a far wider geographic range, and its bird dropping-colored caterpillars feed on a variety of trees in many families including swamp magnolias (Magnoliaceae), cherries (Rosaceae), and citruses (Rutaceae). This species continues to thrive, as its various food sources are abundant.

To complicate the story of the palamedes and tiger swallowtails, consider this: in the Floridian peninsula, tiger swallowtail caterpillars are adapted to feed almost exclusively upon swamp magnolia (Magnolia virginiana). These regional variants have specialist diets instead of the generalist diets of their northern counterparts. Perhaps the behavioral switch was adopted due to the abundance of swamp magnolias in the region, or perhaps the tiger swallowtails that first colonized the peninsula were genetically predisposed to like swamp magnolias over all other trees. Whatever the reason, tiger swallowtails have so far flourished in Florida, just as palamedes swallowtails once did, but if something were to threaten the Florida tiger swallowtails' food source, they too could go the way of the palamedes, possibly becoming locally extinct.

It is not just feeding relationships that determine an organism's survival. For example, a plant pollinated by only one type of insect is far more vulnerable than a plant that may be pollinated by various insects, birds, and even the wind. Organisms evolved generalist and specialist behaviors to accomplish many things, including where they live and how they reproduce. While it may seem to your students that generalist behaviors are preferable, note that there are advantages to specialist behaviors as well. Specialists evolved to capitalize upon resources that few others could use, and thus have a competitive edge in some habitats.

This extension to *Web of Life* shows how specialist and generalist diets affect insect populations. The two swallowtail butterflies are used to model this system. Both the original activity and this extension introduce some aspects of systems properties and behaviors. For more on how to teach about systems and systems dynamics, see *Resources and References*. Also see *Resources and References* for an activity that addresses the local issue of redbay tree and palamedes swallowtail extinction in Florida.

Getting Ready

- Read the *Background*, *Doing the Activity*, and *Student Page* sections to familiarize yourself with the material.
- Prepare the supplies outlined in the *Materials* section.
  - 1 watch to keep time.
  - 10–15 pages of paper in each of four different colors.
  - 1 pair of scissors.
- Cut or tear paper into strips, chips, or leaf shapes, to represent 100 leaves each of the four tree species—swamp magnolia, cherry, orange, and redbay. Alternately, use objects such as various beans to create the leaf sets. If you would like your students to learn tree identification, you might collect 100 leaves each from swamp magnolia, cherry, and orange trees for the game. If you are lucky enough to find living redbay trees, do not pick their leaves, as there are few mature redbays left in Florida. Either use dead redbay leaves, or those of a substitute plant. Later explain to students the significance of your choice—redbay trees are a threatened species in the Southeast.

Doing the Activity

60 minutes

1. Read the original version of *Web of Life* on page 194 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

2. After completing the *Web of Life* activity as originally written, use the *Background* section to introduce students to the terms "generalist species" and "specialist species." Elaborate upon the definition using the example of the two swallowtails. See *Resources and References* for access to pictures of the two butterflies.

For the purposes of this activity, it may be simpler to discuss the palamedes caterpillars as specialists and the tiger caterpillars as generalists, despite the fact that tiger caterpillars have specialist diets in Florida. If you would like to enrich students' understanding of adaptations and variations within a species, consider telling them more about the tiger swallowtails' peculiar local behavior after completing the activity.

Take it outside

You will need floor space to conduct this activity with your students. Consider doing the next steps outdoors.

3. Divide the class in half. Inform half the students that they are tiger swallowtail caterpillars and the other half that they are palamedes swallowtail caterpillars. They've just hatched from their eggs and need food. Review their preferred foods: the tigers can eat swamp magnolia, cherry, and orange leaves; the palamedes can only eat redbay leaves. Hold up examples of each leaf as you remind students of what they can eat, using prepared materials.

4. Scatter half the leaves of each tree type on the ground. Arrange students in a large circle around the leaves and explain the rules of the game they are about to play.

a. Students have five seconds to forage for the leaves they need to survive. You will call out the time for them to start and stop foraging.

b. Palamedes caterpillars need to grab 3 redbay leaves in the five seconds of foraging time.

c. Tiger caterpillars must grab 3 leaves of any of their preferred foods, swamp magnolia, cherry, or orange, in the five seconds of foraging time.

d. At the end of the foraging period, if any of the caterpillars did not collect as many leaves as they needed, they, they die. Ask these students to return their leaves to the ground and sit out the next rounds. All surviving caterpillars must stand still until the next foraging period.

5. After explaining the rules, call out a five-second foraging period. Ask if everyone was able to find enough food. Make the students who weren't able to find food sit out the next round. Call out another five-second foraging period and repeat the process a couple of times so students get the hang of the game. Once you've repeated the process about three times, congratulate the students who managed to find enough to eat—they've pupated and are now butterflies. Ask how many are tigers and how many are palamedes. You may make a note of this and come back to it in discussion.

6. Now that students know what they're doing, and what they're supposed to eat, tell them they are all going to get another chance to find food. Have all students reform the circle and return any previously collected leaves to the ground. Repeat the foraging process, but this time change the ***environmental conditions*** by calling out the following statements and doing the actions in italics.

a. It's spring, and all the trees have put out leaves. Go foraging!

b. *Remove half of the remaining redbay leaves and call out:* There's a fungus attacking redbay leaves, many of them are dying. Still, go foraging!

c. *Scatter lots of redbay leaves and a few more swamp magnolia leaves and call out:* As you crawl around the forest, you've come across some new food, including some living redbays. So go foraging!

d. *Remove half the remaining cherry and redbay leaves and call out*: There's been an unexpected cold snap that killed some cherry trees. Also, the redbay fungus is back, and more redbays are dead. Even so, go foraging!

e. *Scatter some orange and cherry leaves and call out:* What luck, you've wandered into an orchard! So many fruit trees everywhere, go foraging!

f. *Scatter more swamp magnolia leaves and remove half the remaining redbay leaves and then call out*: Now you're in a swamp forest, see all the swamp magnolias? But where are all the redbays? The fungus has already got to them, they're all dead. But you must go foraging!

Make sure that students who are not able to find enough food in a given round sit out the rest of the game. Note that the precise number of leaves you throw down and remove will differ depending on the number of students in your class. You may vary the number of leaves on the ground, how many students are allowed to pick up, and the environmental conditions, with the objective of manipulating the game so that students can see that the tiger swallowtails are better able to survive resource fluctuations than the palamedes because of their generalist diets.

7. After playing the game, check how many tigers and palamedes survived to become butterflies. Use the following questions to check students' understanding of the concept.

a. Which caterpillars found it easier to survive and why?

b. Are generalist species affected differently than a specialist species by changes in a food web?
Generalist species are able to capitalize on alternate resources, and therefore are better equipped to survive changes to the ecosystem. Specialist species are more sensitive and vulnerable to change.

8. Wrap up the activity by discussing with students why this information is important. Ask if students can think of what animals such as raccoons, rats, cockroaches, sparrows, and crows have in common. These are all generalist species that thrive in urban and suburban environments. Many of them, due to their abundance, are ***pests***. Their survival also comes at the cost of specialist organisms that cannot compete with them. The specialists must move away from disturbed or destroyed ecosystems that were once their homes, while the generalists can adapt and flourish. This compromises biodiversity in a region. Explain to students that when an organism is lost from a food web, other organisms may exploit that ***niche*** and the ecosystem compensates for what is missing. But for those that specialize on the missing ecosystem feature, there is often no hope for survival.

Extension Ideas

- Use the ecosystem component cards from *New Activity 2: Inside the World of Forests* (pages 12–15) to solidify students understanding of specialists and generalists. Put students in groups of three. Hand them copies of the following cards: 2, 3, 13, 14, 15, 21, 25, 28, 29, and 32. Ask them to identify each organism as a generalist or specialist species.

Resources and References

- The University of Florida's SFRC Extension website includes several related resources:
  - More details about the demise of the redbays, the attendant population crash of palamedes swallowtails, as well as losses to the avocado industry of Florida may be found in *Beyond the Trees, Activity 6: Unhealthy Forests and the News*.
  - *Web of Life* introduces some aspects of systems and systems dynamics. More details about how systems work and how to teach systems to your students may be found in *Beyond the Trees*.

  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

- More information about the two butterfly species in this extension activity may be found at the University of Florida Department of Entomology and Nematology Extension website, *Featured Creatures*.
  Visit http://entnemdept.ifas.ufl.edu/creatures/

- Extensive picture resources of the two butterflies, their caterpillars, and food sources may be found at the University of Georgia's Center for Invasive Species and Ecosystem Health's website, *Insect Images.*
  Visit http://www.insectimages.org/

Extension to PLT Activity 8

The Forest of S. T. Shrew

Lesson Summary

The original version of *The Forest of S. T. Shrew* includes a story about a magical adventure into a forest, where students see many habitats in and around trees through the eyes of a tiny shrew, a millipede, and a nuthatch.

This extension to *The Forest of S. T. Shrew* encourages students to use their imagination in another way, to develop their own stories from the perspective of various plants and animals in Florida forest ecosystems. Through the story-making process, students gain an understanding of how each organism is part of a complete forest ecosystem. Understanding this system is a precursor to understanding forest health.

Doing the Activity

1. Read the original *The Forest of S. T. Shrew* on page 40 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

2. Instead of, or in addition to, step 6 of *Doing the Activity*, challenge students to create forest stories of their own. Students can stay their own size or use "magic" to become very small, but they must explore a Florida forest and describe the relationships among organisms in their stories. Ask students to think about how these relationships affect the entire forest.

Take it outside

You may inspire your students' creativity by arranging a field trip to a local forest before asking them to write stories. If you do so, first read to your students the story of S. T. Shrew on page 43 of the PLT Activity Guide, then help students explore a local forest in a similar way—getting up close and personal with the minutiae of the forest by peering into the cracks and crevices on tree ***bark***, under logs and leaf litter, upon leaves, and within flowers.

If you take your students outside exploring, forewarn them not to touch plants such as poison ivy or poison oak. Impress upon students the importance of not destroying or disturbing the environment; for instance, if they turn over a log to look for insects or fungi underneath (Figure 7), remind them to turn it back so that the organisms can continue to shelter there.

Students may feel more encouraged to write adventure stories if they have heard some previously. This is the reason for reading *The Forest of S. T. Shrew* to your students before asking them to write their own versions. You may also challenge students by asking them to include at least two plants, a bird, a mammal, and an insect in their stories. *New Activity 2: Inside the World of Forests* includes several ecosystem component cards (pages 12–15) that may be used as writing prompts for your students.

Photo: Geetha S. Iyer

Figure 7. A whole world underfoot: Exploring the forest floor alone reveals a microcosm of activity. Point out to students evidence of decomposers at work—not just insects but also invertebrates such as pillbugs and earthworms, and threadlike fungi as seen above.

3. Wrap up the activity by asking if students would like to share their stories with the class. You may prompt students to share their stories with questions such as, "What's the smallest creature in your story?" and "Did any of your characters get lost while exploring the forest in miniature?"

This activity helps students explore and expand conceptions of forests by having them think about organisms that would normally go unnoticed because they are so small. Encourage students to think about the value of such organisms and the important roles they play in the forest. Could we do without animals like the beetle or the shrew?

Extension to PLT Activity 24

Nature's Recyclers

Lesson Summary

The original version of *Nature's Recyclers* teaches students about the process of decomposition by observing pill bug, sow bug, or earthworm behavior.

This extension to *Nature's Recyclers* places emphasis on the importance of decomposers in a healthy forest ecosystem. It draws students' attention to decomposing organisms that are not often noticed, such as fungi and bacteria.

Doing the Activity

1. Read the original *Nature's Recyclers* on page 108 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

2. This extension builds on the wrap-up question in step 9 of *Doing the Activity*, "How might sow or pill bugs be important to a forest ecosystem?" Make sure to touch upon the following questions in an expanded discussion on the role of ***decomposers*** in an ***ecosystem***.

a. What is an ecosystem service?
An ecosystem service is a vital function that some organisms in the ecosystem provide for the benefit of all the others. For instance, plants produce oxygen that other animals need to survive. Decomposition is another ecosystem service that organisms such as pill bugs and sow bugs provide. If they didn't exist, dead matter would pile up on the forest floor, and all the nutrients locked within that matter would not be recycled back into the ecosystem.

b. Do decomposers obtain their food by killing organisms?
No, most decomposers are not responsible for killing an organism. For instance, decomposers that specialize on dead plant matter usually don't eat living plants—they are not ***herbivores****. Similarly, decomposers don't hunt down living animals like* ***carnivores*** *do; they consume and break down dead animal tissues instead.*

c. What sorts of waste can students imagine finding in a forest?
Leaf litter; pieces of fallen ***bark****; dead trees; dead animals; cast-off skins of animals that molt, such as snakes or cicadas; empty egg shells; animal droppings; and fallen fruit are among the dead matter that may be found in a forest.*

d. What are other examples of decomposing organisms?
Decomposers are abundant in our ecosystem and likely outnumber all other groups of organisms in diversity and quantity. But many of these organisms are unfamiliar to us because they are either microscopic (Figure 8) or hidden deep in the soil or within plants and animals. These may include insects such as beetle grubs or fly maggots, numerous fungi, and countless bacteria.

Illustration: Geetha S. Iyer

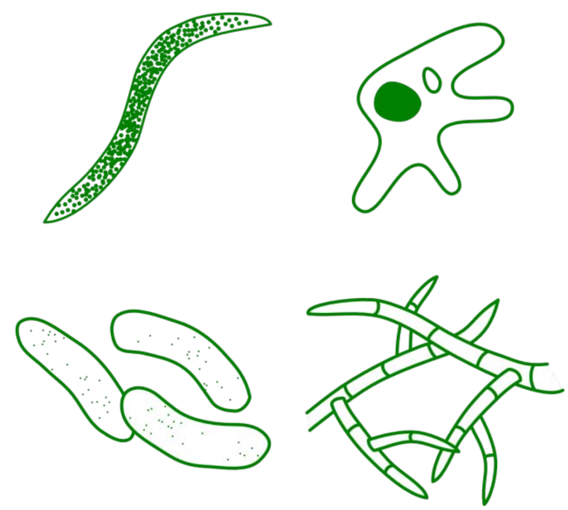


Figure 8. Tiny titans: Most decomposing organisms are microscopic, but they have an immense impact on ecosystem health. Clockwise from top left: nematode, amoeba, filaments of a fungus, and soil bacteria.

3. Wrap up the discussion by telling students that while decomposers such as insects and fungi do not kill organisms, other insects and fungi certainly can. Ask students to contemplate whether organisms that could damage, ***disease***, or kill trees are essentially good or bad for the ecosystem. Can they be both? Impress upon students the important roles of all organisms in a healthy ecosystem—when some organisms die, others profit. This process is cyclic. For instance, the nutrients released by decomposition of an old tree may favor the growth of seeds that the tree produced before it died.

Section 2

Forest Insects and Diseases

Forest health is commonly associated with mitigation of insect pests and disease-causing pathogens such fungi that attack trees in large numbers. While outbreaks certainly do occur, most native insects and pathogens prefer to chisel and seep into weak, injured, or stressed trees. These organisms play a critical role in maintaining healthy forests—not contributing to their demise. Their activities thin out competition and make it possible for the healthiest and strongest trees to reproduce. They also create habitat, recycle nutrients, and are prey for other forest organisms.

Native insects and pathogens, during a population boom, may seem to be wreaking a forest, but it is important to keep in mind that they are merely responding to existing environmental cues. Some historic disease and insect outbreaks have been triggered by changes in the ecosystem. Fire suppression, an altered water table or drought, catastrophic wildfire, or development in the wildland-urban interface are factors that influence the health of trees. Weakened or stressed trees in great numbers create perfect conditions for tree-feeding insects and pathogens to proliferate. In effect, they act as a buffering system, clearing away feeble and dying trees when the forest is unhealthy.

It is sometimes challenging to know if an increase in an insect or pathogen's population is a natural part of a healthy forest cycle or an indicator of poor health that should be addressed by managers. Sometimes, however, there is no doubt. Gypsy moths, redbay ambrosia beetles, and hemlock woolly adelgids are a few examples of insects that have caused irreparable damage to forests. Fungal pathogens causing diseases on American elm, American chestnut, and, recently, redbay trees have the capacity to locally eradicate their hosts and have in fact decimated these tree species in parts of the United States. Not coincidentally, these insects and disease pathogens are invasive exotic organisms, introduced from elsewhere in the world. Invasive exotics in non-native habitats find themselves released from their usual competitive and adaptive pressures—they are thus able to take advantage of native organisms by overwhelming their defenses or out-competing them.

The eight activities in this section help students become more familiar with native and non-native insects and disease-causing pathogens in Florida. A unit on forest health should be complemented by PLT activities from the previous section on forest ecosystems. Modifications to *Birds and Worms* (PLT Activity 25 on page 22), *Tree Factory* (PLT Activity 63 on page 27), *Can It Be Real?* (PLT Activity 11 on page 40), *Dynamic Duos* (PLT Activity 26 on page 43), and *Habitat Pen Pals* (PLT Activity 7 on page 46), encourage you to use examples of Florida insects and fungi when teaching about camouflage, tree biology, and ecological relationships. Information in these pages as well as complementary information on websites provide fascinating glimpses into the world of nature in our own neighborhoods.

Modifications to *Trees in Trouble* (PLT Activity 77 on page 39) and *Tree Cookies* (PLT Activity 76 on page 48) help you focus a bit more on evidence of disease and damage in forests and how individual trees respond to wounds and infection. Both concepts are introduced in the original PLT activities and enhanced in these modifications.

One new activity completes this section by introducing *The Disease Triangle* (page 29)—a concept that conveys when and why diseases are able to progress in an ecosystem. This game has been a favorite in teacher workshops and field days and will help your students better understand the complex ways fungi influence forest health.

Extension to PLT Activity 25

Birds and Worms

Lesson Summary

The original *Birds and Worms* introduces students to the concept of camouflage. Students experience the challenge of hunting for camouflaged objects by pretending to be birds picking worms.

This extension to *Birds and Worms* familiarizes students with some common insects in Florida that use camouflage to escape predators as well as hide from prey. This extension may be used following the original *Birds and Worms* or as a stand-alone activity.

Materials

For each student
1 copy of *Student Page A* (1 page).
1 copy of *Student Page C* (1 page).

For teacher
1 copy of *Student Page B* (1 page).
1 pair of scissors.

Time Considerations

60 minutes

Background

Insects are important elements in a forest food web, as predators and prey, but they live longer and reproduce more if they can hide from their antagonists. In *Birds and Worms*, students are introduced to two ***camouflage*** strategies that prey employ against predators: ***cryptic coloration*** to blend in with the environment; and behavior such as holding still.

Many animals can use a combination of coloration and patterning with behavior to become nearly invisible in their surroundings. A green grasshopper is hard to see in green grass blades. A slender walking stick is easily overlooked in a thicket of twigs and branches. A flat and motionless, speckled moth can be nearly invisible on the ***bark*** of a tree.

Additionally, insects' shapes can also be used to mimic their surroundings. For example, the wings of a katydid (Figure 9) resemble the shape of a leaf, making the insect difficult to tell apart from the leaves of trees and shrubs it feeds on.

Photo: Joseph Berger, Bugwood.org

Figure 9. Good food needs good camouflage: A katydid pretends to be a leaf.

Some insects do not use their camouflage to hide from predators but rather to surprise the animals they intend to eat. Predators can use concealment to remain undetected and ambush prey when they come close enough to be captured. Predators such as the praying mantis use camouflage for hunting and hiding—the mantis is just as appealing a meal to a bird as a beetle might be to the mantis.

While many insects use color to blend into their surroundings, some use coloration to stand out against their environment. Bright colors or flashy patterns may not seem like a good strategy for survival, but some bad-tasting organisms use this to indicate to predators that they are dangerous. For example, monarch caterpillars and butterflies are brightly colored to warn predators of their toxic taste. Curiously, other innocuous insects use ***warning mimicry***, copying these brilliant warning colors, to avoid being eaten. Obviously, this only works for birds or other animals that have first eaten a bad tasting insect and lived to avoid the copycats.

In a healthy forest, insects are key. In their various shapes, sizes, and colors, they are indispensible parts of the ***ecosystem***. Insects have evolved defensive and offensive strategies to maximize their survival in a bug-eat-bug world. Camouflage is one such ingenious adaptation.

Getting Ready

- Read the *Background*, *Doing the Activity*, *Teacher Discussion Guide, Teacher Game Guide*, and *Student Page* sections to familiarize yourself with the material.
- Prepare the supplies outlined in the *Materials* section.

- For each student:
  - 1 copy of *Student Page A* (1 page).
  - 1 copy of *Student Page C* (1 page).
- For the teacher:
  - 1 copy of *Student Page B* (1 page).
  - 1 pair of scissors.

Cut *Student Page* into four individual cards for use in class. You may opt not to print *Student Page A*, which is best used in full color, and instead use a visual presentation.

Doing the Activity

60 minutes

1. Use the following questions to revisit concepts taught in the original *Birds and Worms*.

a. What is camouflage?

b. Can you name some animals that use camouflage?

c. Why do animals use camouflage?
Point out that both predators and prey may use it.

d. How do animals camouflage themselves?
They use shape, color, and behavior.

2. Distribute copies of *Student Page A*. Alternately, see *Resources and References* to access a full-color visual presentation of the *Student Page* pictures to be used instead of the handout.

Ask students to hunt for the insects in the pictures and guess how (through shape, color, and behavior) and why each is camouflaged. List answers on the blackboard.

3. Divide the class into four groups and give each an insect card copied from *Student Page B*. Allow students ten minutes to decide how to act out their insects so other students can try to guess which picture matches the skit. When correctly guessed, the group can verify the name of its insect.

4. Distribute *Student Page C*, with descriptions of all four insects. Allow students time to read each of the descriptions and match them to the correct picture. Review the answers with your students using the *Answer Key*. Ask them the following hypothetical questions.

a. Did all of the insects in the activity use camouflage for protection against predators?
No, camouflage hides both predators and prey. Just as a tiger's stripes help it blend into the long grasses while it hunts, tiny predators such as wheel bugs lurk among leaves and twigs to viciously ambush their prey.

b. If part of a forest were cut down and converted to a grass pasture, would all of the insects be camouflaged? How would this affect each insect's survival?
Displaced insects have a lot to worry about—they may lose their specific food sources and shelter areas. Even if an insect were able to find food and shelter in a disturbed environment, it would have to contend with being mismatched with its surroundings. It could be preyed upon by opportunistic predators that hunt in disturbed habitats.

5. Wrap up the activity with a discussion about how essential each student thinks these four insects are to the health of the forest. Ask them to rate, from 1 to 4, the most-to-least valuable of the insects and make a tally of the results. You may do so by asking questions such as "What is the most useful insect in the forest?" or "What is the most destructive insect in the forest?" and counting students' show of hands for each insect.

Students may say that the forest tent caterpillar is the most destructive of the insects, and the wheel bug is the most useful. You can push students to think harder about why they perceive some insects to be more important than others by asking, "So, can we do away with this insect for the good of the whole forest?" Help them realize that while some insects may be destructive to other plants or animals, this is part of their role in the forest. For instance, if forest tent caterpillars didn't exist, what would the birds eat instead? How would plants on the forest floor photosynthesize if the caterpillars didn't eat away the shade leaves in the canopy?

All the insects in this activity are Florida ***natives***. Questions of usefulness, value, and importance may be answered very differently if ***exotic invasive*** insects were under consideration. See *New Activity 4: Secrets of the Invasive Exotics* (page 58) for more on this concept.

Student Page C Answer Key

1. b. Wheel bug, **2.** c. Aphid, **3.** d. Forest tent caterpillar, **4.** a. Cicada

Resources and References

- The University of Florida's SFRC Extension website for educators includes a supplementary visual presentation to this activity.
  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

Student Page A

Name:

Where am I?

Instructions

There are four strange creatures hidden in these pictures. Can you spot them all? What makes them so hard to find? Who are they hiding from?

a.

b.

c.

d.

Photos: a) G. Keith Douce, University of Georgia, Bugwood.org, b) Joseph Berger, Bugwood.org, c) Whitney Cranshaw, Colorado State University, Bugwood.org, d) Steven Katovich, USDA Forest Service, Bugwood.org.

Student Page B

Insect Cards

Instructions

Copy this page and cut along the dotted lines. Divide your class into four groups, hand a card to each group, and ask the groups to come up with a skit that represents the insect described on their card.

I am a dark brown insect. I have a tube-like mouth similar to a butterfly, but I do not eat nectar. Instead, I feed on the insects that visit forest flowers, like bees, aphids, beetles, and butterflies. I am usually found on blooming plants. I wait for an opportunity to ambush an insect. I insert my sharp mouth part into the insect and drink my meal. I am considered a good insect because I eat many of the pests that feed upon plants. My name comes from the semicircle-shaped bump on my back. I am the wheel bug.

I am a tiny insect. I am so small that I can hide on the undersides of leaves, on stems, and in flowers. I suck juices from inside plant leaves. Sometimes, I spread diseases when I travel from plant to plant in the forest. Honeydew, my sugary waste, also creates problems for a plant by causing a mold to grow on its leaves and stems. This can make photosynthesis difficult. Ladybugs and lacewing flies love to eat me, but I use camouflage to hide from my predators. I am the aphid.

I live with my brothers and sisters and am often seen crawling up tree trunks in the forest. I love to eat the leaves from oaks, elms, and maples. I spin silk to travel to other parts of the tree where more leaves may be found. Sometimes my siblings and I are so hungry that we eat until the tree doesn't have any leaves left. Don't worry. The leaves grow back. If you are trying to spot me, look for a dark, hairy caterpillar with white markings on the back. My pattern helps me blend into the tree bark. I am the forest tent caterpillar.

As a young insect I live underground. I eat xylem sap from plant roots. To become an adult, I must crawl from the soil and latch onto a tree trunk or stem, where I shed my exoskeleton. Although many of my kind emerge only once every 13 or 17 years, as an adult I emerge every year in Florida forests. I can be heard calling to attract females; this often draws the attention of birds and other predators. I use camouflage to hide on tree bark. If that doesn't work I can squawk to frighten the predator away. I am the cicada.

Student Page C

Name:

Who am I?

Instructions

You've just seen four insects that are really good at hiding in plain sight. Can you name them all? Read the descriptions and try to match them to the right insect.

1. I am a dark brown insect. I have a tube-like mouth similar to a butterfly, but I do not eat nectar. Instead, I feed on the insects that visit forest flowers, like bees, aphids, beetles, and butterflies. I am usually found on blooming plants. I wait for an opportunity to ambush an insect. I insert my sharp mouth part into the insect and drink my meal. I am considered a good insect because I eat many of the pests that feed upon plants. My name comes from the semicircle-shaped bump on my back. Who am I?________________________________	**2.** I am a tiny insect. I am so small that I can hide on the undersides of leaves, on stems, and in flowers. I suck juices from inside plant leaves. Sometimes, I spread diseases when I travel from plant to plant in the forest. Honeydew, my sugary waste, also creates problems for a plant by causing a mold to grow on its leaves and stems. This can make photosynthesis difficult. Ladybugs and lacewing flies love to eat me, but I use camouflage to hide from my predators. Who am I?________________________________
3. I live with my brothers and sisters and am often seen crawling up tree trunks in the forest. I love to eat the leaves from oaks, elms, and maples. I spin silk to travel to other parts of the tree where more leaves may be found. Sometimes my siblings and I are so hungry that we eat until the tree doesn't have any leaves left. Don't worry. The leaves grow back. If you are trying to spot me, look for a dark, hairy caterpillar with white markings on the back. My pattern helps me blend into the tree bark. Who am I?________________________________	**4.** As a young insect I live underground. I eat xylem sap from plant roots. To become an adult, I must crawl from the soil and latch onto a tree trunk or stem, where I shed my exoskeleton. Although many of my kind emerge only once every 13 or 17 years, as an adult I emerge every year in Florida forests. I can be heard calling to attract females; this often draws the attention of birds and other predators. I use camouflage to hide on tree bark. If that doesn't work I can squawk to frighten the predator away. Who am I?________________________________

Extension to PLT Activity 63

Tree Factory

Lesson Summary

The original *Tree Factory* asks students to “build a tree” by acting out different tree parts, such as leaves, bark, and roots. As they act out these roles, they learn about the functions of the various parts of the tree.

This extension to *Tree Factory* allows students to represent organisms that feed upon virtually every part of a tree. Insects and fungi, both closely evolved with plants, have developed multiple relationships with trees. The extension focuses on feeding relationships of insects and fungi upon various parts of the tree, and their effects on tree health. Should populations of some of these insects or fungi reach epidemic levels, they could affect the health of the entire forest.

Doing the Activity

1. Read the original version of *Tree Factory* on page 269 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

Tree Factory originally assigns 30 roles for students to play as different parts of a single tree. In this extension more roles are created for insects and fungi. Many insects and fungi are ***host***-specific—they only attack particular genera or species of trees. Since it would be inaccurate to model all these ***pests*** and ***pathogens*** attacking the same generic tree, you will have students act out parts of specific tree species instead.

2. After completing the original *Tree Factory*, review the various parts of the tree. Explain that each of these parts may provide food for organisms that have developed ways to obtain it.

Take it outside

This activity requires space for students to act and can be easily conducted outdoors. Consider finding a place where you can reinforce students’ understanding of the tree parts they are playing by pointing to the relevant parts of real trees in their surroundings.

3. Assign some students new roles—they will now become plant pests or pathogens that attack the various tree parts. You may find it useful to copy out the following roles on slips of paper to hand to students.

a. I am a *Ganoderma* (gan-o-DER-mah) fungus, and I like feeding on ***lateral roots***. I say “Rot away side roots! Rot away side roots!” as I surround the base of the tree with my net of fungal hairs.

b. I am a *Heterobasidion* (HET-er-o-ba-SEE-di-on) fungus, and I like feeding on the tree’s ***taproot***. I say “Yum, yum, anchor root chum! Yum, yum, anchor root chum!” as I decay the main root with my net of fungal hairs.

c. I am the red heart fungus, and I like feeding on the ***heartwood*** of longleaf pine trees. I say, “Hollow out heartwood! Hollow out heartwood!” as I work my way deep into the heart of the tree.

d. I am the larva of a metallic wood-boring beetle, and I tunnel through the ***xylem*** of living trees. I say “Eat wood, tunneling forward. Tunnel forward, eating wood!” as I cozily munch within the tree.

e. I am the long-horned beetle. I tunnel through the ***phloem***, or inner bark, causing damage to the tree. I say, “Sugar sap, I like that! This inner bark can’t bite back!” as I chew away inside the tree.

f. I am the ***exotic*** beech scale insect. I sit on the thin, smooth, outside ***bark*** of a beech tree with my sisters and use my needle mouth to suck at the sap from the inner bark. This makes wounds that let in beech bark fungus too. Together, the fungus and I are killing beech forests all over eastern North America. I say, “Slurp, slurp, sugar sap, beech bark fungus, try some of that!”

g. I am the forest tent caterpillar. I make webby tents in the branches with my brothers and sisters and feed on tree leaves. I say, “Chew away leaves, chew them all, chew away leaves, make the tree bald!” as I eat all the leaves off the tree.

4. Using the information in step 3, and what students have already learned, have students come up in turns to act out what happens below ground, within and upon the trunk, and in the canopy. Assign enough students to each role so that everyone gets a chance to act out a part. Have the tree parts repeat the sounds and words they chanted when playing the whole tree in the original PLT activity. Remember that students playing tree parts are not making up one tree, but several specific tree species' parts.

- Below ground scene: Taproot, lateral roots, *Ganoderma* fungus, *Annosum* fungus.
- Trunk scene: Heartwood, xylem, cambium, phloem, bark, metallic wood-boring beetle larva, long-horned beetle.
- Longleaf pine trunk scene: Heartwood, xylem, cambium, phloem, bark, red heart fungus.
- Beech trunk scene: Heartwood, xylem, cambium, phloem, bark, beech scale insect.
- Canopy scene: Heartwood (with strings for branches), leaves, forest tent caterpillar.

5. Wrap up the activity with a discussion about the significance of insects and fungi in forests. Consider using the following questions to guide your discussion.

a. Do trees have defenses to protect from insects and fungi?

Yes, trees have several defenses against pests and pathogens. Toxic chemicals in the leaves and sap; sticky resin; thick bark; and unpalatable, hairy leaves and stems are among the adaptations that trees have developed.

b. Why are some insects and fungi still able to feed upon trees?

All organisms struggle to survive, and many insects and fungi have adapted to counteract tree defenses so they can feed. Many kinds of insects and fungi cannot attack a tree unless it is already stressed, weakened, or dying. Ask students to describe some of the adaptations they noticed that were used to counteract the trees defenses. For instance, the beech scale insect has a long, needle-like mouth to pierce through the outer bark of beech trees. Fungi put out specialized enzymes to break down tree parts like heartwood or bark.

c. Are insects and fungi necessary in a forest? Why?

*Prompt students to think about how other organisms may benefit from the damage and **disease** wrought by pests and pathogens. For instance, forest tent caterpillars may defoliate trees, but this lets in light to the forest floor, to the advantage of understory plants. Most insects become food for other organisms, such as lizards and birds. The red heart fungus of longleaf pines creates valuable habitat for the endangered red-cockaded woodpecker, which nests in the cavities left behind after the inner wood has rotted away. Other fungi recycle valuable nutrients into the soil, even as they rot away roots and stems of trees.*

d. When can insects or fungi be harmful in a forest?

*As noted previously, trees, insects, and fungi are co-evolved, and keep each others' growth in check. But sometimes an **ecosystem** can be destabilized—such as when a new organism is introduced to an area where none of the **natives** have evolved defenses against it. Such has been the case with the exotic beech scale insect. The beeches of North America have no adaptations to counter the attack of this organism, which is why beech trees have nearly disappeared from the eastern United States.*

*Ecosystems are naturally resilient—they can bounce back from disruptions. Generally, the more diverse an ecosystem, the better able it is to adapt to changes. However, the health of an ecosystem may be compromised when the quality of the system's dynamics is altered. For example, fragmentation by roads, water pollution, climate change, and the presence of many **invasive** exotic species may cumulatively take a toll on a forest. So while the effects of any one pest or pathogenic organism may not normally alter the forest, in a stressed or compromised ecosystem, the impacts of such organisms may be magnified.*

Photo: Larry Korhnak

New Activity 3

The Disease Triangle

Sunshine State Standards

SC.5.L.15.1: Describe how, when the environment changes, differences between individuals allow some plants and animals to survive and reproduce while others die or move to new locations.
SC.5.L.17.1: Compare and contrast adaptations displayed by animals and plants that enable them to survive in different environments such as life cycles variations, animal behaviors, and physical characteristics.
SC.7.L.15.2: Explore the scientific theory of evolution by recognizing and explaining ways in which genetic variation and environmental factors contribute to evolution by natural selection and diversity of organisms.
SC.7.L.17.2: Compare and contrast the relationships among organisms such as mutualism, predation, parasitism, competition, and commensalism.
SC.7.L.17.3: Describe and investigate various limiting factors in the local ecosystem and their impact on native populations, including food, shelter, water, space, disease, parasitism, predation, and nesting sites.

Materials

For each student:
3 paper plates.
1 marker.

For the teacher (optional):
2–3 copies of the *Student Page* section (2 pages).
1 pair of scissors.
1 copy of the Teacher Guides (2 pages).

Time Considerations

90 minutes

Behavioral Objectives

Students should be able to do the following:

- Identify the three components of the disease triangle.
- Name the pathogen, host, and environmental conditions necessary for a particular disease to occur.
- Describe how a particular forest management technique can decrease disease incidence in a forest.

Lesson Summary

This activity introduces students to an important forest health concept—the disease triangle. Students participate in an outdoor game where they act as pathogenic organisms infecting "trees" in a model forest. Through this simulation of the dynamics of infection they learn about the importance of pathogen, host, and environmental specificity—the three prerequisites necessary for disease occurrence in an organism.

The disease triangle is an important tool for understanding the dynamics of infectious disease in populations, as much for trees in a forest as for people in a city. Management of disease is effectively carried out by manipulating at least one side of the triangle to reduce the likelihood of infection.

Background

The Disease Triangle

A ***disease*** is a sustained or progressive impairment of an organism's cells or tissues that causes structural or functional abnormalities. Some diseases are superficial, marring only the physical appearance of the plant or animal they infect, while other diseases may take a greater toll by affecting tissues critical to the organism's growth, weakening or even killing the infected plant or animal. A disease occurs when a disease-causing agent, or ***pathogen***, meets the right ***host*** organism under ***environmental conditions*** favorable to disease development.

These three elements, pathogen, host, and environmental conditions, make up the ***disease triangle***. The disease triangle is a concept that illustrates the importance of all three elements—just as there are three sides to a triangle, there are three critical factors necessary for disease to develop.

First, a pathogen must be present in the environment. Disease-causing plant pathogens include fungi, viruses, bacteria, and other microbes. Next, a pathogen must come in contact with a susceptible host. Pathogen-host interactions are often very specific, some pathogens having evolved to attack only a particular genus or even species of organism. If an appropriate host cannot be found, the disease will not be present, since the pathogen is missing its food source.

Additionally, even if a species is susceptible, not all individuals within that species will have the same level of susceptibility. An individual tree may have genes that defend it against infection. This is known as ***resistance***. Finally, the right environmental conditions must be present for the pathogen to cause disease. Many pathogens thrive in conditions that stress host trees: flooding, drought, imbalanced nutrition, inadequate sunlight, and wounds, for example, can induce stress or injury in host plants, making them vulnerable to disease.

In this activity, students explore the relationship between pathogens, hosts, and the environment over time, by playing an interactive game. Two organisms, the pitch canker fungus and the oak leaf blister fungus, are used to demonstrate this relationship. For a similar game that explores insect damage on trees in the forest, see *Resources and References*.

Pitch Canker and Oak Wilt

Pitch canker is a disease that affects pine trees. The pitch canker fungus, *Fusarium circinatum*, favors slash pine trees, although it can be hosted by all species of southern pines including longleaf, loblolly, and sand pine. The fungus releases airborne ***spores*** that germinate in entry points upon pine trees such as wounds caused by insect **herbivores**, lightning or wind damage, or mechanical injury from equipment. Once inside a tree, the fungus feeds upon woody stem and branch tissue causing lesions, or cankers, to form. The diseased tissue in the cankers becomes soaked with resin, or pitch, so much so that the pitch begins to seep out of the cankers—this characteristic bleeding is a symptom of pitch canker disease (Figure 10).

Signs of pitch canker disease in trees include whole branches dying off—their needles turning brown, and the tree developing "flags" of dead branches. If the infection is severe, the pine may die of the disease. The fungus requires warm, wet weather to release its spores into the environment, and host wounds are necessary to facilitate infection.

Photo: L. D. Dwinell, USDA Forest Service, Bugwood.org l

Figure 10. Pitch soaking: This branch is soaked with resin from infection. Resin that has seeped out of the canker forms a clotted, sticky, white residue on the branch.

Pitch canker disease is problematic because it can severely impact pine plantations. In the Southeast, slash pine plantations are particularly vulnerable. In California, the much-valued ***native*** Monterey pine is heavily impacted. Furthermore, since Monterey pine is grown internationally on timber plantations, pitch canker is a disease that concerns forest managers around the world.

Oak leaf blister is another fungal disease. The fungal pathogen, *Taphrina caerulescens*, produces light green or brown-colored blisters on the leaves of susceptible oak trees in the spring (Figure 11). During the summer, these blisters produce microscopic spores that can create a white or yellow powder on the oak leaves. The spores are carried to new leaves by wind or rain. Spores remain dormant on twigs or in bud scales on new host trees through the fall and winter, waiting for cool, wet weather to germinate and infect young leaves produced in the spring. While this disease does not typically kill oak trees, oak leaf blister can cause early defoliation in late spring or early summer. Oak leaf blister is often called a cosmetic disease, because it may appear ugly, but does not substantially affect infected trees.

Photo: Andrew J. Boone, South Carolina Forestry Commission, Bugwood.org

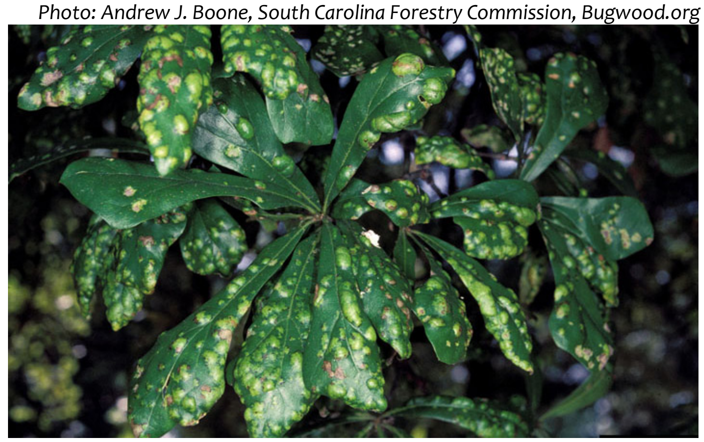


Figure 11. Beauty and the blister: Although oak leaf blister looks alarming on oak leaves, it does not jeopardize the tree's health.

Ecosystem health: Does the disease matter?

Disease is a natural occurrence—it is a function of an ***ecosystem*** containing multiple interacting parts. Fungi, bacteria, viruses, nematodes, and various other microorganisms prey upon plants and animals, and may infect them with varying degrees of severity. Nutritional deficiencies and other ***abiotic stressors*** may also trigger disease in organisms. Is disease always a bad thing?

While disease-causing agents are often seen in a negative light, there are positive and even indispensible roles that these agents play. They place adaptive pressures on organisms, such that those plants and animals with adaptations against infection are selected for, and those that are poorly adapted are disadvantaged. Apart from the role that infectious agents have played in organismal evolution, on a day-to-day basis pathogens are directly or indirectly responsible for ***decomposition*** in ecosystems. Death and subsequent decomposition recycles valuable matter in an ecosystem and allows living organisms to flourish.

It may not be easy to visualize bacteria or fungi infecting trees. However, the impacts, both positive and negative, of tree diseases cannot be overlooked. They are as significant as diseases in humans in terms of the effects they have on populations and ecosystems. In some ways, it may be easy to teach about tree diseases using human diseases as an analogy. However, there are limitations to this strategy—while it may be equally true that disease agents place selective pressures on individuals, and that individual deaths occur to the advantage of a population, it does make a difference when talking about individual humans as opposed to trees. And in both scenarios, while some level of disease is always present in the system, be it forest or city, an epidemic that can decimate populations has severe consequences.

Getting Ready

- Read the *Background*, *Doing the Activity*, *Teacher Discussion Guide*, *Teacher Game Guide*, and *Student Page* sections to familiarize yourself with the material.
- Prepare the supplies outlined in the *Materials* section.
  - For each student:
    - 3 paper plates.
    - 1 marker.
  - For the teacher (optional):
    - 2–3 copies of the *Student Page* section, depending on the size of the class.
    - 1 pair of scissors.

    Make enough copies and to cut out pathogen cards for each student.
    - 1 copy of the *Teacher Discussion Guide* and *Teacher Game Guide* (2 pages) for your convenience while doing the activity.

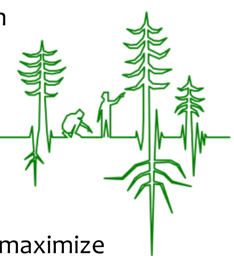
Doing the Activity

90 minutes

1. Ask students what they think a disease is. The *Background* section provides a definition that you may use in class. Additionally, the *Teacher Discussion Guide* on page 34 has information to help you facilitate a discussion on disease development; you may wish to make a copy of the page as a quick reference during class. Be sure to cover each of the topics outlined and clearly indicate to students that a pathogen, an appropriate host, and the right environmental conditions are necessary for disease to occur on a tree. Also, point out the importance of tree resistance to disease.

2. Tell students that they are going to take part in an activity to understand how disease spreads through a forest. Hand out three plates and a marker to each student. Ask each student to draw a big "P" on the top of two plates. The "P" plates represent pine trees. Ask the students to draw an "O" on the top of their third plate. The "O" plates represent oak trees.

Collect all the plates; write "R" on the bottom of about a quarter of the "O" plates and about a quarter of the "P" plates. This "R" represents resistance in a tree. You can also prepare these "trees" before class to reduce the activity time. See *Extension Ideas* for a student variation on making paper plates.



Take it outside

The rest of this activity requires open space for students to move around. Consider taking the activity outdoors to maximize students' ability to have fun and learn at the same time.

3. Inform students that each of the paper plates represents a tree; a plate with a "P" represents a pine tree and a plate with an "O" represents an oak tree. Ask students to help you create a pine-dominated forest by scattering the plates on the ground. Make sure none of the plates are overlapping and the "P" and "O" sides are facing up.

4. The remaining steps instruct you to carry out this activity using both pitch canker and oak leaf blister to explain concepts. If you wish to conduct this activity with younger audiences, merely omit any references to pitch canker. In other words, *all* students will play the roles of oak leaf blister fungi and you need only read out the description of oak leaf blister fungus from Table 1 and make copies of only page 1 of the *Student Page* section, which includes information about the oak leaf blister fungus.

Ask each student to pretend to be one of two pathogens. Split the class in half and designate one half as the oak leaf blister fungus and the other as the pitch canker fungus. Tell each group of students to listen carefully to the description of the disease their fungus causes. You may ask students to write down the pathogen, host, and environmental conditions necessary for their disease to form (Figure 12) or you may hand out copies of the pathogen cards found in the *Student Page* section as a memory aid. Read both statements that follow (Table 1) out loud to the class, placing emphasis where indicated in bold caps.

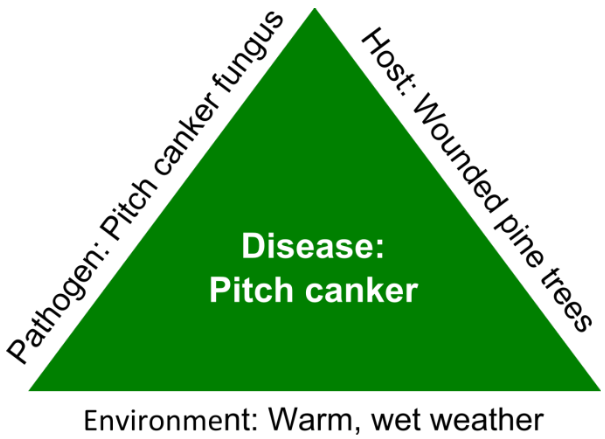


Figure 12. You may ask students to make a disease triangle memory aid as shown here for pitch canker. Ask students to draw a triangle and complete each side with the appropriate host, environmental conditions, and pathogen for their diseases.

Table 1. Diseases of trees.

Oak leaf blister	The disease, oak leaf blister, is caused by a fungus that grows on **OAK LEAVES**. **COOL, WET WEATHER** is needed for this fungus to germinate on new, young leaves each year.
Pitch canker	The disease, pitch canker, is caused by a fungus that grows within pine wood and bark tissues by entering through wounds in the stems and branches. **WARM, WET WEATHER** is needed for this fungus to germinate and infect **WOUNDED PINES**.

5. Tell students that as pathogens they will try to spread disease in the forest, but point out that not all of the trees are the same. Remind them that some are oak trees and others are pine trees. The pitch canker fungus only attacks pine trees and the oak leaf blister fungus only affects oak trees. In addition, some of the hosts have genes that make them resistant to oak leaf blister or pitch canker. A resistant tree is identified by an "R" on the bottom of the plate. Remind students of the disease triangle by asking them to identify the three elements necessary for their disease to occur and how each is represented in the game: a pathogen (each student), a fitting host (the correctly lettered paper plates without an "R" on the back), and the right environmental conditions (read out loud by you) are necessary for the disease to develop and spread.

6. Ask the students to stand around the edges of the "forest" with their markers in hand. Read the following instructions to the students.

"We are all standing around the edges of a mixed hardwood forest. The paper plates you see in front of you represent the trees in the forest. Would someone like to remind us what the "P" on the paper plate stands for? *(Pine)* And what about the "O," what kind of tree does that represent? *(Oak)*.

"Now, all of you are going to play the roles of fungi that feed on trees. You are pathogens, because you can spread disease to trees. You travel in the form of tiny, seed-like spores through the wind. When you land on a tree, you try to germinate, infect the tree and cause disease.

"I am going to tell you what the environmental conditions are like for each round. If the environmental conditions are right for you, the fungus, you must travel into the forest in search of your preferred host tree. I will tell you how many steps to take if the environmental conditions are right. You must take each step with one foot in front of the other, heel touching toe. Once your foot touches a plate that is a suitable host, you may flip the plate to see if it is resistant. If the tree is resistant (has an "R" on the bottom of the plate), you may not infect the tree, unless otherwise stated in the round. If the tree is susceptible (not resistant or has nothing on the bottom of the plate) you may draw a small "x" on that tree. The "x" shows that that tree is diseased. Make sure you place the plate back on the ground with the top facing up.

"Pitch canker disease may eventually kill a tree. If the tree is infected three times, in other words, if you are the third pitch canker fungus to mark an "x" on a pine tree, fold up the plate so that others may know it is dead and cannot be infected. Oak leaf blister fungus only causes a cosmetic defect; this does not affect the life of the tree. The oak leaf blister fungus may infect oak trees many times, no matter how many "x" marks are already on it.

"If you reach a tree and still have steps remaining in that round, you may infect that tree and keep on moving toward another one. If you reach another tree in the same turn, you are allowed to infect the second tree as well. Multiple students may infect a tree during each round, but each student, after infecting a tree, cannot revisit that tree again."

7. Using the Teacher Game Guide on page 35, read the first round to instruct the pathogens on what the environmental conditions are like, and whether or not they can move. Allow ample time for students to move through the forest and infect trees before reading the next round. Continue through all 10 rounds.

8. After, the activity, ask the students to gather around the forest once again. Ask them to think about what was necessary for disease to form. Review the disease triangle again. Guide a discussion about how the forest changed and what made pathogens successful or unsuccessful. Use the following questions to guide your discussion. Note that the answers to some of these questions will differ depending on whether you conduct the advanced or simpler version of the activity. Use the appropriate suggested answers to guide discussion.

a. How many trees were killed?

b. What types of trees were killed?

c. Does this change the ***composition*** of the forest? In other words, does the forest look different now than it did before?

Advanced version: There are now more dead trees in the forest. If the pitch canker fungus has been particularly effective, the forest has changed from a mixed pine/oak forest to one that is dominated by oaks.

Simple version: The forest composition has not changed, although some of the oaks are now diseased with oak leaf blister fungus.

d. If the forest were made up of only pine trees, what would have happened?

Advanced version: There would be a drastic increase in the number of dead trees in the forest, and only resistant pine trees may have remained standing.

Simple version: The oak leaf blister fungus, having no available hosts, would not have been able to affect the trees. The forest would remain unchanged.

e. What made you successful or unsuccessful at infecting a tree?

There needed to be appropriate environmental conditions for the fungus to travel. There needed to be available host trees to cause a disease. Resistant trees hindered the fungus' spread.

f. Were trees closer to a recently infected tree more likely to become diseased by a pathogen than trees on the other side of the forest?

Yes, proximity to diseased trees makes it easier for a fungus to travel from infected host to new host.

g. Do you think the same number of trees in the forest would have been killed if the trees were farther apart?

No, trees spread farther apart would have been harder to infect.

h. If you were planting trees in a park, what could you do to decrease the likelihood of disease?

Space them out and plant several species. Plant trees resistant to disease if possible.

9. You can rearrange the trees and conduct the activity again, or try the advanced version if you used the simpler version the first time. Use the *Disease Triangle* visual presentation on the website (*Resources and References*) to help students understand what forest management is. Choose a management technique to use in the activity. For example:

- Have students "plant fewer trees" by laying out fewer paper plates on the ground.
- Have students "plant trees further apart" by spacing out the paper plates.
- Have students "thin out an overcrowded forest" by going into a "pre-planted" overcrowded forest and removing selected paper plates.
- Have students "plant resistant trees" by selectively laying out only plates labeled with an "R."
- Repeat steps 6 through 8.

10. Discuss the changes in the forest and the impact of the selected management decision. Use the following questions to guide a closing discussion.

a. How many trees were killed?

b. How many trees were infected but not killed?

c. Did more trees survive using the selected management strategy?

d. Was this strategy successful?

e. What other ways might forest managers try to prevent or control disease?

Teacher Discussion Guide

Use the following questions to facilitate discussion throughout this activity. You may use all or some of the provided details to fit the scope of the discussion.

General disease

1. What kinds of diseases do people get?

Colds, flus, ear infections, cancer, heart disease, etc.

2. What causes them?

Bacteria, viruses, fungi, and other microbes cause many diseases. Environmental stressors and genetic predisposition contribute to others.

3. What do we do to protect ourselves against infections?

We may wash our hands, take vitamins, maintain a healthy diet, get plenty of sleep, or stay away from others who are sick.

Appropriate hosts

4. Do humans and cats get all of the same diseases?

No, they don't. For example, cats are susceptible to Feline Immunodeficiency Virus (FIV). There is no evidence that humans can contract this disease. Most diseases are species specific. However, some pathogens may act upon different species, usually related ones.

Environmental conditions

5. If someone spends the whole night awake outdoors in the rain, do you think he or she would be more likely to catch a cold than someone who hasn't?

Yes, staying outdoors in the rain puts stress on the body and makes a person more susceptible to attack by pathogens such as the cold virus.

Pathogens

6. Why are some sick students told not to come to school?

You can only catch a disease like the flu if you're exposed to the pathogen—in this case, the flu virus. Sick people carry the virus in their bodies and can release it into the air and onto surfaces by sneezing. The virus can then be transferred to other people who become new disease hosts. One method to stop disease from spreading is to remove pathogen carriers from the disease triangle equation—such as by asking sick students not to come to school while they are contagious.

Resistance

7. Do all people have the same likelihood of catching a disease?

No, some people may be resistant to a disease—that means their bodies may be more capable of fighting off the pathogen before it can do any damage. Some people may be genetically resistant to a disease. For example, during the 1300s, the Black Plague spread throughout Europe. Although everyone in a town may have been exposed to the deadly disease, only the susceptible members of the population died. two thirds of the Europe's population survived the Black Plague.

As another example, how many of us in the room have had chicken pox? Those who have already had chicken pox are now immune, or resistant, to the virus, and won't be affected by it again. Those who have never had chicken pox should be careful not to come in contact with those who currently have it, because their bodies have no resistance to the disease.

Trees and Disease

8. Do trees get diseases?

Yes. Trees are living organisms, just like humans and cats, and they are just as vulnerable to diseases.

9. What do you think may cause them?

Bacteria, viruses, fungi, and other microbes.

10. Do you think some kinds of trees are better hosts than others for a certain disease?

Yes. Refer to question 4. Trees have co-evolved with many other organisms, including pathogens such as fungi and bacteria. Specific trees have built up specific resistant mechanisms to some pathogens, and likewise, some pathogens have evolved special mechanisms to attack particular species of trees.

11. Can trees be stressed like humans?

Yes. Refer to question 5. When organisms are environmentally stressed, they are weakened and less able to defend themselves against attack by pathogens.

12. Can trees exhibit resistance?

Yes. Refer to question 7. Some trees have genetic resistance to disease, and others can fight back against a disease after being previously exposed to it. One of the worries for growers—especially those who plant crops such as corn, potatoes, oranges, or pines—is that if a disease hits one plant, it might spread to the entire crop. If the plants are all genetically similar (the seeds come from the same batch of plants and are all related), or if they are genetically identical clones, they may have no resistance to a particular disease once it enters their field or plantation. Tree genetic diversity is a way of ensuring that there will be at least some resistant individuals in a population.

Teacher Game Guide

Read the text for each round out loud to the class. Give students time to move between rounds.

Round 1: "It is early springtime, and the weather is damp and cool. Move **8 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Only the oak leaf fungus is able to move and cause infection.

Round 2: "Spring continues, but although it is cool, it hasn't rained in a few weeks. Move **2 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Neither the pitch canker fungus nor the oak leaf fungus is able to move.

Round 3: "It's now summertime, and there have been many thunderstorms. A lot of trees have broken branches on them. The air is hot and humid."

Representing the thunderstorm, you should walk through the forest crumpling up some of the paper plates (both oaks and pines), indicating that these are trees with broken branches. Alternately, have a student volunteer to be the storm and crumple some plates for you.

"Move **3 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Only the pitch canker fungus is able to able to move and cause infection.

Round 4: "There's an outbreak of eastern pine weevils. These beetles chew on pine tree twigs and cause wounds all over the trees while feeding and laying eggs."

Representing the weevils, again walk through the forest with a pencil to pierce holes representing weevil damage on the trees. Remember to only damage pine trees this time. Alternately, have a student volunteer to be the eastern pine weevils.

"Move **4 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Only the pitch canker fungus is able to able to move and cause infection.

Round 5: "It's now late fall and there has been a dry spell. The temperature is also dropping. Move **3 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Neither the pitch canker fungus nor the oak leaf fungus is able to move.

Round 6: "After a long cold winter, it's now spring again. There's new growth on the oak trees and there have been some cool spring showers. Move **10 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Only the oak leaf fungus is able to move and cause infection.

Round 7: "The forest is cool and damp because it has been raining persistently for weeks this early summer. Move **9 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Only the oak leaf fungus is able to move and cause infection.

Round 8: "It's the beginning of summer and the air is hot and dry. Move **3 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Neither the pitch canker fungus nor the oak leaf fungus is able to move.

Round 9: "It's timber harvest season! A timber company has driven giant tractors and other harvesting machines into the forest. Operating heavy machinery is difficult, and the harvesters have accidentally scraped against some trees and broken a few branches of neighboring while cutting down the trees they need. There hasn't been a rainstorm in weeks, and the forest it quite dry, though hot."

Representing the timber harversters, walk through the forest crumpling or damaging paper plates representing oaks and pines. Take away a couple of plates as your "harvest." Alternately, have a student represent the harvesters.

"Move **5 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Only the pitch canker fungus is able to move and cause infection.

Round 10: "Towards the end of summer there have been thunderstorms all month. It is humid and windy. Move **7 STEPS** if these conditions are right for you. If you reach a tree, remember to check for resistance."

Only the pitch canker fungus is able to move and cause infection.

Assessment

Using observations of students' behavior and responses during discussion, check that they can do the following:

- Understand that tree disease only occurs if a pathogen attacks a specific host under specific environmental conditions.
  Seen in students' actions during each round of the game.

Note that this is a group assessment rubric. To assess students individually, consider one of the following options.

- Ask each student to write a "wanted" ad from the perspective of the pathogen they played. They should include the environmental conditions and host needed.
- Each student can research a common disease found in trees. See *Resources and References* for ID cards that will give students material to work with. Students should include information about each of the three corners of the disease triangle for the disease card they are assigned.

Extension Ideas

- The preparation of paper plates representing pines and oaks can be an art activity carried out the day or week prior to conducting *The Disease Triangle*. Hand each student three paper plates. Ask them to paint a pine tree on each of two plates and an oak tree on the third plate. Pine trees are painted tall and spiky with dark green and dark brown paint. Oak trees are painted broad and fuzzy with light green and light brown paint. These can now be used to build the forest as described in the activity.

- Tell students to pretend they are natural resource managers. Their agency just inherited 200 acres of longleaf pine forest. The longleaf pine is a highly valued native tree that is an integral part of southeastern ecosystems. As a result, managers do not want to develop this land and would like to maintain it as a natural area devoted to longleaf pine restoration. Two miles away from the north end of the property, a land owner has discovered an outbreak of pitch canker on his slash pine plantation. Ask students to research pitch canker disease. Students should decide if action needs to be taken to protect the longleaf pine forest. What are the susceptible hosts for the pitch canker fungus? Would longleaf pine trees be affected by the fungus if it spreads from the slash pine plantation? Facilitate a discussion with students about how they would approach longleaf pine management with the owner of the slash pine plantation. Would there be conflicting interests between these two kinds of land managers? How might they cooperate?

Resources and References

- The University of Florida's SFRC Extension website for educators includes several related resources:
  - A *Disease Triangle* visual presentation complements this activity.
  - For another activity that models the disease triangle with a game see *Activity 3: How to Eat a Forest –Southern Pine Beetle-Style*, available in *Beyond the Trees*.
  - Several examples of tree disease are found in the *Pocket ID Guide*. These flash cards can be used to test students' understanding of the three sides of the disease triangle.

  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

- More information on the disease triangle and other aspects of forest pathology and health, are provided at James. J. Worrall, USDA Forest Service plant pathologist's website *Forest & Shade Tree Pathology.* Specific information related to this activity is found under "General Topics," "Disease, pathogen, names."
  Visit http://www.forestpathology.org/

Photo: Larry Kohrnak

Pathogen Cards

Instructions

Make copies and cut out the following cards to hand out to students as a reference while playing the disease triangle game. If you are working with younger audiences and want to conduct a simple version of this activity, only make copies OF page 1.

Oak Leaf Blister

Oak leaf blister is a disease caused by the **oak leaf blister fungus**. This fungus only affects **oak trees**. The oak leaf blister fungus produces microscopic, seed-like spores on oak leaves. These spores are spread by the wind. The spores need **cool, damp weather** to germinate and infect new oak leaves in the spring.

Oak Leaf Blister

Oak leaf blister is a disease caused by the **oak leaf blister fungus**. This fungus only affects **oak trees**. The oak leaf blister fungus produces microscopic, seed-like spores on oak leaves. These spores are spread by the wind. The spores need **cool, damp weather** to germinate and infect new oak leaves in the spring.

Oak Leaf Blister

Oak leaf blister is a disease caused by the **oak leaf blister fungus**. This fungus only affects **oak trees**. The oak leaf blister fungus produces microscopic, seed-like spores on oak leaves. These spores are spread by the wind. The spores need **cool, damp weather** to germinate and infect new oak leaves in the spring.

Oak Leaf Blister

Oak leaf blister is a disease caused by the **oak leaf blister fungus**. This fungus only affects **oak trees**. The oak leaf blister fungus produces microscopic, seed-like spores on oak leaves. These spores are spread by the wind. The spores need **cool, damp weather** to germinate and infect new oak leaves in the spring.

Student Page

Pitch Canker

The disease, pitch canker, is caused by the **pitch canker fungus**. The fungus releases microscopic, seed-like spores into the wind. **Warm, wet weather** is needed for germinating spores to infect **wounded pine branches and stems**. Wounds are created by stormy weather, human-caused damages, or insect feeding. As the fungus grows it makes the pine develop sunken scars called cankers that "bleed" out pine resin, or pitch. A tree with many cankers can weaken and die.

Pitch Canker

The disease, pitch canker, is caused by the **pitch canker fungus**. The fungus releases microscopic, seed-like spores into the wind. **Warm, wet weather** is needed for germinating spores to infect **wounded pine branches and stems**. Wounds are created by stormy weather, human-caused damages, or insect feeding. As the fungus grows it makes the pine develop sunken scars called cankers that "bleed" out pine resin, or pitch. A tree with many cankers can weaken and die.

Pitch Canker

The disease, pitch canker, is caused by the **pitch canker fungus**. The fungus releases microscopic, seed-like spores into the wind. **Warm, wet weather** is needed for germinating spores to infect **wounded pine branches and stems**. Wounds are created by stormy weather, human-caused damages, or insect feeding. As the fungus grows it makes the pine develop sunken scars called cankers that "bleed" out pine resin, or pitch. A tree with many cankers can weaken and die.

Pitch Canker

The disease, pitch canker, is caused by the **pitch canker fungus**. The fungus releases microscopic, seed-like spores into the wind. **Warm, wet weather** is needed for germinating spores to infect **wounded pine branches and stems**. Wounds are created by stormy weather, human-caused damages, or insect feeding. As the fungus grows it makes the pine develop sunken scars called cankers that "bleed" out pine resin, or pitch. A tree with many cankers can weaken and die.

Extension to PLT Activity 77

Trees in Trouble

Lesson Summary

The original *Trees in Trouble* asks students to assess the health of neighborhood trees, using a key to identify symptoms and signs of damage, disease, nutritional deficiencies, insect activity, and so on.

This extension to *Trees in Trouble* encourages students to look past the tree and consider its neighbors. If the cause of tree damage or disease is reproducible and other trees run the risk of exhibiting these conditions in the future, what could that mean for a forest's overall state? What is the connection between tree health and urban forest health?

Doing the Activity

1. Read the original version of *Trees in Trouble* on page 332 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

Doing the Activity includes two parts, A and B. The following instructions expand upon *Part A—Neighborhood Checkup*.

Take it outside

2. As described in *Part A—Neighborhood Checkup*, conduct a hike in a nearby forested area looking for trees in trouble. Use the following questions to facilitate discussion about your findings.

a. For each troubled tree that a student finds, ask the class whether this is a ***biotic*** problem or an ***abiotic*** one.

Biotic issues are caused by living organisms, such as insects, fungi, birds, or mammals. Abiotic issues are caused by nonliving entities, such as fire, flooding, pollution, climate change, wind, frost, or soil ***compaction****.*

b. Are humans responsible for biotic or abiotic issues in forests?

Some biotic ***disease*** *and damage agents have been introduced by humans.* ***Invasive*** *plants and insects are examples of biotic agents for which humans are responsible. Examples of anthropogenic abiotic issues include lawn mower damage, over-watering, soil compaction from cars or construction, over-fertilization, and air pollution.*

c. For each troubled tree, ask students to consider if the issue is an isolated case or whether nearby trees also show similar symptoms or signs of poor health.

Some health issues may be systematic. For instance, just as humans can pass infections to each other, trees infested with insects or infected with disease-causing fungi or bacteria may spread these organisms to their neighbors. If students find a tree showing signs of insect activity or fungi sprouting from the base, it is possible that nearby trees, especially those of the same species, may also be affected. Likewise, abiotic issues may not be restricted to individual trees. For example, all the trees along a roadside may experience the effect of soil compaction, and all trees in urban areas may be affected by air pollution. Lightning strikes and lawnmower damage, on the other hand, are usually restricted to individual trees rather than groups.

d. Why might damage or disease found on more than one tree be something to worry about?

Introduce the concept of an epidemic—when an entire tree population is attacked by insects or disease-causing organisms. Epidemics can affect ***forest health*** *by stressing, weakening, or killing great numbers of trees. Sometimes forests can recover from such issues, but occasionally the impact is irreversible and entire species may be lost. Widespread abiotic issues such as soil, air, or water pollution also have far-reaching consequences and can change the forest's makeup. These factors can stress trees, making them susceptible to attack from biotic agents as well.*

3. Wrap up the discussion by talking about how humans, including your students, affect forest health. As previously noted, humans are often responsible for biotic or abiotic forest issues. But this isn't always a bad thing. Ask students to brainstorm helpful ways we can improve a forest's health.

Point out that issues such as construction damage or invasive species introduction are often avoidable and issues such as air pollution may be reduced if humans proactively minimize impacts on the environment. Also, just as students played the role of "tree-tectives," there are professionals who do this as well. Tree and forest experts work in local forestry departments, universities, and research labs as real "tree-tectives," monitoring trees in forests, trying to diagnose and reverse problems they might find. You might ask one of them to visit your classroom to share their experiences and suggest ways students might participate.

Extension to PLT Activity 11

Can It Be Real?

Lesson Summary

The original *Can It Be Real?* introduces students to creatures with bizarre environmental adaptations. It allows students to appreciate the diversity of organisms on the planet.

This variation upon *Can It Be Real?* focuses on some of the extraordinary insects, fungi, and other soil organisms found in the forests of Florida. Although hundreds of organisms have amazing life histories, this extension introduces a few creatures that may damage trees or cause disease. Though many people are unaware of their existence, these organisms are commercially important or integral to the ecosystem.

Doing the Activity

1. Read the original *Can It Be Real?* on page 54 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

Doing the Activity includes two parts, A and B. The following instructions provide a variation to *Part A—Stranger Than Fiction*. For a variation upon *Part B—The Adaptables*, see *Resources and References*.

2. Follow the *Doing the Activity* instructions, but read from the following examples instead of those on the PLT Activity Guide's page 56, and hand out the *Student Page* provided here. First read only the text in italics. The non-italicized text provides further factual information. As with the original activity, all the organisms in this variation do exist and are found in Florida.

a. Honey mushroom: *I am a fungus and live in roots and stumps and under the **bark** of trees. My body is a collection of microscopic, branching threads. I can fuse these threads together and push them out from the base of trees in the shape of honey-colored mushrooms. My mushrooms release **spores** that spread to other trees. I can also spread underground—my threads fuse and grow like roots through the soil in search of new homes. Sometimes my threads fuse to form white sheets that glow in the dark!*

Honey mushrooms belong to the genus Armillaria, a group of wood-rotting fungi. They are commonly found in dead logs, roots, and stumps, but may occasionally ***colonize*** weakened or stressed living trees. The microscopic threads of the fungus are called ***hyphae*** (singular: hypha). Hyphae fuse together to form thicker threads or sheets called ***mycelia*** (singular: mycelium). Hyphae can also aggregate to form fruiting bodies, the mushrooms, or hardy, root-like structures called rhizomorphs that spread through soil.

b. Gypsy moth: *I begin as a tiny larva, hatched from an egg. I spin a long thread of silk that I attach to a tree, and hang from the other end. When the wind picks up, the thread acts like a parachute, letting me travel to new feeding grounds. Some of my brothers and sisters hitchhike on cars, trailers, people, and planes! I eat the leaves of hardwoods such as oak trees. I grow into a fuzzy, blue and red spotted caterpillar and eventually metamorphose into a moth.*

Gypsy moths (*Lymantria dispar*) are not native to the United States. They were accidentally introduced when some escaped from a laboratory that was raising them for silk. Since then, they have grown in exponential numbers and attack whole forests of hardwoods. When outbreaks of gypsy moths occur, they can defoliate swathes of forests during the growing season. Some trees may survive such defoliation if they have enough energy stores to put on a second flush of leaves. However, other trees may not have such stores, or may have been so weakened by previous defoliations that they cannot survive the attack.

c. Pine-cone willow gall midge: *You might think I live on pine cones, but surprise! I am actually found on willow leaves. My mother, a gall midge, is a tiny fly that lays my egg inside a willow tree leaf. When I hatch, I release a chemical into the leaf that causes it to form a pine cone-like swelling around me. This structure, called a gall, is my new home and food source all in one—I live and feed inside it all through winter. During the warm spring I metamorphose into a tiny fly, just like my mother.*

Gall-forming insects like the gall midge (*Rhabdophaga strobiloides*) lay their eggs within plants to protect their young from predation. The young release chemical triggers that affect the surrounding plant cells—so cells that originally formed leaf tissue might suddenly make woody tissue instead. The swellings protect and nourish growing larvae, but life is still not easy—there are specialized predators that can find gall-dwelling insects and parasitize them! For instance, some species of wasp use long, saw-like ovipositors to deposit their eggs inside gall midge larvae. So what emerges from the galls the next season is not a young fly but a wasp that has fed upon the fly larva all winter.

d. Pine bark beetle: *I am only the size of a grain of rice, but with my brothers and sisters I can kill an entire forest of pine trees! I tunnel through pine trees eating the yummy inner bark and lay my eggs there as well. I also introduce a fungus into the trees that can prevent the transport of water and nutrients, and stain the inner wood blue.*

Bark beetles are a significant problem in many parts of the United States. Although many of them only colonize dead trees, live trees may be targeted by beetles if the trees are not able to defend themselves against attack. Forests that are underharvested, drought-stressed, or overcrowded hold stands of stressed, weakened trees. When bark beetles attack such trees, there is no ***resistance***, and epidemic explosions of beetles may result.

e. Root knot nematode: *I may be microscopic but I am very highly developed, with a wormlike body, digestive tract, skin, and muscles. I live inside plant roots, making them swell abnormally to create a home for me. These swellings, called galls, give me food and shelter. I affect many different plants, including crops, by decreasing their ability to take up water and nutrients. As the plants suffer, I flourish.*

Nematodes are a hugely diverse phylum of animals, potentially outnumbering all other animal species combined. As a group, the nematodes are the most abundant living organisms on the planet, and may be found everywhere from ocean floors to forest soils. Many nematodes are plant ***parasites***. The root knot nematode is particularly devastating to plants. Other nematodes, however, are beneficial.

f. Fusiform rust: *I am a very picky fungus. Some of the year, I can live only on oak trees leaves. Other times of the year, I can live only inside pine tree stems. I make five different types of spores during my two-year life cycle. Some of my spores can travel over 300 miles. When I land on oak leaves, I make spore-producing blisters on the leaf surfaces. When I land on pine stems, I make them swell up and erupt with yellow-orange spore-producing pustules.*

Rust fungi are unusual organisms—many of them require two different ***hosts*** to complete their life cycles, and produce up to five different types of spores that can only germinate at specific times and on specific host trees. Fusiform rust (*Cronartium quorum* f. sp. *fusiforme*) is a commercially devastating fungus in Florida, as it can reduce the value of pines grown for timber. The swollen galls that the fungus induces upon pines cause the stems to warp, making them unsuitable for timber.

g. Cedar-apple rust: *I am a fungus with two homes, apple leaves and cedar twigs. When I am on apple leaves, I make spores that can grow only on cedar twigs. When I am on cedar twigs, I make spores that can grow only on apple leaves. You may think I can't make up my mind, but that's not true, I'm just very, very particular. I am usually microscopic and hard to see, but when I am visible, I look out of this world! I make huge globs of orange, gooey horns on cedar twigs, and much smaller blisters on apple leaves.*

Cedar-apple rust (*Gymnosporangium juniperi-virginianae*), like other rust fungi, has an elaborate life cycle involving two host trees and five spore stages specific to each host. This fungus' most showy feature is the fruiting body it produces on cedars, a cluster of horn-like extensions called telia (singular: telium). The telia become extended and jelly-like in moist conditions before releasing spores; telia are analogous to mushrooms because they are a kind of fungal fruiting body.

3. Reveal to students that all the organisms on the *Student Page* are real, supplementing your explanation with the extra information provided here, and with pictures from the SFRC Extension website for educators (see *Resources and References*).

4. Wrap up the activity by discussing with students why it might be important to understand the life cycles of these strange creatures. Point out that many of these organisms can reproduce in large numbers, causing uncontrollable damage to forests if left unchecked. Learning what they look like, where to find them, and how they travel is a first step to controlling outbreaks before they happen.

Also discuss with students whether such organisms are "bad" or "good." While they may cause commercial damage, they are also integral ***ecosystem*** components. Consider, for example, what would happen to a gall wasp if its prey, the pine cone willow gall midge, was eradicated. ***Exotic invasive pests*** and ***pathogens*** like the gypsy moth are more harmful than ***native*** ones, often because they don't have specialized predators to keep their populations in check.

Resources and References

- The University of Florida's SFRC Extension website for educators includes several related resources.
  - To introduce students to insect adaptations for plant herbivory, see *Beyond the Trees, Activity 3: How to Eat a Tree – An Insect's Guide to Finding Food in the Forest*.
  - Pictures corresponding to the *Student Page* illustrations may be found at the website. Illustrations were adapted from Bugwood.org.
  - Flash cards from the *Pocket ID Guide* describe similar organisms.

  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

Name:

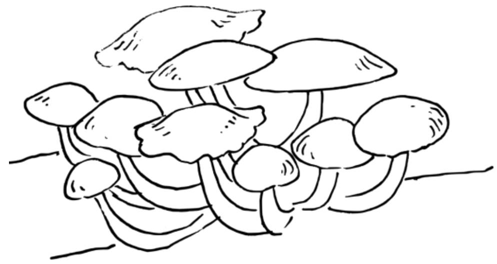
Bugs and Fungi, Oh My!

Instructions

Do these creatures really exist?

Listen to your teacher's descriptions of the creatures and choose whether it is real or fictitious by checking one of the boxes next to each picture.

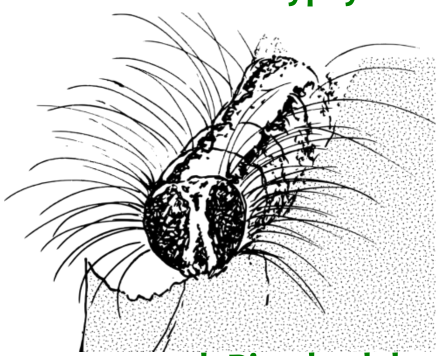
a. Honey mushroom



☐ Real

☐ Fictitious

b. Gypsy moth



☐ Real

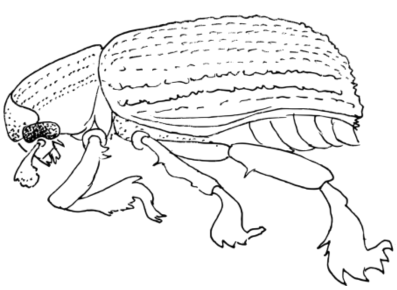
☐ Fictitious

c. Pine cone willow gall midge

☐ Real

☐ Fictitious

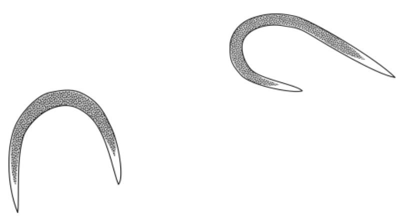
d. Pine bark beetle



☐ Real

☐ Fictitious

e. Root knot nematode



☐ Real

☐ Fictitious

f. Fusiform rust

☐ Real

☐ Fictitious

g. Cedar-apple rust

☐ Real

☐ Fictitious

Illustrations: Geetha S. Iyer

Extension to PLT Activity 26

Dynamic Duos

Lesson Summary

The original version of *Dynamic Duos* teaches students about symbiotic relationships between organisms through class discussion and a worksheet involving partner match-ups.

This variation on *Dynamic Duos* specifically introduces students to symbiotic organisms found in Florida. Many of these organisms play integral roles in Florida forests, and their relationships can influence overall forest health.

Doing the Activity

1. Read the original *Dynamic Duos* on page 113 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

Photo: Randy Cyr, Greentree, Bugwood.org

Figure 13. Hanging out: A live oak draped in Spanish moss.

2. Use the following *Student Page* section in addition to, or instead of, the one found in the original *Dynamic Duos (page 115)*. The new *Student Page* focuses on Florida-specific ***symbiotic relationships***. Use the *Answer Key* provided in this activity to check students' answers and offer students more information about the organisms in question. For additional information on many of the featured organisms, see *Resources and References.*

Take it outside

Some of the relationships covered here may be observed in natural areas in your neighborhood. Consider enhancing the activity by taking your students to a natural area to search for some of the relationships in action. Challenge students to find other symbiotic organisms beyond those in the activity.

3. Wrap up the activity by discussing with students the greater role that dynamic duos play in the forest. The gopher tortoise, for example, is a ***keystone species*** that supports biodiversity in southeastern longleaf pine forests. Other species, such as the ambrosia beetle and laurel wilt fungus, are ***exotic invasive*** threats that are altering the makeup of southeastern forests, greatly compromising their health. While each pair of organisms plays a specific role in each other's lives, many other organisms and ***ecosystem*** functions depend upon them as well. This activity ties in with *New Activity 2: Inside the World of Forests*. Consider doing both activities one after the other to help students see the connections between organism interactions and the greater network of the ecosystem to which they belong.

Student Page Answer Key

a. Spanish Moss (*Tillandsia usneoides*) and Partner 4, live oak (*Quercus virginiana*). Spanish moss is an ***epiphyte***—it grows on top of (epi-) another plant (-phyte)—related to bromeliads and pineapples. It has no roots, only curving stems and scaly leaves, giving it a shaggy appearance. It benefits from growing upon live oaks because it can capture water and nutrients that drip off the trees' leaves and branches (Figure 13). The oaks are not usually disadvantaged by this, and *Tillandsia* is generally described as having a ***commensal*** relationship with the trees. However, excessive proliferation of the epiphyte sometimes hinders the trees—they cast shade upon the trees' leaves and occasionally weigh down branches so much that they may break off under the strain or during hurricanes.

Photo: Brytten Steed, USDA Forest Service, Bugwood.org

Figure 14. Treats for travels: A mistletoe advertises to birds.

b. Mistletoe (*Phoradendron leucarpum*) and Partner 2, a bird like the cedar waxwing (*Bombycilla cedrorum*). Mistletoes produce edible berries with sticky seeds (Figure 14). They share a ***mutualistic*** relationship with birds that eat the berries and pass the seeds onto other trees where they may sprout. Mistletoes have a ***parasitic*** relationship with trees. A mistletoe seed puts out a root-like structure that embeds itself within a tree branch. The structure grows into the tree's vascular system, stealing resources from it. Heavily parasitized trees are weakened and may become susceptible to other ***pests*** and ***diseases***.

Photo: Albert (Bud) Mayfield, USDA Forest Service, Bugwood.org

Figure 15. On its way out: This redbay's canopy is partially wilted from the laurel wilt fungus. As the fungus spreads, it will kill the whole tree.

c. Ambrosia beetle (*Xyleborus glabratus*) and Partner 5, the laurel wilt fungus (*Raffaelea lauricola*). The beetle and fungus share a mutualistic relationship and together parasitize redbay trees (*Persea borbonia*). The fungus' ***spores*** are carried by beetles to living redbays, into which the beetles tunnel to feed and reproduce. The fungus grows through the trees' vascular tissues, blocking water and nutrient transport, resulting in tree death (Figure 15). The beetle and the fungus are native to Asia and do not harm living trees there. In the United States, though, these exotic invasives are decimating redbay populations.

Photo: Robert L. Anderson, USDA Forest Service, Bugwood.org

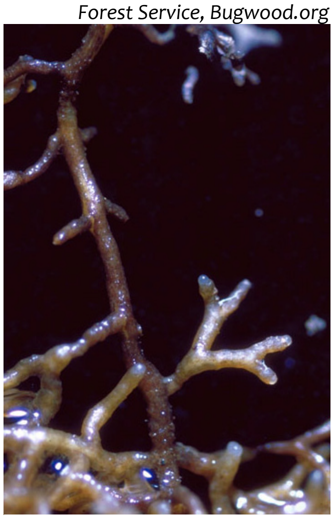


Figure 16. Better together: The stubby root hairs (brown) of this pine seedling are thickly sheathed by a helpful mycorrhizal fungus (white).

d. Mycorrhizal fungus and Partner 1, pine seedling (*Pinus* species). ***Mycorrhizal fungi*** are composed of hair-like threads that envelop plant root tips (Figure 16). Some of the fungal hairs may penetrate root cells to take sugars from the plant. While this seems similar to the parasitic relationship mistletoes share with trees, mycorrhizae are in fact mutually beneficial to plants. Their hairs increase the roots' absorptive capacity, aiding in mineral and water uptake by the plant. A pine seedling growing in impoverished soil would not survive long without mycorrizal fungi to help it.

e. Gopher tortoise (*Gopherus polyphemus*) and Partner 3, Eastern indigo snake (*Drymarchon couperi*). Gopher tortoises are a keystone species in longleaf pine ecosystems in Florida, maintaining biodiversity and health (Figure 17). They dig extensive burrows in the impoverished soils of longleaf pine forests, bringing up fresh earth and helping turn over soil nutrients in the process. More importantly, their burrows are used by hundreds of other species (many endangered or unique to longleaf pine systems) for shelter against heat or cold, protection from predators, and as a secure place to live and raise young. Animals like the endangered Eastern indigo snake live commensally within gopher tortoise burrows. The indigo snake, the largest native snake in the United States, preys on insects, amphibians, rodents, lizards, and other venomous snakes, keeping their numbers in check.

Photo: Chuck Bargeron, University of Georgia, Bugwood.org

Figure 17. Keystone species: The gopher tortoise is essential in a healthy longleaf pine forest. Many other organisms depend on it.

Resources and References

- To teach your students more about the laurel wilt fungus and redbay ambrosia beetles, you may adapt the stories found in *Beyond the Trees, Activity 6: Unhealthy Forests and the News*, at the University of Florida's SFRC Extension website for educators.
  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html
- If you would like to show students pictures of the organisms featured in this activity, an extensive selection of images is available at the University of Georgia's Center for Invasive Species and Ecosystem Health's website, *Forestry Images.*
  Visit http://www.forestryimages.org/

Student Page

Name:

Dynamic Duos

Instructions

Match Potential Partners 1 through 5 with the letter corresponding to the classified ad that best meets their interests. Can you guess who the Partners are?

Classified Ads

a

Spanish moss
¡Buenos días! Looking for someone to hang on to. Won't take your food, but would love grab some sun at the top of your canopy. Long, widespread, limbs necessary. Fences and posts need not apply.

Call Moss, 555-6787

b

Mistletoe
Laurel oak has provided a great home with nutrients and water, but my seeds are ready to move on. Looking for wings to transport my seeds. Fresh berries in return for your help!

Text Ms. L. Towe at 555-9453

c

Ambrosia beetle
Hey, this forest has plenty of redbay trees to make homes and feed within, but I can't digest wood. I need a fungus to partner with so we can both steal what we need. You help me, I help you!

Contact Ambrose B. Tull: 555-7665

d

Mycorrhizal fungus
Help, my spores just germinated and need help finding sugary food! Looking for a young pine seedling with lots of roots. In exchange for food I can help you collect water and minerals.

Call Myc (pronounced Mike) at 555-9768

e

Gopher tortoise
I just finished making an excellent underground home in a beautiful longleaf pine forest! I'm happy to share my place with anyone else who likes burrows to shelter in.

Call Gophee, 555-4435

Potential Partners

1. Although I'm still young, I have a large root system. I make sugars and will have plenty to share but first need help absorbing minerals and water because I am growing in very poor sandy soil.

Who should I call? ____________________

Who am I? ____________________

2. I love to fly around the forest looking for yummy things to eat. My favorite food is berries! I don't have teeth, just a beak, so I can't chew the berry seeds. I just leave the seeds behind on tree branches in the forest.

Who should I call? ____________________

Who am I? ____________________

3. I hunt insects, rats, and small lizards, but I'm endangered and in need of a safe home. I feel safest in burrows underground, so I can snake in and out of them when I need to feed or hide.

Who should I call? ____________________

Who am I? ____________________

4. I have long, thick branches so I'm able to support a large amount of weight. I make acorns, and photosynthesis is a piece of cake for me because I have a large canopy.

Who should I call? ____________________

Who am I? ____________________

5. I digest wood and provide food for beetles. I really like wood from redbay trees but since I don't have legs or wings, I need help getting to them. I am still quite a mysterious fungus to scientists.

Who should I call? ____________________

Who am I? ____________________

Extension to PLT Activity 7

Habitat Pen Pals

Lesson Summary

The original *Habitat Pen Pals* has students write pen pal letters from an animal's perspective, with emphasis placed on the its habitat. Students read each other's letters to guess which animal wrote it based on the habitat clues provided.

This variation of *Habitat Pen Pals* encourages students to learn more about the insects and fungi that are right under their noses. And since insects and fungi are so much smaller than most organisms, students also learn about microhabitats, such as the canopy of a broadleaf tree or the inner bark of a conifer. The organisms used in this variation are all found in Florida. Many of them are commercially important or play important roles in the ecosystem—their activities impact both the residents and the forests of Florida.

Doing the Activity

1. Read the original *Habitat Pen Pals* on page 37 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

2. Getting Ready: This variation of *Habitat Pen Pals* focuses on microhabitats found within, upon, and below trees. Try to find pictures of the microhabitats and organisms in Table 2. You may find images in the *Pocket ID Guide*, available online. See *Resources and References* for more information.

Table 1. Whose microhabitat is that? Find pictures of the following places and the creatures that live there.

Microhabitat	*Organisms*
Below the forest floor	Cicadas, honey mushrooms
Canopy of a cherry tree	Leafy mistletoes, eastern tent caterpillars
Pine tree trunk	Southern pine beetles, woodpeckers
Canopy of a pine tree	Pine tip moths, brown spot fungus

3. You may choose to conduct this variation instead of or in addition to the original *Habitat Pen Pals*. As with step 3 of the original activity, review with your students what a habitat is. Then ask students what they think microhabitats are. The distinction between habitats and microhabitats is one of scale—a deer's foraging range determine the ***boundaries*** of its habitat, and the ***parasites*** clinging to the deer's fur might consider their habitat the entirety of the deer's body. Animals occupying microhabitats, such as at different depths within a lake, or parts upon a tree (Figure 18), are often ***specialists***. For instance, a deer tick cannot survive upon a bird, and a bird tick cannot survive upon a deer. Likewise a root fungus cannot survive in the tree canopy.

Photo: Joseph O'Brien, USDA Forest Service, Bugwood.org

Figure 18. Honey mushroom fungus: You will not find this fungus anywhere but in the soil, roots, lower trunks of dying trees, and dead trees and stumps.

4. Follow steps 4 through 12 of the original activity, but use the microhabitats and organisms in Table 2 to make posters, write letters, and lead discussion. See *Resources and References* for student research and writing aids. Instead of using the writing prompts in step 8 of the original activity, use the following to help your students write letters without revealing the identities of their assigned organisms.

a. Do you live above, below, within, or upon a tree?

b. How much sunlight do you get?

c. Is it very moist where you are, or very dry?

d. Is it very windy where you are, or is the air still?

e. Are you an adult or still very young?

f. Do you make your own food, feed upon something else, or steal your food?

g. Can you name another organism that is similar in some way to you?

h. Do you depend on other organisms in your microhabitat, or do they depend on you?

Resources and References

- The University of Florida's SFRC Extension website for educators includes several related resources:
  As student research and writing aids, you may make and distribute copies of flash cards from the *Pocket ID Guide*, for the following organisms: *Cicadas*, *Armillaria Root Rot, Leafy Mistletoes, Eastern Tent Caterpillar*, *Southern Pine Beetle*, *Woodpeckers, Pine Tip Moths, Brown Spot Needle Blight*. Some of the organisms in the activity are referred to in the flash cards by the tree diseases they cause—for instance, brown spot needle blight is caused by the brown spot fungus.
  - For a similar creative writing activity in this handbook, see the *Extension to PLT Activity 8 – The Forest of S. T. Shrew* (page 19), which asks students to write stories from the perspectives of tiny forest organisms.
  - For a creative activity in poster-making together with a lesson about insect herbivory, see *Activity 3: How to Eat a Tree – An Insect's Guide to Finding Food in the Forest*, in *Beyond the Trees*.

  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

- An alternative student research and writing aid may be found at the University of Florida School of Forest Resources and Conservation's website for Florida 4H Forest Ecology, on their webpage, "Forest Health." The information found on this website is less technical than the *Pocket ID Guide*.
  Visit http://www.sfrc.ufl.edu/4h/Health/health.html

Photo: Edward L. Barnard, Florida Department of Agriculture and Consumer Services, Bugwood.org

Extension to PLT Activity 76

Tree Cookies

Lesson Summary

The original *Tree Cookies* teaches students about annual tree rings and their records of changes in tree growth.

This extension to *Tree Cookies* uses tree trunk cross-sections to reveal a history of injury or disease, and includes details on wound recovery in trees for educators. Tree cookies provide another tool to understand forest health. Unhealthy trees are less able to heal over wounds and infections. Maintaining healthy trees is thus important because it maximizes their ability to protect themselves.

Background

Trees face a continual barrage of attacks from sources such as lightning, hail, insects, fungi, and machinery, to name a few. But instead of replacing destroyed tissues as animals do, trees block off affected areas in a **compartmentalization** process—the healthy cells immediately surrounding unhealthy ones change their makeup to form an infection barrier. In effect, a tree walls off wounds and ***disease***-causing organisms and tries to grow around them. The affected tissues eventually die and that part of the tree never recovers its previous function.

Trees can compartmentalize wounds because of their tissue organization. A whole tree may be thought of as a Russian nesting doll—each year's growth like a "new tree" that envelops "older trees" within. The vascular stem vessels that carry water and nutrients are arranged in concentric cylinders, one inside the next. Other cells are arranged in radially oriented rays, like the spokes of a bicycle wheel. The rays, of varying length and thickness, dissect the vascular tissue into a random, maze-like structure.

When a tree is wounded, or if an organism such as a bacterium or fungus penetrates the tissues, both longitudinal and ray cells respond to wall off the threat (Figure 19). There are four kinds of walls. WALL 1 is a plug formed at the ends of each longitudinal vessel to stop an infection from spreading vertically along the tree. New cells, those in the outer rings, respond faster than older cells, those in the inner rings—this is why wounds often seem to have spread further in the inner tissues than the outer ones. WALL 2 prevents infection from penetrating inward—it is formed by the cells that compose the growth ring directly beneath the wound. WALL 3 is made by the ray cells. It prevents infection from spreading laterally around the trunk. WALL 4 is formed by the cambium to seal the surface of the wound or infection. New growth may eventually cover over an old wound, and although the infected part of the tree might rot away as fungi and bacteria digest the tissues, the walls surrounding it will remain.

Illustration: Geetha S. Iyer

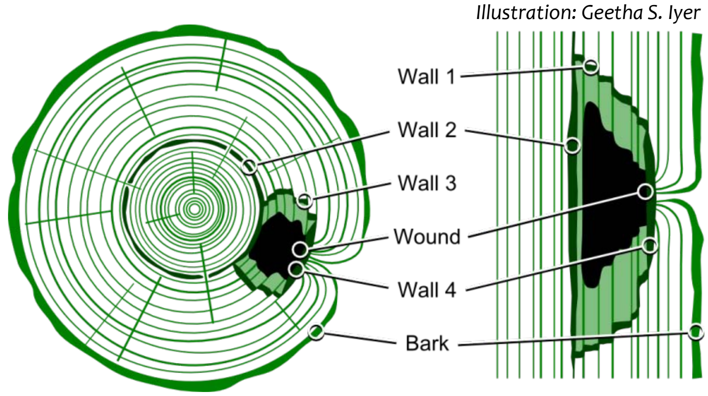


Figure 19. Wound compartmentalization in trees: Diseased tissue (black) is surrounded by discolored tissues (light green) and walled off by surrounding healthy cells (thick band of dark green). Radial ray cells are visible in the transverse cutting (left). The outer growth rings consist of younger, healthier tissues and generally respond faster to wounding and infection than older, inner tissues, hence the greater spread of damage to inner tissues (left).

Different species, and even individuals within a species, show varying ability to compartmentalize damage and disease. Much of this is determined by genetic makeup—such genes are of interest to those who would like to restore threatened or vulnerable trees to their habitat, those who would like to breed trees for forest products, and even those who would like to plant hardy trees in ***urban forests***.

However, there is an environmental component to trees' ***resistance*** and ability to restrict damage and disease. Healthy trees are better able to respond to attack by creating physical and chemical barriers around affected tissues. Maintaining healthy forests ensures that trees are given the best possible chance to compartmentalize wounds and recover from infections that they are exposed to every day.

Doing the Activity

1. Read the original *Tree Cookies* on page 327 of the PLT Activity Guide, including the *Background Information, Getting Ready, and Doing the Activity sections.*

Doing the Activity includes two parts, A and B. The following instructions expand upon *Part A—Cookie Counting*.

2. The *Student Page* titled "Reading Tree Cookies" on page 331 briefly touches on signs of tree responses to stress, damage, or disease. To help your students better understand the way such tree ring formations are made, you may draw representative cross sections of trees and walk students through the steps involved in compartmentalization and wound closure.

The *Background* section provides a brief overview of tree physiology in response to wounding. Horizontal and vertical cross-sections help illustrate three-dimensionally what happens within the tree. Consider creating large-scale versions of unwounded cross-sections before class. Then "animate" the wounding and compartmentalization process to students by adding new layers of tree growth as it seals off and grows over a fresh wound, while explaining your changes out loud. See *Resources and References* for more information.

3. The original activity notes that signs of damage from branch fall, insects, low nutrient availability, and fire can be seen in tree cookies, either as constrictions in annual rings or as pockets of blackened scar tissue. Freeze damage and bacterial and fungal infections also leave detectable signs in tree cross-sections. Prepare copies of the *Student Page*, also available online, to show students other examples of damage and disease in cross-section. Use the following information to discuss what happened to the trees before they were cut.

a. Heartrot decay in a white oak: Heartrot is a distinctive feature of trees whose ***heartwood*** has been degraded by fungi. These fungi are specialized to feed on heartwood but not sapwood and leave trees with hollow centers. As the tree grows, the heartrot expands. Branches do not contain heartwood and so remain resistant to decay, as seen in the picture.

Heartrot-causing fungi are important components of a healthy ***ecosystem***, because the hollowed out trunks they produce become important sites for nesting and shelter by a wide variety of organisms, including snakes, lizards, woodpeckers, owls, raccoons, and flying squirrels. Hollow trees may not be desirable in some situations, however.

b. Sapwood decay in a maple: Fungi are often ***specialists***, evolved to attack certain genera or species of trees, as well as certain tissue types within trees. Sapwood-rotting fungi are restricted to just the sapwood tissue. In the picture, the tree has left a stain in the wood (darkened area) as it restricted the fungus from reaching the ***phloem*** tissue (marked off by arrows).

Damaged and decayed trees are sometimes unusable because their wood has been warped by scars, rots, or stains. On the other hand, for wood turners, carpenters, and artists, wood stained by fungi may create interesting patterns to work with.

c. Cracks or radial shakes in a post oak: Trees may contract during freezing weather. During contraction, old wounds may fissure and crack. In the next cold snap, even more strain is put on the cracks from the previous year, expanding them. In the picture, cracks formed at old wound sites extend out toward the ***bark*** in a post oak tree.

Trees with structural instabilities such as scars or cracks may break off at these points, providing shelter in the snags for other organisms. However, falling branches and trees can be destructive as well—in urban areas, they may damage cars, power lines, houses, or people

d. Compartmentalized wounds in an oak: New wood tissue may fuse over an old tree wound, just as new bone tissue may seal a cracked bone. But an X-ray reveals traces of the old crack or the swollen portion of newly-healed bone, just as a tree cookie may reveal traces of an old scar that has been covered in subsequent years. Can you tell where the original wounds occurred in the picture? Hint: Look for the abrupt changes in growth rings. The pen and pencil point to where the scar tissue began closing over the wound.

Note that the overall health of an organism determines its ability to recover from wounding or illness. In old people, bones take longer to heal as the cells and tissues do not divide and reproduce as rapidly as they once did. In general, the younger and healthier any organism is, be it tree or person, the faster and more effectively it will recover from wounds.

4. Wrap up the activity by discussing why maintaining overall ***forest health*** may be important for individual trees. For one thing, it sustains lower levels of stress-inducing agents like disease-causing fungi. It also increased the trees ability to fight off infections should they occur. Note, however, that damage and decay, as seen above, may also have its uses.

Resources and References

- The University of Florida's SFRC Extension website has a visual presentation including the pictures used in this activity. Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

- A. L. Shigo's *Tree Decay – An Expanded Concept*, a USDA Forest Service Bulletin 419, closely details and illustrates wound healing. Visit http://www.na.fs.fed.us/spfo/pubs/misc/treedecay/cover.htm

Tree Cookies

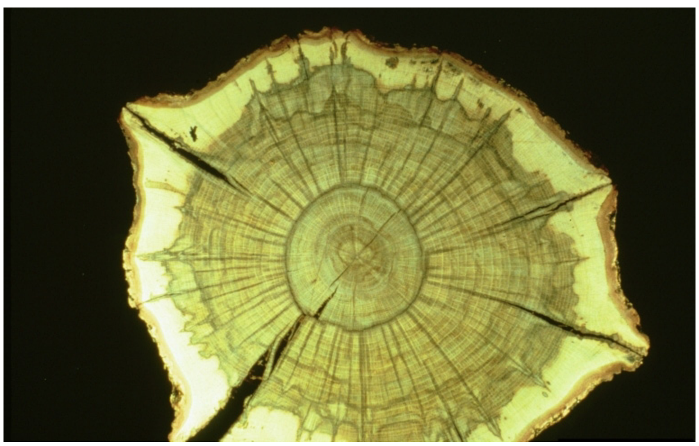
a. Heartrot decay in a white oak

Can you see where the branches used to be on this tree?

b. Sapwood decay in a maple

Where did the tree stop the fungus from growing?

c. Cracks or radial shakes in a post oak



What do you think made the cracks in this tree?

d. Compartmentalized wounds in an oak

How many times was this tree wounded?

Photos: a) Randy Cyr, Greentree, Bugwood.org, b), c), and d) USDA Forest Service – Northeastern Area Archive, USDA Forest Service, Bugwood.org

Section 3

Forest Management

People influence forests in many ways. We indirectly affect forests with nearby urban development, invasive species introduction, air pollutants, climate change, and changes in groundwater levels. We also have direct effects when we plant, thin, and harvest forests; carve hiking trails or roads; allow off-road vehicles; conduct prescribed fires; manage wildlife; and build subdivisions. Each of these activities involves choices and decisions.

Direct effects, because they are caused by activities within the forest, are typically included under the umbrella of forest management responsibilities. Interestingly, foresters are also called upon to manage forest health in response to the indirect effects we have on forests—those activities such as urban air pollution which occur outside forests. Foresters are usually powerless to manage the causes of these indirect influences, which makes public awareness of things that impact forest health so important.

Forest management involves using forestry practices to achieve a desired goal. These goals are determined by landowners and may be based on wildlife, aesthetic, economic, environmental, and recreation values—or any combination of these objectives. Forest managers typically balance several values to develop a management plan. In Florida, forest managers use prescribed fires, pesticide application, timber harvesting, tree planting, fertilizers, invasive exotic removal, and endangered species monitoring to maintain healthy forests that meets their goals. Some of these management activities help repair damage caused by human activity.

The activities in this section help students understand ways in which land-use decisions can impact forest ecosystems and how forest managers address the consequences of these decisions to protect human interests and forest health. A number of existing PLT activities can be used to introduce students to forest management:

Activity 12	Invasive Species
Activity 33	Forest Consequences
Activity 50	400-Acre Wood
Activity 56	We Can Work It Out
Activity 69	Forest for the Trees
Activity 81	Living with Fire

The following pages contain three modifications of PLT activities and two new activities. A few additional discussion questions are suggested for *Sunlight and Shades of Green* (PLT Activity 42 on page 52) to help students consider why trees might not be able to effectively photosynthesize and how this impacts forest health. Similarly, additional discussion questions for *A Forest of Many Uses* (PLT Activity 32 on page 67) help you guide students to think about the ways forest management affects forest health. Additions to *Viewpoints on the Line* (PLT Activity 19 on page 69) offer potentially controversial value statements on forest health.

The new activities convey additional information that can complete a unit on forest health. *Secrets of the Invasive Exotics* (page 54) uses a worksheet to provide information about organisms that can effectively colonize Florida's forests. *A Changing Forest* (page 60) uses a popular cooperative learning strategy called "six bits" to solve a mystery. The mysteries, of course, invite discussion about natural and unnatural changes to forests; solving the mystery enables educators to draw attention to effective group communication and leadership patterns.

Extension to PLT Activity 42

Sunlight and Shades of Green

Lesson Summary

The original *Sunlight and Shades of Green* introduces students to the concept of photosynthesis by asking them to conduct an experiment with leaves—using pieces of cardboard to partially block light on leaf surfaces.

This extension to *Sunlight and Shades of Green* looks further into the consequences of being unable to photosynthesize. There are many natural and artificial impediments to photosynthesis. Some of these interferences may occur on such a large scale that they affect net primary productivity in the forest and may be responsible for a decline in overall forest health.

Doing the Activity

1. Read the original version of *Sunlight and Shades of Green* on page 182 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

Doing the Activity includes two different learning opportunities. In step 7, students wrap up their experiment by discussing the elements necessary for photosynthesis. In step 8, students are asked to imagine and act out what it might be like to be a tree photosynthesizing in the forest. The following instructions expand upon both steps 7 and 8.

Photo: Kerry Briton, USDA Forest Service, Bugwood.org

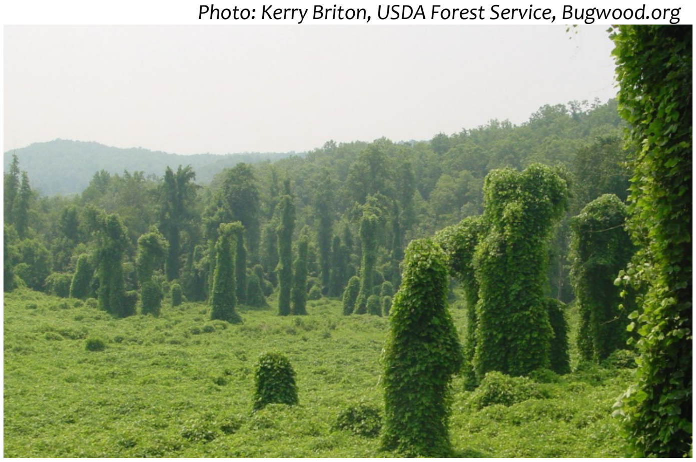


Figure 20. Not always greener: This seemingly lush draping of vegetation is the invasive kudzu vine, smothering native vegetation underneath it.

2. After going over the questions outlined in step 7, ask students to describe other ways plants may be prevented from photosynthesizing. What natural or artificial circumstances might block sunlight the way cardboard did? What might be the consequences to the trees and to the forest? Following are examples that may help your discussion.

a. Vines grow up supporting structures like trees to reach sunlight in the canopy. They do so to photosynthesize, but cast shade over the plants they grow on top of. ***Invasive*** vines, unhindered by natural predators, may rapidly smother trees from light. Kudzu (*Pueraria montana* var.*lobata*) does so in the Appalachian region of the southern United States (Figure 20), and Japanese climbing fern (*Lygodium japonicum*) does the same in southern Florida. Students have previously discovered that photosynthesis provides food for the plant. How might invasive vines affect the trees below them?

*Invasive vines threaten **forest health** because they weaken the trees over which they grow. The weakened trees are more susceptible to plant **pests** and **disease pathogens**, produce less oxygen, and may not be able to collect enough nutrients to reproduce. Animals that depend upon these trees may find themselves without homes or food.*

b. Some trees show knot-like scars on their lower trunks. These are places where the lower branches have died and dropped off. The lower branches on a tree are shaded out by the top branches, causing them to wither and fall off. This is called "natural pruning." What is the advantage to a tree that does this?

Trees are in a continual race to extend branches higher and wider to maximize the leaf area that can capture sunlight. As they do so, they act like umbrellas, casting shade over plants growing beneath them, but also casting shade over their lower branches. These branches were once important, but as the tree grows bigger, they no longer serve a purpose. Branches cost a tree energy. A tree that is able to drop branches that no longer capture sunlight has an advantage over others.

c. Why are invasive ***exotic*** trees, such as Japanese mimosa (*Albizia julibrissin*) or the Chinese tallow (*Sapium sebifera*), so problematic in southern forests?

When trees grow close together, they compete for sunlight and other resources. The shade cast by taller trees can inhibit the growth of trees lower down. As a result, while upper story trees may be flourishing, younger and *shorter trees may be spindly or small. These trees may have to bide their time until a big tree falls so they can take advantage of the flood of light and claim the canopy for themselves. When invasive exotic trees enter the system, they can drastically alter forest* ***composition****. The invasive exotics may out-compete* ***native*** *plants by stealing sunlight, water, and soil nutrients away from them. For a deeper look at the impacts of invasive exotics in* ***light gaps****, see* Resources and References.

d. Some insects are ***herbivores***—they eat the leaves or needles of a plant. When insects such as Eastern tent caterpillars or pine sawflies go munching, they can do so in such large numbers that they completely defoliate the trees they feed upon. Why might this be problematic?

Trees use their leaves to make food, so if they are completely defoliated, they cannot perform this vital activity anymore. Trees must then put out another set of leaves or needles to stay alive. For broadleaf, deciduous trees, this may not be an issue, as they can produce a second flush of leaves within one growing season. For evergreen, coniferous trees, it is not so simple—since many of them only put out one set of needles a year, if they lose those leaves, they will not be able to replace them until the next spring. Some conifers may become severely stunted after multiple years of defoliation. They may even die.

e. How could urban issues such as smog from car fumes or factory exhaust affect photosynthesis?

Smog is composed of nitrogen oxides, volatile organic compounds, and soot, and just as clouds cast shade upon trees, smog can interfere with light penetration to plants. Smog additionally may coat the surfaces of leaves with a blackish film that can be seen in ***urban forests*** *in polluted areas. The smog residue coating leaves can interfere directly with photosynthesis.*

3. Wrap up the discussion with observations on why it is important to ensure that trees can photosynthesize. Trees naturally compete with each other for light, and even individual branches on a tree may compete with each other. While some plants compete to overtop each other, others have adapted to become more efficient in shady conditions.

Competition from invasive organisms and ***abiotic*** issues such as air pollution may also interfere with photosynthesis, and humans can either exacerbate or mitigate these factors. Trees are ***primary producers*** of food in a forest and if their health is compromised, the entire ***ecosystem*** might be transformed to a grassland or desert. If humans are responsible for air pollution or the introduction of invasive organisms, perhaps they may also be responsible for solving those problems. Can your students think of any ways they might reduce such issues as invasive species introduction and air pollution?

Consider facilitating a discussion or debate on the pros and cons of geoengineering—artificially manipulating the climate by seeding clouds or erecting sun shades in space to reduce global temperatures. How might this affect photosynthesizing plants?

4. To follow up on step 8 of the original activity, have students act out not just photosynthesizing trees, but also impediments to photosynthesis such as a) kudzu vine, and b) pine sawflies (*Neodiprion lecontei*). Divide the class into two groups, the trees and the impediments. Hand out green crepe paper strips to students representing kudzu. Hand out stickers to students representing pine sawflies. First read out loud the passage included in the original activity so that the "tree" students may grow. Then read out loud the following to the "impediment" students so they can interfere with "tree" students' growth.

a. Some of you are the exotic invasive vine, kudzu. You sprout at the forest's edge where the light is strong and are eager to reach the treetops. Throw your vines (the green crepe paper) over the nearest tree so you can steal some sunlight. How far can you extend your vines? There's another tree nearby, try to grow over that one as well.

b. Some of you are pine sawflies. You're looking for trees with juicy leaves to lay your eggs on (attach stickers onto hands and arms of "tree" students). Your larvae will have a nice meal when they hatch! The larvae have sharp, biting mouthparts to nibble away leaves.

"Tree" students covered in crepe paper should crouch lower under the "weight" of the kudzu vines. "Tree" students with stickers on their hands and arms should curl up their fingers or fold their arms to show they have been defoliated.

5. Wrap up the activity by asking students if they'd like to share their feelings on what it's like to be a tree growing unimpeded in a forest? How is it different from a tree trying to grow while it's competing with kudzu, or nibbled upon by sawflies? How do the students who were kudzu or pine sawflies feel about their role in the forest? Is it important for them to have space to grow as well?

Resources and References

- For an advanced activity on how forest composition is affected by invasive exotic plants, see *Beyond the Trees*, Activity *1: A Walk in the Woods* on the SFRC website. Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

New Activity 4

Secrets of the Invasive Exotics

Lesson Summary

This activity introduces students to exotic and invasive exotic species found in Florida. Students learn about the behaviors and adaptations of these species that allow them to successfully colonize an area and the impacts they can have on an ecosystem as a result.

The activity allows opportunities to discuss the importance of invasive exotics, the effects they have on ecosystem health, the role that humans play in introducing invasive exotics to ecosystems, and the potential ways in which humans might prevent more invasives from getting a foothold in Florida ecosystems.

Background

The Exotic and the Invasive Exotic

Introduced, or ***exotic species***, are those that are found in a place where they do not naturally occur. Exotic species are often unintentionally carried through trade; for example, many exotic insects, fungi, and plant seeds travel in the soil of ornamental plants or on timber imported from other parts of the world. Some species have also been introduced through exotic pet trade, sometimes as a result of unintentional escapes from pet stores. Other species may also be released by pet owners; in Florida some python owners have released their pet snakes when they've grown too big. Some exotic species are sought-after and are deliberately established in the environment because they are useful or aesthetically pleasing. Oranges and roses are just a few of the many introduced species that are beneficial in Florida.

Exotic species are only a problem if they can reproduce and spread into native ***ecosystems***. If they die before reproducing, or if their young cannot survive in the new habitat, there is no effect on the ecosystem. However, when a species can successfully establish itself in the new environment, and produces offspring that are equally capable of surviving, it may become an aggressive ***colonizer***—an exotic ***invasive*** species. Invasive exotics are problematic because they disrupt original ecosystem processes by competing with ***native species*** for valuable and ***limiting resources***, displacing original populations and changing environmental features such as soil properties or hydrology.

Sunshine State Standards

SC.5.L.15.1: Describe how, when the environment changes, differences between individuals allow some plants and animals to survive and reproduce while others die or move to new locations.
SC.5.L.17.1: Compare and contrast adaptations displayed by animals and plants that enable them to survive in different environments such as life cycles variations, animal behaviors and physical characteristics.
SC.7.L.17.2: Compare and contrast the relationships among organisms such as mutualism, predation, parasitism, competition, and commensalism.
SC.7.L.17.3: Describe and investigate various limiting factors in the local ecosystem and their impact on native populations, including food, shelter, water, space, disease, parasitism, predation, and nesting sites.

Materials

For each student

1 copy of the *Student Page* section (2 pages).

Time Considerations

60 minutes

Behavioral Objectives

Students should be able to do the following:

- Recognize five invasive exotic species in Florida.
- Define an invasive exotic species.
- Describe at least three invasion strategies used by Florida invaders.
- Describe why exotic species can be problematic.

Invasive exotic species are typically opportunistic organisms that will take advantage of the resources available to them. For example, an opportunistic plant may need minimal sun exposure for growth while a specialized native plant may require much more sunlight and so risks being shaded out. Successful invaders have other characteristics that may allow them to establish themselves in a new environment—a ***generalist*** diet, fast growth, or rapid reproduction rate. A lack of native competitors or predators can also contribute to the success of exotic species colonization and persistence.

However, there are many exceptions to these general characteristics. For example, having a slow growing period may seem like a counterproductive adaptation, but for an exotic plant this could give it valuable time to gather resources, enough to eventually produce seeds in mass. As another example, while a generalist diet may prove useful to capitalize on diverse food sources, a lucky enough ***specialist*** may find itself in a new ecosystem with a cornucopia of food and few competitors. This is especially the case in manipulated ecosystems where monocultures are grown from genetically identical stock. For example, on farms and plantations where crop plants may share desirable qualities, there is little natural variation in the population, and potentially no ***resistance*** to an invasive exotic species.

Photo: USDA Forest Service – Region 8 – Southern Archive, USDA Forest Service, Bugwood.org

Figure 21. Lethal infection: Chestnut blight fungus caused this chestnut stem to swell and crack. Orange fungal fruiting bodies are produced in the cracks.

Chestnut blight provides a dramatic example of how successful a specialist diet can be. The American chestnut tree (*Castanea dentata*) was once common and abundant throughout the eastern United States. Around 1900, a fungus (*Cryphonectria parasitica*) believed to have been carried by plants imported from Asia began attacking American chestnut trees. The fungus enters the tree through small cracks or wounds and quickly spreads inside, causing the trunk to swell and crack (Figure 21). The ***disease*** caused by the fungus, chestnut blight, ultimately kills the tree.

Few American chestnut trees had any natural resistance to the fungus and more than three and a half billion of them died of the chestnut blight by 1940. The fungus effectively exterminated the species from eastern forest ecosystems. Today, scientists are trying to restore American chestnut tree populations by crossing genes of the American chestnut with genes from the blight-resistant Chinese chestnut (*Castanea mollissima*).

Ecosystem health: Invasibility and resistance

An ecosystem's ***invasibility*** is the degree to which it can be invaded by an exotic organism. Ecosystems boasting great biotic diversity are less invasible than those that are less diverse. Genetic diversity in plants offers one form of resistance to invasive organisms. Another form of resistance comes from organismal diversity—the more complex an ecosystem, the greater the likelihood of there being an organism equipped to counterattack an invasive, and the fewer the vacant ***niches*** available for an invasive to occupy.

Ecosystems may offer very little in terms of biotic resistance to exotic species. This is because native prey, predators, ***pathogens***, and ***parasites*** have evolved to keep each other in check, and they often aren't adapted to defend themselves against, or take advantage of, a newly introduced exotic species. As a result, if an exotic species is able to adapt to the ***abiotic*** features of its new environment, it will likely be able to flourish without being consumed.

The vast majority of exotic species are unequipped to take advantage of a new environment. Many of them die because they are unable to collect resources, hunt, or reproduce. However, the successful ones are prolific and can have a great impact on ecosystems.

Unfortunately, there are few completely undisturbed ecosystems. Many are fragmented, impacted by pollution or development, and have reduced biotic diversity. Exotic species establishment is facilitated by unhealthy ecosystems, which are not robust enough to put up a defense against these organisms. An exotic may become invasive if after establishing itself, it can push further into the system.

Getting Ready

- Read the *Background*, *Doing the Activity*, and *Student Page* sections to familiarize yourself with the material.

- Prepare the supplies outlined in the *Materials* section.
  - One copy of the *Student Page* section (2 pages) for each student.

Doing the Activity

60 minutes

1. Lead a discussion about exotic and invasive exotic species. Use the *Background Information* to guide a discussion with the following questions.

a. What is an example of an exotic species?

You might use the example of a gingko tree (Ginkgo biloba), native to Asia, but planted in the United States for its ornamental properties and ability to withstand urban pollution.

b. What defines an exotic species?

An exotic species is simply one that is not native to the area.

c. What is an example of an invasive exotic species?

The Chinese tallow tree (Sapium sebiferum) is another Asian native that was introduced to the United States as an ornamental, but has established itself invasively in the South. For more examples, see Resources and References.

d. What defines a species as invasive?

An invasive species aggressively establishes itself in an environment, out-competing and displacing native organisms and in some cases changing environmental features such as hydrology or soil properties. Chinese tallow forms monocultures and greatly reduces biodiversity in the area.

2. Distribute copies of the *Student Page* section to students and ask them to read the descriptions of the exotic invasives. Remind students that these species are just a few of the organisms that threaten natural ecosystems in Florida. Instruct students to pay careful attention to the way each species affects native plants or animals. Ask them to answer the questions at the end of the *Student Page* section.

3. Once everyone has finished answering the questions, go over the answers as a class. Use this opportunity to review with students the various strategies these particular invasive exotics have used to out-compete native species. Each of the questions on *Student Page* 2 corresponds to a strategy that has been successful for at least one of the invasive species introduced in this activity.

4. Have students brainstorm other strategies that exotic organisms might use to establish themselves in an ecosystem. Guide a closing discussion with the following questions.

a. What are some of the ways exotic species came to the southeastern United States?

b. Can you think of any other ways you may not have read about?

You may want to bring up the example of python and other exotic pet releases in Florida.

c. How do invasive exotic species affect native ecosystems?

d. How are invasive exotic species dangerous to native ecosystems?

e. What can we do to prevent the release of exotic species?

f. What can we do to prevent the spread of invasive exotic species?

Invasive exotic species, once established, are often very difficult to remove completely from an ecosystem. ***Biological control*** *is one method of keeping their numbers in check—a predatory species that only targets the invasive is released into the environment. Genetically resistant organisms may also be released, such as American chestnut crosses with Chinese chestnut. Some invasive exotics may be prevented from spreading by manually removing them from the environment. However, investing in keeping out invasive exotics may be far more effective in the long run than spending energy on controlling their populations once established.*

5. To assess understanding, you may ask students to write out a paragraph describing what they learned about invasive exotic species. Each student should include the following:

- A definition, in their own words, of what an invasive exotic species is.
- At least three examples of characteristics that make exotic species successful colonizers.
- Whether or not they think invasive species are problematic, and why.

Student Page Answer Key

These are suggested answers to the *Student Page* section. Students may come up with slightly different answers based on how they interpret the questions. For instance, in answer to question 1, some students have argued that it is not just the redbay ambrosia beetle (d) that brings along its own food. The Japanese climbing fern (b) and air potato (e), being plants, do the same thing—they "bring" their photosynthesizing leaves with them, to make their own food. If there are conflicts between students' answers, use the opportunity to engage students in a critical discussion of why their answers might be right, giving them the opportunity to justify their reasoning and debate the plausibility of each other's arguments.

1. Who brings their food along? *d*

2. Who has no known natural predator? *a, b, c, d, e*

3. Who shades out native plants? *b, e*

4. Who eats anything? *a*

5. Who travels far, wide, and fast? *b, c, d, e*

6. Who grows incredibly quickly? *b, e*

Assessment

Using students' answers to *Doing the Activity*, step 5, check that they can do the following:

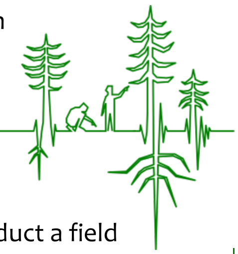
- Define an invasive exotic species.
  Seen in students' responses to the paragraph-writing prompt in step 5.
- Describe at least three invasion strategies used by Florida invaders.
  Seen in students' responses to the paragraph-writing prompt in step 5.
- Describe why exotic species can be problematic.
  Seen in students' responses to the paragraph-writing prompt in step 5.

Extension Ideas

- In many parts of Florida, invasive species control is organized using volunteers. For example, several cities conduct air potato (*Dioscorea bulbifera*) "round-ups" where citizens gather together to find and remove these problem plants. Find out if there is an exotic species removal program in your area and organize a class field trip to help.

- Ask students to research an exotic species found in the United States. Has this organism adapted to its new environment? Has the exotic species become a problem? What issues has it caused?

- Consider assigning students to research common backyard invasive exotic plants found in Florida. Some examples include the Japanese mimosa, coral berry, and air potato. See *Resources and References* for more. Many of these plants are showy, with brightly colored flowers or fruit, and may grow unimpeded in people's backyards precisely because of their aesthetic value. Ask students to make presentations to the rest of the class on the species they researched.



Take it outside

Equipped with pictures, notes on how to identify these plants, and the newfound knowledge of your class, conduct a field trip—to the backyard! Explore school grounds with your class or have your students search around their own homes to see if there are any invasive exotics in the neighborhood. Debate with your class whether anything should be done about these problem plants. Should they be removed? Whose permission would be needed? How often should the neighborhood be rechecked to ensure that the plants don't re-establish themselves? This extension provides an opportunity to practically consider the problem of invasive exotic species removal in a local context.

Resources and References

- The National Invasive Species Information Center provides information and links to resources on local, regional, national, and international invasive species issues. You can search for organisms by geography or by species type. Visit http://www.invasivespeciesinfo.gov/

- For Florida invasive plant information, see *Recognition Cards: Invasive and Non-native Plants You Should Know*, UF IFAS Publication # SP 431. You can search for species by common name, scientific name, and plant morphology. Visit http://plants.ifas.ufl.edu/node/683

- The Florida Fish and Wildlife Conservation Commission provides information and links to resources on various non-native and invasive vertebrates. Visit http://www.myfwc.com/wildlifehabitats/nonnatives/

- The Center for Invasive Species and Ecosystem Health includes images, distribution maps, and other resources on organisms including insects, fungal, and bacterial pathogens. Visit http://www.invasive.org/

Student Page

Name:

Secrets of the Invasive Exotics

Instructions

What makes these invasive exotic species so successful? Read their stories to find out their secrets. Answer the questions that follow by listing all the species that use the invasion strategies described in each question.

Making Themselves Right at Home

a. Cane toad or marine toad

The cane toad is native to South and Central America. Two separate releases contributed to the established populations now found in south Florida. The toad was intentionally released in sugar cane fields to help control pest insects. In addition, 100 cane toads were accidentally released in Miami in the 1960s. Cane toads have a generalist diet and thrive in Florida, eating native frogs and toads, small birds, mammals, snakes, vegetation, food scraps, and even pet food. These toads can be found in urban areas, lakes, ponds, and canals but seem not to be expanding their range beyond south Florida. The cane toad secretes a toxic, milky liquid from its skin that can be dangerous to native wildlife, pets, and humans.

b. Japanese climbing fern

Japanese climbing fern is native to Africa, Asia, and Australia; the first Florida record of this plant was in 1958. The Japanese climbing fern prefers south Florida swamp forests such as cypress domes and the Everglades' tree islands, but is now in north Florida as well. This fern climbs up trees, competing for light and shading out the vegetation it grows upon. Japanese climbing fern also encourages ground fires to reach high into the canopy, burning the sensitive crowns of trees. This plant reproduces by wind-dispersed seed-like spores, and re-sprouts rapidly after fire.

c. Emerald ash borer

The emerald ash borer is a beetle native to Asia that was first discovered in Michigan in 2002. These beetles are currently found as far south as Tennessee. Although this insect has not yet reached Florida, it has the potential to affect ash trees throughout the state. The adult insect is about half an inch long and feeds on the leaves of ash trees. The larvae feed on the wood or inner bark of ash trees. At maturity, the adults fly to new host trees. While adult feeding on leaves causes little damage, larvae feeding on inner bark prevents the transport of nutrients, killing trees in the process.

d. Redbay ambrosia beetle

The redbay ambrosia beetle is native to Asia. In 2002 this insect was discovered in Georgia; by 2005 it had spread to Florida. The redbay ambrosia beetle is only about 2 millimeters long. It forms tunnels through the wood of redbay trees and transfers a fungus to the tree. The beetles feed on this fungus and the fungus feeds on the sapwood. The fungus blocks the movement of water and nutrients within the tree, eventually causing its death.

e. Air potato

Air potato is a vine native to Asia. It was introduced to Florida in 1905 for its medicinal purposes and was promoted as a great garden plant. Air potato develops aerial tubers. While these growths may resemble commonly eaten potatoes, they are actually poisonous. Air potato vines, which reproduce through the aerial tubers, can grow to 70 feet in length at a rate of up to 8 inches a day! The vines climb over trees and shrubs and compete with native plants for sunlight.

Whose strategy is that?

1. Who brings their food along with them?

____

2. Who has no known natural predator?

____

3. Who shades out native plants?

____

4. Who eats anything?

____

5. Who travels far, wide, and fast?

____

6. Who grows incredibly quickly?

____

Photos from Bugwood.org: a) Alex Popovkin, Florula of Fazenda Rio do Negro, Bahia, Brazil, b) Peggy Greb, USDA Agricultural Research Service, c) David Cappaert, Michigan State University, d) Michael C. Thomas, Florida Department of Agriculture and Consumer Services, e) Karen Brown, University of Florida

New Activity 5

A Changing Forest

Lesson Summary

This activity helps students explore the consequences of ecosystem disturbances both manmade and natural. They learn about temporary and long-term effects that such disturbances may have on forests.

The activity is conducted using a group collaboration strategy. Each student has part of the solution to a puzzle, and must work in a group to solve it. Through the activity, they learn not only about ecosystem processes and human and natural effects on the forest, but also about the power of cooperation in learning and problem solving.

Background

Forests in Flux

A forest is constantly growing and changing over time. Part of this transformation is a result of seasonal or periodic changes in the physical and natural elements of the ***ecosystem***. Trees go through cycles of growth and dormancy, responding to seasonal differences in light levels, temperature, and weather conditions. As a result, visiting a forest in the height of summer may impart a very different view of plant and animal activity than in the midst of winter.

Individual trees change as well. Trees in the forest canopy—the tallest and sometimes the oldest—eventually die and fall over. New trees in the understory race to claim the newly available ***light gaps***. The population dynamics of trees in a forest often follow patterns of ***ecological succession***. The fastest and tallest growing species are the first to claim the canopy, but slower growing species with longer life spans eventually push through and out-compete them. The ***composition*** of trees in a forest is also influenced by features such as drought and fire—elements of the environment that may selectively kill susceptible trees. For more information on changes to forest composition, see *Resources and References*.

Other organisms in the forest, from microbes to fungi to animals, also experience population fluxes. Since the ecosystem is an organic collective of interrelated organisms and ***abiotic*** elements, population shifts in one organism may cause cascading shifts in others.

Sunshine State Standards

SC.5.L.15.1: Describe how, when the environment changes, differences between individuals allow some plants and animals to survive and reproduce while others die or move to new locations.
SC.7.L.17.1: Explain and illustrate the roles of and relationships among producers, consumers, and decomposers in the process of energy transfer in a food web.
SC.7.L.17.3: Describe and investigate various limiting factors in the local ecosystem and their impact on native populations, including food, shelter, water, space, disease, parasitism, predation, and nesting sites.

Materials

For each group of six students
1 copy of the *Student Page A* or *B* (1 page).
1 calculator.
6 pencils.
6 pieces of scrap paper.

For the teacher
1 pair of scissors.

Time Considerations

Part A: 30 minutes
Part B: 30 minutes

Behavioral Objectives

Students should be able to do the following:
- Identify events as natural or human influenced.
- Identify ways in which a forest may be affected by changes.
- Link human activity to changes in the forest.
- Identify skills needed to work effectively in cooperative groups.

This dynamic system has internal motion, but it may be affected by external factors as well. Humans are an important source of changes to forest ecosystems. They harvest from, plant within, and live around forests, and in doing so introduce various biotic and abiotic agents to these ecosystems. The proliferation of ***invasive exotic*** species and the effects of urban development are additional influences humans have on the composition of forests. Humans often aid ***forest health*** by using positive management strategies to counteract some of the negative effects of their actions.

Ecosystem health: Figuring things out together

This activity enables students to contemplate the impacts that natural and human-influenced events can have on a forest. The activity is a puzzle and can be only solved through cooperation and collaboration. Students in groups of six are each given a card. Each card contains a few lines of seemingly unconnected information, and the group needs to put their "six bits" of information together to solve the mystery.

The mystery itself explores issues of changing forests, but since no individual knows everything about the problem, they cannot solve the puzzle alone. The activity helps students explore the types of leadership and teamwork skills that enable groups to accomplish a task. It also models an important societal skill showing how cooperative actions help solve problems and how everyone has valuable knowledge to contribute. In conducting this activity with your students, you may point out that collaboration works on more than just the classroom level—it may also help people think through real-world issues such the changing state of forest health and the environment in general.

Getting Ready

- Read the *Background*, *Doing the Activity*, and *Student Page* sections to familiarize yourself with the material.
- Prepare the supplies outlined in the *Materials* section.
  - For each group of six students in your class:
    - One copy of the *Student Page* sections *A* or *B* (1 page). You may choose to do either Part A, B, or both.
    - One calculator.
    - 6 pencils.
    - 6 pieces of scrap paper.
  - For the teacher:
    - One pair of scissors.
- Cut each *Student Page* along dotted lines to form sets of six cards for each group.

Doing the Activity

Part A
30 minutes

1. Discuss with your students how a forest ecosystem changes over time. You can help them understand that individuals grow and die on a regular basis, but the forest is still a forest. Use the following questions and the *Background Information* to guide the discussion.

a. If you visit a forest and return five years later, what would be different?

On a very basic level, population changes in the forest include births, deaths, and migrations to and from the ecosystem. Natural population shifts may also be influenced by external forces—deforestation is one dramatic example, hurricane damage is another.

b. If a forest looks different, does it mean it has changed?

Forests change on micro and macro levels. If within the course of five years nothing drastic has happened, while individual trees and animals may be older, newly arrived, or dead, the forest would still look and function much as previously had. However, if in that time a wildfire, pollutant, or invasive species had disrupted the ecosystem, the forest may have reverted to a grassland or scrub-like ecosystem.

c. What kinds of changes in individual trees constitute a change in the forest?

Species composition may change over the course of many years. Ecological succession results in fast-growing, light-dependent shrubs and trees being replaced by slow-growing, shade-tolerant species. Organisms dependent on the primary growth may have to move on, while organisms dependent on the secondary growth have a place to call "home." The forest remains, but its makeup has changed.

*The transformation of a forest may be caused by changes in water, sunlight, weather, climate, **disease**, nutrients, or human activity. The inputs to a forest can affect the output of a forest and ultimately, the structure of a forest ecosystem. While each of these changes has an immediate effect, they also can have several cascading effects as the system changes over time.*

2. Separate the class into groups of six students. Groups of less than six are preferable to greater than six, to make division of cards easier. To each group, you will be handing cards from *Student Page A*, "Six Bits of Exotics."In this six bits puzzle, students learn about the potential effects of an exotic pet release into a forest. Note that the organisms used in this six bits scenario, the wilia snake, roosroos frog, hilo grasshopper, gawa hawk, and fanfin grass, are all fictitious.

However, the relationships between them and their roles in the forest are modeled after real ecosystem processes and reflect what might actually happen if a non-native organism such as the wilia snake were to be released into a forest. For example, exotic invasive Burmese pythons that were once pets have been released into the Florida Everglades and have similarly compromised that ecosystem.

3. Distribute the six bits cards from *Student Page A* to each group. Each student should receive one card; for groups short of six students, you may hand a student an extra card so that the group still has all the information needed to solve the puzzle. Ask the students not to look at their cards yet.

One of the statements on one of the cards is a question that each group must answer. Information from each of the six cards will be necessary to answer the question; however, some of the statements may be red herrings—they do not help to solve the puzzle.

To prevent students from discarding responsibility and to keep them engaged, they may not show their cards to anyone else, but may read information from their cards out loud. Since each group has the same set of cards, it allows you to discuss differences in problem-solving strategies and the comparative effectiveness of each group.

4. Instruct students in the rules of six bits:

- Each group gets a set of six cards.
- Each student in the group gets one of the six cards.
- They are not allowed to show their card to anyone else.
- They are not allowed to look at anyone else's cards.
- They may tell people in their group, verbally, what is written on their card.
- **Each group is responsible for finding out the answer to the question posed on one of their cards.**
- The puzzle is also a race—groups compete to solve the puzzle first.

When everyone has received a card and understands the directions, allow students to look at their cards and try to answer the question. Students may initially be frustrated at not knowing what to do. Assure them that someone in the group has the question that they should work on and that they have everything they need within their group to solve the puzzle. You don't have to guide the groups; the objective is to allow them to discover their own leadership skills and problem-solving strategies as they work out the puzzle.

5. Once all the groups have solved the puzzle, ask students the question posed by the activity: **"Will the wilia snake be able to survive in Brandywine Forest?"**

Have each group of students share their answer to the question. Students should have discovered that the exotic wilia snake, released into Brandywine Forest by its owner Arno, is in an environment perfectly suited for survival—the snake has plenty of prey to eat and the temperatures are within a habitable range in that particular forest.

6. Further explore the issue of exotic pet releases. Ask your students to refer back to their cards for information, and use the following questions to guide discussion.

a. What are the potential consequences of the wilia snake's release in the forest?

Students should pick up on the cascading series of problems the wilia snake could bring to the forest. It eats roosroos frogs, of which there are many in Brandywine Forest. The frogs feed upon hilo grasshoppers, so if the frogs' population goes down, the grasshoppers will proliferate. The grasshoppers feed on fanfin grass in Brandywine, resulting in less grass for deer. Meanwhile, with less roosroos frogs, the endangered gawa hawk loses its only source of food. There are no natural predators of the wilia snake. It could be hugely destructive to the Brandywine ecosystem.

However, is the wilia snake female? If female, is it pregnant and can it lay eggs? Are there more wilia snakes in Brandywine Forest already? The ultimate effects of the wilia snake's release aren't predictable as long as these unknowns remain.

b. Will the wilia snake's survival affect other organisms in the forest? If so, which organisms and how? Do these changes alter the forest ecosystem if the snake is unable to reproduce?

As noted above, deer, roosroos frogs, fanfin grass, and gawa hawks may all experience dips in population as a result of the wilia snake's activity. The hilo grasshoppers will flourish. If the wilia snake dies before reproducing, or is unable to reproduce, then it is unlikely that this individual could affect long-term changes to Brandywine forest, as there are many more roosross frogs than it could eat in a lifetime.

c. Was this event influenced by humans or nature?

Exotic pet releases are a human-caused event. The exotic pet trade results in both accidental and deliberate releases of exotic animals.

d. If other wilia snakes were released in the same forest at the same time, what might happen?

This would most likely result in reproduction. Refer to previous answers.

e. If the composition and structure of the wildlife populations change, does that mean the forest changes?

Yes, the organisms in a forest ecosystem are interdependent; if the populations of key species are altered, there will be in changes to the rest of the ecosystem as well. As the composition of animals in Brandywine Forest might change if wilia snakes were able to invade the ecosystem, this would alter the vegetation found there as well. The disappearance of fanfin grass, for example, would open up ***niches*** *for other vegetation to take hold.*

7. Now broaden the discussion to talk about how students solved the puzzle. Use the following questions as a guide.

a. Who took a leadership role in your group? What skills and resources did that person have?

Leadership may manifest itself in many ways during a six bits activity. It could be that a person with the foresight to ask everyone else questions is the one who gets the ball rolling on solving the puzzle. It could be the person who has a pencil and is able to take notes. It could even be the gender ratio in a group that either favors or hinders group cooperation.

b. Did everyone participate equally?

c. How effectively did the group function? What might have improved efficiency?

You may ask the group that finished first why they solved the problem so quickly.

d. What skills were used to complete this task as a group?

e. What different strategies enabled some groups to finish before others?

Part B
30 minutes

8. Divide the class back into the same groups as in Part A, and now distribute cards from *Student Page B,* "Six Bits of Wildfire."Have them solve the puzzle as they did before. You may choose to hand out calculators and scrap paper to help them solve the problem, as it requires mathematical skills. This version of six bits allows students to take a different look at changes to a forest. Groups try to figure out if a wildfire will reach a small town. Once again, a fictional scenario is used to describe real issues in Florida—including the proximity of housing and development to forested land, the regional risk of wildfire, and the presence of fire-adapted ecosystems.

9. As in Part A, ask groups to volunteer their answer to the question posed by the puzzle: **Can the fire fighters stop the fire before it reaches Starville?**

Students should find that the helicopter pilots could put out the fire before it would have reached the town.

10. Explore the scenario in greater detail with your students. Use the following questions to guide discussion.

a. Was this fire created naturally or through human influence?

It was naturally created.

b. What are some other ways that an ecosystem may be naturally altered, either temporarily or permanently?

Rainfall, hurricanes, flooding, tornadoes, volcanoes, atypical local temperatures, drought, disease, or insect defoliation, just to name a few. However, some of these natural alterations may also be influenced by humans. For instance, urban areas increase local temperatures and reduce groundwater, increasing the likelihood of drought.

c. What might have been some potential consequences if the fire had reached the city?

The fire would have burned many acres of forest and may have burned parts of the town, including houses, businesses, and schools; displaced residents; or disrupted communication and transportation. It may have continued beyond the town.

d. How do you think the fire in the forest affected plants and animals?

Some plants and animals die in wildfires but many survive. Mobile organisms may flee and migrate to a safe part of the forest and others find holes in the ground to hide. While many plants may die, some may have specialized adaptations to take advantage of the fire. In Florida forests where fire is natural and frequent, many plants have protective thick ***bark****, root balls deep below ground to avoid the heat of the fire, stiff leaf layers to shield new growth from the heat, the ability to quickly re-sprout after a fire, and cones that release seeds soon after a fire when the area has been cleared of competitive vegetation.*

e. What systems are affected by this event? How? Does the fire ultimately change the system in the long term?

The forest ecosystem and Lake Talla could both be affected by the fire. However, because Jackson Pine forest is an ecosystem that experiences fire often, it is not altered in the long term. The fire actually maintains the health of the forest. Lake Talla could be impacted by this fire in several ways. The biotic make-up of the lake system could be changed if a significant amount of water is removed.

Cont'd on next page

Cont'd from previous page

If the fire reaches the lake's watershed, rain could wash cinders into the lake and increase erosion, changing the water chemistry in the lake. In addition, the residents of Starville may be motivated to create Firewise landscapes (see Resources and References*).*

f. If this forest were a different type of ecosystem that did not experience regular fire, would it be changed?

Yes, because the plants and animals in a community that doesn't experience fire are not adapted to survive such an extreme ***disturbance****.*

g. Do you think the trees that live in this area are adapted in any way? What is the ***limiting factor*** for many plants in this environment?

Yes, this forest experiences frequent fires, so these pine trees are likely fire-adapted. Many pine trees have thick bark to protect their inner structures during fire. Others even depend on fire to trigger the release of their seeds. Fire could be the limiting factor for plants in this environment. Some plants cannot survive the intense heat but several, such as many pine species, take advantage of the reduced ***competition*** *to flourish.*

11. Now discuss the groups' problem-solving strategies, using the following questions as a guide.

a. Who took a leadership role in your group? What skills and resources did that person have?

b. Did everyone participate equally?

c. How effectively did the group function? What might have improved efficiency?

d. What skills were used to complete this task as a group?

e. What different strategies enabled some groups to finish before others?

12. Wrap up the activity by discussing with students the advantages of group collaboration. You may ask if they enjoyed depending on each other for information, or whether they were frustrated because they couldn't work alone. Most real-world situations do require cooperation between parties with different interests, including forest health issues. Learning how to capitalize on the skills and knowledge of all parties is in the best interests of all. For more examples of six bits puzzles and brief introduction to concept mapping as a connected learning strategy, see *Resources and References*.

Assessment

Using observations of students' behavior and responses during discussion, check that they can do the following:

- Identify events as natural or human influenced.
  Seen in students' answers to Doing the Activity *Part A, step 6, question c and Part B, step 3, question a.*
- Identify ways in which a forest may be affected by changes.
  Seen in answers to Doing the Activity *Part A, step 6 and Part B, step 3.*
- Identify skills needed to work effectively in cooperative groups.
  Seen in answers to Doing the Activity *Part A, step 7 and Part B, step 4.*

Note that these are group assessment suggestions. To assess students individually, you may ask them to write short paragraphs on one of the following topics: a) What sort of changes may occur within a forest and when are these changes cause for concern? or b) What did you learn from having to work in a group to solve a problem? Was it easy or difficult to do so, and why?

Extension Ideas

- Have students research the longleaf pine ecosystem, which was previously the dominant ecosystem in Florida. Today, longleaf pine habitat has greatly decreased. Ask students to research why the longleaf pine ecosystem has declined. Students will no doubt encounter several reasons, such as fire suppression, urban development, and timber harvest. What steps are being taken to restore longleaf pines, and why does it matter?

Resources and References

- The University of Florida's SFRC Extension website for educators includes several related resources:
  - For an extended look at forest composition changes, see *Beyond the Trees*, *Activity 1: A Walk in the Woods*.
  - For another six bits scenario, see *Activity 2: Six Bits of Abiotics* in *Beyond the Trees,* which covers abiotic forest health issues and includes a concept-mapping strategy to help students understand how information is connected.

  Visit http://.sfrc.ufl.edu/extension/ee/foresthealth.html
- You can find out more about Firewise landscapes through the SFRC Extension Fire in Florida website and the Electronic Data Information Source (EDIS).
  Visit http://fireinflorida.ifas.ufl.edu and http://edis.ifas.ufl.edu

Student Page A

Six Bits of Exotics

Instructions

For each group of six students in your class, make one copy of this sheet. Cut the six cards along the dotted lines. Distribute a set of cards for each group—one card per person for each group of six. Remind students that they cannot show others their cards to each other.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- Roosroos frogs eat many things, including hilo grasshoppers, if they live in the same forest.
- The small gawa hawk feeds strictly on roosroos frogs.
- Fanfin grass is an important food source for many grazing animals like deer.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- Hilo grasshoppers are abundant in Brandywine Forest.
- Wilia snakes can reach lengths up to 18 feet long and lay 40 to 70 eggs each breeding season after maturity
- Arno can no longer care for his large pet wilia snake.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- Fanfin grass grows in this forest.
- No regulations or permits are required to own a non-venomous, exotic snake such as the wilia snake in Florida.
- Roosroos frogs are abundant in Florida forests with high hilo grasshopper populations.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- The wilia snake prefers a warmer climate—80° to 90° F.
- Hilo grasshoppers eat fanfin grass when they can find it.
- No Florida animal will be able to kill and eat a wilia snake.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- Wilia snakes only eat roosroos frogs.
- There are close to 40 exotic reptiles breeding in natural Florida habitats.
- Arno releases the non-native wilia snake into the nearby Brandywine Forest in Florida.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- Gawa hawks are an endangered species.
- Will the wilia snake be able to survive in Brandywine Forest?
- Brandywine Forest is subtropical and tends to be 80° to 90°F during the day.

Six Bits of Wildfire

Instructions

For each group of six students in your class, make one copy of this sheet. Cut the six cards along the dotted lines. Distribute a set of cards for each group—one card per person for each group of six. Remind students that they cannot show others their cards to each other.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- Can the fire fighters stop the fire before it reaches Starville?
- Lake Talla is located 15 miles west of Starville.
- Fire needs oxygen, fuel, and heat to burn.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- The fire is moving at a rate of 5 miles per hour.
- The Incident Commander has obtained four helicopters from nearby cities and outfitted them with water buckets.
- Fire has historically burned in Jackson Pine Forest every seven years.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- Starville is located 20 miles directly north of the Jackson Pine Forest.
- Lake Talla contains about 2,000,000 gallons of water.
- The pine trees in Jackson Pine Forest require fire to germinate.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- Each helicopter bucket has a 250 gallon capacity.
- Lake Talla provides a home for many native fish and aquatic life and is an important source of water for terrestrial life.
- Each helicopter flight between the fire and Lake Talla and back takes about 30 minutes.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- The fire in Jackson Pine Forest was ignited by lighting.
- The Incident Commander is asking helicopter pilots to collect water from Lake Talla and dump it on the fire.
- Starville is built in and around a pine forest.

DIRECTIONS: You may NOT show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to solve the problem.

- Winds are pushing the fire north.
- The Incident Commander estimates that it will take about 5,000 gallons of water to contain the fire.
- 3,000 residents live in Starville.

Extension to PLT Activity 32

A Forest of Many Uses

Lesson Summary

The original *A Forest of Many Uses* has students imagine that they have to manage a forest for more than one purpose: encouraging wildlife, recreational opportunities, and harvest of forest products.

In this extension to *A Forest of Many Uses*, students are pushed a step further. They are asked to consider the impacts of their management strategies upon the health of a forest. In other words, they are asked to think about the consequences of management strategies and to brainstorm methods to counteract negative consequences.

Doing the Activity

1. Read the original version of *A Forest of Many Uses* on page 135 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* section.

Doing the Activity includes two parts, A and B. *Part B—Management Decisions* concludes with a student discussion on whether forests can always be managed for multiple purposes, or whether some management goals might conflict with one another. This extension focuses on Part B.

2. Continue the discussion with the following questions that link management decisions to their effects on overall ***forest health***. The answers provided here are not comprehensive; you and your students may come up with other ideas for discussion.

a. Forests may be managed to simultaneously encourage wildlife populations and recreational usage; however, recreational activities might negatively impact wildlife populations and, by extension, the forest's health. Can you think of any alternative measures to minimize conflict?

*To help students answer this question, have them consider the forest from the perspective of the wildlife. Hikers, bird watchers, hunters, and other recreationalists constitute **disturbances**, since they may inadvertently scare off wildlife, disrupt shelter and feeding grounds, facilitate **invasive** species introduction, or remove or upset endangered or threatened **native species**. Plants may suffer as well—Florida's endangered ghost orchid, for example, has greatly declined in numbers, in part because of unlegislated collecting by orchid hunters in early twentieth century. Threats to plants and wildlife have repercussions, as they may affect the overall health of forest **ecosystems**.*

Management might address these issues in several ways: restricting access to forests at particular times of the year, such as breeding season; encouraging responsible behaviors through campaigns and slogans such as "leave no trace," and "pack it in, pack it out"; and building roads and trails that avoid important or sensitive habitats, such as feeding and shelter grounds.

b. Forests that are managed for forest products are closely monitored for signs of tree ***diseases*** or insect damage. Management strategies, such as using pesticide or fungicide and promptly removing diseased or insect-infested trees, are employed to encourage healthy, productive forests. But can there be conflicts if the forest is also managed for wildlife? What are alternative strategies?

*Many insect **pests** and disease-causing organisms are natural components of the ecosystem; they may damage, weaken, or kill trees, but by doing so they release nutrients into the environment and provide sources of food. What would birds, bears, snakes, and frogs feed upon if pesticides were used to kill insects attacking pines? Where would beetles, raccoons, and lizards seek shelter if there were no fungus-rotted trees in their habitat?*

*Management might address these issues by being cautious with their pest and disease removal strategies. They may try breeding genetic-**resistance** in trees instead of using fungicides; avoid using pesticides that would build up and harm larger organisms such as birds; or concentrate their efforts on the eradication of **exotic** and invasive pests and disease **pathogens** while leaving native pests and pathogens to perform their natural role as **herbivores** and **decomposers** in the environment.*

c. In forests maintained for recreational purposes as well as forest products, conflicts may arise between people expecting different services from forests. What sort of conflicts might arise when managing, for example, a pine plantation where camping and hiking may occur? How might these conflicts be reconciled?

Some of the strategies used by forest managers may seem alarming to the general public—for instance, the use of herbicides to kill understory plants, or the practice of rotational clearcuts to harvest trees. While these strategies

Cont'd on next page

Cont'd from previous page

*are necessary to efficiently grow and extract valuable resources from the forest, they may conflict with a recreationalist's expectations—tree stumps and dead vegetation may not be the idealized view of a forest. Recreational users may interfere with forest processes as well. Hikers may accidentally introduce fungal **spores** or bacterial pathogens to a new environment, caught in the mud caked around their boots from previous expeditions (Figure 22). Campers bringing firewood from their homes to use in the woods may unintentionally carry hitchhikers along—bark beetles and other insect pests have often been introduced inadvertently through contaminated logs brought from elsewhere.*

Management might address these issues by creating opportunities for education and outreach: the public could be familiarized with the importance of understory clearance and harvesting rotations, and informed about the dangers of hitchhiking insects and tree pathogens. Moreover, outreach may address the misconception that plantation forests operate in the same ways that natural forests do—with minimal management and manipulation of the ecosystem.

d. Foresters and ecologists in Florida are working to restore and re-establish the native longleaf pine ecosystem. This involves exotic species removal, native plant removal, and periodic fires to recreate conditions suitable for longleaf pine growth. Residents in neighboring ***urban forests*** are affected by these management decisions. They may be required to adapt to drifting smoke and deal with the fear of fire crossing into their backyards. They may also have to part with exotic invasive and native trees that they have grown accustomed to—such as Brazilian pepper (*Schinus terebinthifolius*) and laurel oak (*Quercus laurifolia*)—because these trees do not belong in longleaf pine forest and radically alter the ecosystem. How would managers handle such a conflict?

*Management might address this issue by once again creating opportunities for outreach and education. Misconceptions about the purpose and safety of prescribed fire could be addressed so that residents are not alarmed when prescribed burns occur nearby. Education about invasive exotic species and native species **competition** would also be helpful—the eradication of unwanted plants in a restoration area would be futile if the surrounding residential areas contained the same plants, ready to spread seed onto fresh ground. Suggestions of replacement species would also be productive.*

*Another educational tactic addresses people's **values**—the longleaf pine ecosystem is a rich support system for a diverse range of organisms, many of which are unique to Florida and the Southeast. Longleaf pine restoration, apart from being an ecologically beneficial endeavor, could also be thought of as a source of regional identity and pride.*

Photo: Martha. C. Monroe

Figure 22. Brush your feet! This sign, from the National Parks and Wildlife, South Australia, reminds park visitors to brush mud off their footwear as they enter a natural area to prevent the spread of fungal pathogens.

3. Wrap up the discussion by reinforcing the key concepts. Wildlife flourishes in healthy ecosystems, and these ecosystems are also highly useful to people for recreation and as sources of forest products. However, managing forests for more than one purpose may result in conflicts of opinion between people who have different agendas. People in forests may also inadvertently stress or weaken the ecosystem by disturbing wildlife, introducing invasive organisms, or removing valuable trees or animals. Management strategies should take into account how to maximize the use of forests while minimizing damage and potential sources of conflict.

Extension to PLT Activity 19

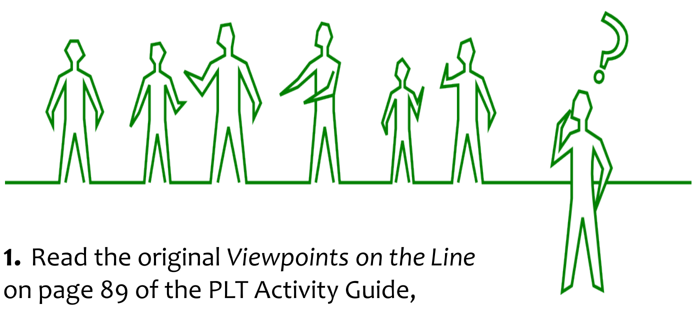
Viewpoints on the Line

Lesson Summary

The original *Viewpoints on the Line* gives students an opportunity to express opinions on current environmental issues, explain why those opinions are important to them, listen to other students' opinions, and then re-evaluate their feelings based on hearing about the issues from other perspectives.

This variation of *Viewpoints on the Line* allows students to form and evaluate their opinions on current forest health issues. It takes everyday scenarios such "tree planting" or "pesticide use" and puts them in a potentially controversial context where the health of forests is implicated.

Doing the Activity



1. Read the original *Viewpoints on the Line* on page 89 of the PLT Activity Guide, including the *Background Information*, *Getting Ready*, and *Doing the Activity* sections.

2. Use the following statements in addition to, or instead of, the opinion statements provided in *Student Page* on page 91. Each of these statements addresses a topic related to ***forest health***.

a. Some trees that are in urban areas today may be remnants of the forest that existed before the city expanded, and they may be hundreds of years old. As these trees die their branches fall off, birds, raccoons, and other animals roost in the hollowed trunks, and eventually the whole tree topples over. To protect people who live in urban areas from falling branches, some old trees and certainly all dying trees should be removed from towns and cities.

b. *Native* insects that may have negative economic impact to the forest industry should be killed with pesticides before their populations grow significantly, even if it is expensive and a lot of other beneficial insects may die in the process.

c. *Exotic* insects that have the potential to wipe out a tree species should be killed with pesticides before their populations grow to significant numbers, but only if the endangered tree is really valuable to people —for example, because its ***bark*** can be used to extract medicine.

d. *Invasive* exotic species should be removed from the environment regardless of the cost—even if it means using expensive pesticides and herbicides; paying for research to find new ways to stop the organisms; yearly volunteer efforts to search out, remove, and destroy invasives to make sure there are no hideaways for them to reemerge from; and telling people they can't keep exotic pets at home or grow exotic plants in their gardens.

e. In this age of global trade and transportation, we can't expect species to stay put. There is no such thing as an exotic species anymore. So we should stop trying so hard to get rid of them. Besides, even if an exotic species could cause billions of dollars in damage to the environment if it spread out of control, most exotic species never become invasive, so it's not a problem.

f. Putting roads into forests changes the forest structure in many ways: they allow in more light, create pathways that can introduce invasive organisms, and also allow more development to occur within forests—both houses and research stations can be built there. Because of this, we should not put roads through protected forests.

g. In some cases, people can change a forest ***ecosystem***, such as by accidentally bringing in ***disease***-causing fungi; ***compacting*** soil and compressing roots along trails; and hunting wildlife. Because of this, some wilderness areas should be off limits to people.

h. Since trees are renewable resources, all forests should be harvested for biomass energy and replanted continuously. And to make things more efficient, instead of replanting slow-growing, long-lived trees such as longleaf pines, we should plant fast-growing, short-lived trees such as loblolly pine.

Cont'd on next page

Cont'd from previous page

i. A planted forest is just as healthy as a natural forest, even if its species ***composition*** is different. It still contains trees, shrubs, grasses, insects, fungi, bacteria, birds, reptiles, and mammals, even if there are fewer and different kinds of these organisms than those that you might find in a natural forest. Planted forests are easier to explore, too, because the trees are planted around pathways so people can access them for forest products.

j. There really isn't anything bad about invasive exotic species. Ecosystems have been adapting and evolving for millions of years, so it will be easy for them to incorporate new organisms.

k. Trees that are diseased or infested with harmful organisms should be removed before they die to halt a possible epidemic, even if it means cutting down beautiful big trees in someone's front yard.

3. Wrap up the activity by discussing the importance of developing opinions on forest health as well as listening to the opinions of others. Many aspects of forest health are controversial because determining right and wrong or good and bad depend on value judgments. Helping youth become more knowledgeable and able to express opinions helps build a community that is able to understand and debate these issues. Ultimately, your students are ***stakeholders*** and future decision makers responsible for the planet's natural resources. The ***values*** they hold and express will determine how forests are used, conserved, preserved, and managed.

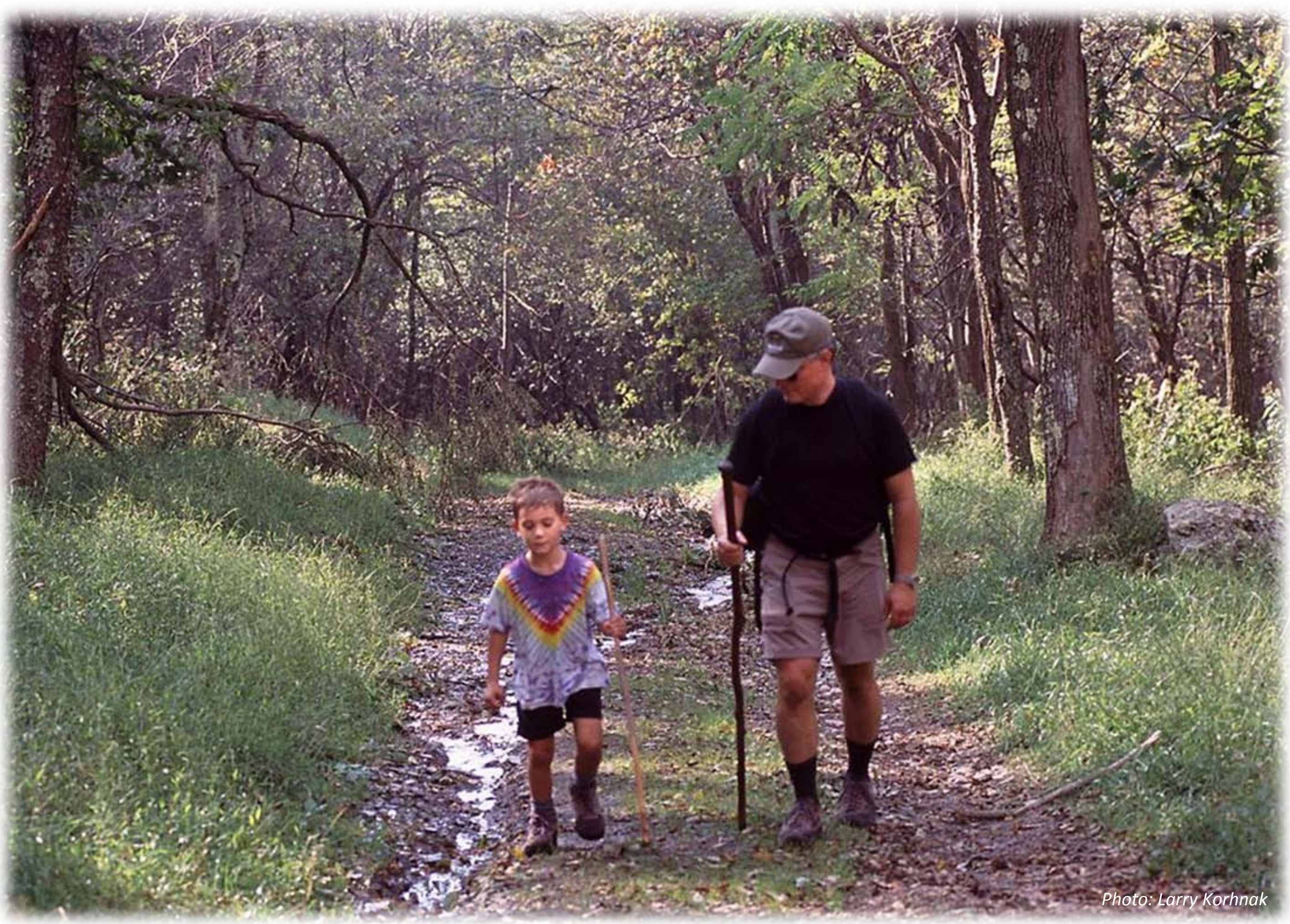


Photo: Larry Korhnak

Glossary

Many of the words listed here also appear in the Project Learning Tree PreK–8 Environmental Education Activity Guide (PLT) and have been reproduced or modified here for your convenience.

Abiotic
A nonliving factor or element in an environment; e.g., light, water, heat, rock, and gases. (PLT)

Bark
The tough exterior covering a woody root or stem. (PLT)

Boundary
The limits drawn around a system; the boundaries may be physical or abstract.

Biological control
The use of a parasitic or predatory organism to target and control populations of a pest organism. For example, gardeners release ladybird beetles to feed on aphids.

Biotic
An environmental factor related to or produced by living organisms. This includes plants, animals, and fungi, but also leaf litter, bones, and organic matter produced from digestion. (Modified from PLT)

Camouflage
Color, tones, patterns, shapes, or behaviors that enable an organism to blend in with its surroundings. (PLT)

Carnivore
An animal that consumes other animals. (PLT)

Colonize
Successful establishment of a species in a new environment.

Compaction
When pressure on surface soil packs it densely, it decreases the soil's ability to hold air and water and restricts tree root growth. Compaction occurs naturally, such as under the weight of glaciers, and anthropogenically, such as with foot or automobile traffic.

Composition
The makeup or characteristics of a forest, referring to the types of trees species and age classes of trees found there as well as other environmental characteristics such as the type of soil, the microclimate in the region, biotic elements, and so on.

Commensalism
A relationship between two organisms of different species in which one benefits while the other is generally neither helped nor harmed. (PLT)

Compartmentalization
In woody tissue, the development of physical or chemical barriers between a wound and healthy cells.

Competition
The struggle between individuals of the same or different species for needed resources such as nutrients, sunlight, water, space, or food.

Cryptic coloration
A type of camouflage using color and patterns to become hidden.

Decomposer
A plant, bacterium, fungus, or animal that feeds on dead material and causes it to be reduced to nutrients and organic matter through mechanical or chemical means. (Modified from PLT)

Decomposition
The breakdown of dead matter into organic compounds and nutrients.

Disease
An abnormality that has disruptive effects on an organism, compromising its ability to function normally, and sometimes affecting its ability to survive. Diseases may be caused by nutritional deficiencies, environmental stressors, or biotic organisms (pathogens) such as fungi and bacteria.

Disease triangle
A concept used to describe how the right kind of host and the right kind of pathogen both need to be present in an environment under conditions that favor the pathogen's ability to damage the host and the host's susceptibility to damage. If these three conditions are not met, no disease occurs. Tree pathogens include fungi, insect-transmitted microbes, viruses, bacteria, and nematodes.

Disturbances
Factors that disrupt or halt normal growth in a forest. Natural disturbances include lightning or hurricane damage. Anthropogenic or man-made disturbances include deforestation or fire suppression.

Glossary

Ecological succession
The changes, over time, in the structure and fuction of an ecosystem. Plant succession in an ecosystem typically involves turnover from grassland and shrubs to trees, or from fast growing, short-lived trees to slow growing, long-lived trees. (Modified from PLT)

Ecosystem
The interacting system of a biological community and its nonliving environment and the place where these interactions occur. (PLT)

Environmental conditions
The influences, such as weather and nutrient cycles, that affect the survival of an organism and its population growth. (Modified from PLT)

Epiphyte
A plant that grows on the surface of another plant. (PLT)

Exotic species
A species that has been introduced by human action, either intentionally or by accident, into areas outside its natural range (also called a non-native species). (PLT)

Forest health
The state of a forest, dependent on many factors including its composition, functional properties and uses, and the reasons for which it is valued. Typically, it has an appropriate degree of diversity and is able to withstand disturbances and continue to flourish.

Generalist
A species that uses a variety of resources to meet its needs; most typically, an animal that can eat a variety of foods.

Heartwood
The older, harder, nonliving central portion of wood of some trees that is usually darker, denser, less permeable, and more durable than the surrounding sapwood. Many trees do not form true heartwood. (PLT)

Heat island
An urban phenomenon where development causes the land surface to retain heat rather than reflect it; this causes urban areas to be hotter than neighboring rural areas, where the vegetation keeps the land slightly cooler.

Herbivore
An organism that feeds on vegetation. (PLT)

Host
An organism upon which another species can live. A host may support species that cause no harm to the organism, such as lichen on tree bark, or they may support parasites and pathogens such as mistletoes and root fungi, which grow into a tree to steal its resources.

Hyphae (singular: hypha)
Microscopic filaments or tubular threads that form the vegetative body of a fungus. Masses or organized structures of multiple hyphal hairs form what is known as mycelia.

Invasive species
A plant, animal, or other organism that is typically exotic to a particular ecosystem and whose introduction causes—or is likely to cause—harm to the economy, the environment, or human health. (Modified from PLT)

Invasibility
The degree to which an ecosystem may be invaded by exotic species.

Keystone species
An organism whose influences greatly affect the composition and function of an ecosystem, to the extent that fluctuations in its population can have vast repercussive effects on other species as well abiotic factors in the system.

Lateral root
An offshoot from a primary taproot that helps anchor the plant in soil, as well as collecting water and minerals.

Light gap
The space created in a forest after a tree falls; the opening in the canopy allows light to stream down to the forest floor where there was previously shade.

Limiting resource
A needed resource in short supply such that it restrains the growth of a population or organism.

Mutualism
A symbiotic relationship between organisms of two different species in which both benefit from the association. (PLT)

Mycelia (singular: mycelium)
The thickened mass of hyphal hairs, mycelia form the physical, vegetative parts of the fungus and can take many forms, ranging from sheets to ropes to globular clusters.

Glossary

Mycorrhizal fungi
These highly specialized fungi form symbiotic associations with plant roots. The mycorrhizae increase the absorptive surface area of plant roots by enveloping them in a sheath that helps absorb water and minerals such as phosphorus from the soil. In exchange for supplying limiting resources to their plant hosts, the fungi receive sugar and other nutrient essentials from the plants.

Native species
A species that occurs naturally in an area or habitat. (PLT)

Niche
The ecological role played by organisms. The food it eats, the territory it lives on, the influences it has on other organisms and on the landscape all are characteristics of that organism's niche. (PLT)

Nutrient cycles
The circular pattern in which nutrients such as carbon and nitrogen move between biotic and abiotic components of the ecosystem.

Omnivore
An organism that eats both plants and animals. (PLT)

Parasite
An organism that lives off a host species, to the detriment of the host.

Parasitism
Any relationship in which a consumer organism lives on or in and feeds on a living plant or animal, known as the host. The parasite draws nourishment from and may gradually weaken its host and kill it. (PLT)

Pathogen
An organism such as a bacterium, fungus, or virus, that causes disease.

Pest
A nuisance organism. The term is typically used to describe destructive plant-feeding, stem or root-boring insects, usually in the context of the damage they cause to economically valuable trees.

Phloem
The plant tissue that transports dissolved nutrients from the leaves to the other parts of the plant. Also called the inner bark. (PLT)

Primary consumer
An organism that obtains energy by feeding on primary producers.

Primary producer
An organism that makes its own food, using sunlight or inorganic chemical compounds. Plants and algae are photosynthesizing primary producers. Some bacteria, such as those found in deep ocean vents, synthesize chemicals to make food.

Resistance
The ability of an organism to ward off insect attacks or disease. Organisms can express genetic resistance to pests or pathogens, or the environment might favor their fitness against attackers. Resistance may also be applied loosely to describe an ecosystem's ability to withstand disturbances such as invasive exotic encroachment or population explosions.

Secondary consumer
An organism that obtains energy by eating other organisms, particularly other consumers. However, some secondary consumers may be omnivorous, eating producers, consumers, and decomposers.

Specialist
An organism that is limited to a specific resource to meet its needs, such as one type of food, one type of nesting material, or one host organism.

Spores
Microscopic reproductive units that function much like seeds, spores are a primary means of fungal reproduction and dissemination.

Stakeholder
A person who has some involvement or connection to a particular issue or situation, such that the outcome would influence his or her interests.

Stressor
A factor that affects the healthy functioning of organisms; for example, tree stressors affect a tree's ability to grow and reproduce at peak capacity. Severe stressors can compromise a tree's ability to survive or resist attack by certain insects and pathogens.

Symbiotic relationship
Species interaction in which two kinds of organisms live together in an intimate association, with members of one or both species benefiting from the association. For example, a lichen is a symbiotic association between a fungus and an algal species. (Modified from PLT)

Taproot
A primary root that grows vertically downward and gives off small lateral roots. (PLT)

Glossary

Trophic level
The position, as producer or consumer, that an organism occupies in a food chain.

Urban forest
A type of forest found within and/or surrounding areas where people work, live, and recreate. Urban forests are either those trees that are retained after building construction in cities, or planted after, to re-vegetate the land. They can be in cities, villages, suburban areas, parks or cemeteries.

Values
Those criteria by which people judge things as worthy.

Warning mimicry
When a species copies another toxic or venomous species' coloration or patterning as a defense mechanism, to announce that it too is dangerous and ought not to be interfered with. Warning mimics may be dangerous in themselves (as with bees and wasps having similar yellow-black coloration and defensive stingers) or they may be defenseless but for their false coloring (as with yellow-black striped hover flies, which have no stings or biting mouthparts).

Xylem
The complex woody tissue of higher plants that includes systems for transporting water, storing nutrients, and providing structural support. (PLT)

Photo: Larry Korhnak