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FireWorks Curriculum

Featuring Ponderosa, Lodgepole, and Whitebark Pine Forests

**Jane Kapler Smith and
Nancy E. McMurray**

Abstract

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FireWorks is an educational program for students in grades 1-10. The program consists of the curriculum in this report and a trunk of laboratory materials, specimens, and reference materials. It provides interactive, hands-on activities for studying fire ecology, fire behavior, and the influences of people on three fire-dependent forest types—*Pinus ponderosa* (ponderosa pine), *Pinus contorta* var. *latifolia* (interior lodgepole pine), and *Pinus albicaulis* (whitebark pine). Wildland fire provides a rich context for education because it promotes understanding and integration of numerous concepts: properties of matter, ecosystem fluctuations and cycles, plant and animal habitat and survival, and human interactions with ecosystems. The curriculum links each activity to national and local educational standards; research has shown it increases student understanding of wildland fire. *FireWorks* is most appropriate for students in locations where the three featured tree species occur, and it may serve as a prototype for wildland fire education in other geographic areas.

Keywords: fire ecology, fire behavior, education, habitat, lodgepole pine, management, ponderosa pine, succession, whitebark pine, wildlife

This curriculum is on-line, complete with color graphics, at
http://www.fs.fed.us/rm/pubs/rmrs_gtr65.html

For assistance in implementing *FireWorks*:
The Internet site **www.firelab.org** lists *FireWorks* **workshops** and **locations where trunks are available for loan**. A CD-ROM containing the curriculum, posters, booklets, and handouts used in the *FireWorks* trunk is available from the authors (Jane Kapler Smith, jsmith09@fs.fed.us; Nancy E. McMurray, nmcmurray@fs.fed.us).

Fort Collins Service Center
Telephone (970) 498-1392
FAX (970) 498-1396
E-mail rschneider/rmrs@fs.fed.us
Web site http://www.fs.fed.us/rm
Mailing address Publications Distribution
Rocky Mountain Research Station
240 W. Prospect Road
Fort Collins, CO 80526-2098

Cover photo—Eighth graders investigate convection and the effect of slope on fire spread.

Contents

[1] P=Primary, grades 1-2; E=Elementary, grades 3-5; M=Middle, grades 6-8; H=High, grades 9-12.

Acknowledgments

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Chapter 1. Introduction

FireWorks: Why?

Change is an integral part of a healthy, enduring forest. *FireWorks* provides students with interactive, hands-on materials to study the forces that cause change in forests, particularly wildland fire. *FireWorks* provides teachers with a flexible curriculum linked to national and state educational standards. Teachers can use the curriculum for specific class levels; programs are suggested for the primary (K-2), elementary (3-5), middle (6-8), and high school (9-10) levels. An alternative program (K-8) focuses on wildland fire throughout the school and may be especially useful for small or rural schools. In addition, lessons can be selected individually or by theme (chapter) from the curriculum. The curriculum addresses seven topics in Chapters 2 through 8 and suggests field trips that will help students integrate learning (Chapter 9):

Chapter	Title	Contents
2	Getting Acquainted with Fire	survey of three kinds of forest & fire patterns, "fire feelings"
3	Burning Questions	combustion & wildland fire behavior
4	All in One House	populations & communities, especially in forests
5	Fire History	tree rings, fire scars, fire intervals
6	Tough Plants, Tough Animals	adaptations to fire
7	Communities in Action	succession, fire effects on biological communities
8	People in Fire's Homeland	fire prevention, home safety in wildlands, fire management
9	In the Woods	integrative field trips

The science of wildland fire provides a context for learning about properties of matter, ecosystem fluctuations and cycles, habitat and survival, and human effects on ecosystems. These concepts are considered benchmarks for science literacy (American Association for the Advancement of Science 1993). Students using *FireWorks* ask questions about new subjects, gather information, analyze and interpret it, and communicate their discoveries. They often work in pairs or small groups. These are learning styles that enhance understanding, cognitive skills, and social skills (Moreno 1999; National Research Council 1996).

Students learn best about ecology when it is close to home—when they can study the plants, animals, and fire regimes typical of local ecosystems (Lindholdt 1999; North American Association for Environmental Education 1999). *FireWorks* uses hands-on materials to describe the fire ecology of three kinds of forest that grow in the western states: ponderosa pine[1]/Douglas-fir, lodgepole pine/subalpine fir, and whitebark pine/subalpine fir. These forest types are widespread throughout the West (fig. 1); they co-occur mainly in the northern Rocky Mountains and the "intermountain" area, which lies between the Rockies and the North Cascades.

[1] Common names are used for all species mentioned in the text; Appendix 1 lists scientific names for plant and fungus species; Appendix 2 lists scientific names for animal species.

Several excellent programs are available for studying fire ecology throughout the U.S.[2], and *FireWorks* draws upon many of them. Investigating the most interesting aspects of wildland fire, however, requires special materials. Fire-scarred tree "cookies" and collections of photos and essays about local plants, animals, and fungi are examples. Laboratory equipment is a third. Hoping to share the excitement of learning first-hand about fire, we have developed this educational trunk. For learning about the woods, however, there is nothing as good as being out there! We encourage you to go on a field trip after studying *FireWorks.* Two field trips are described in Chapter 9, and several *Extension* suggestions (at the end of activities) also describe field trips. Call someone at your local land management agency to see if a professional ecologist, biologist, or fire manager can provide a guided tour; the outdoor experience and contact with people who work in the field may capture the attention of your students and help them integrate what they have learned.

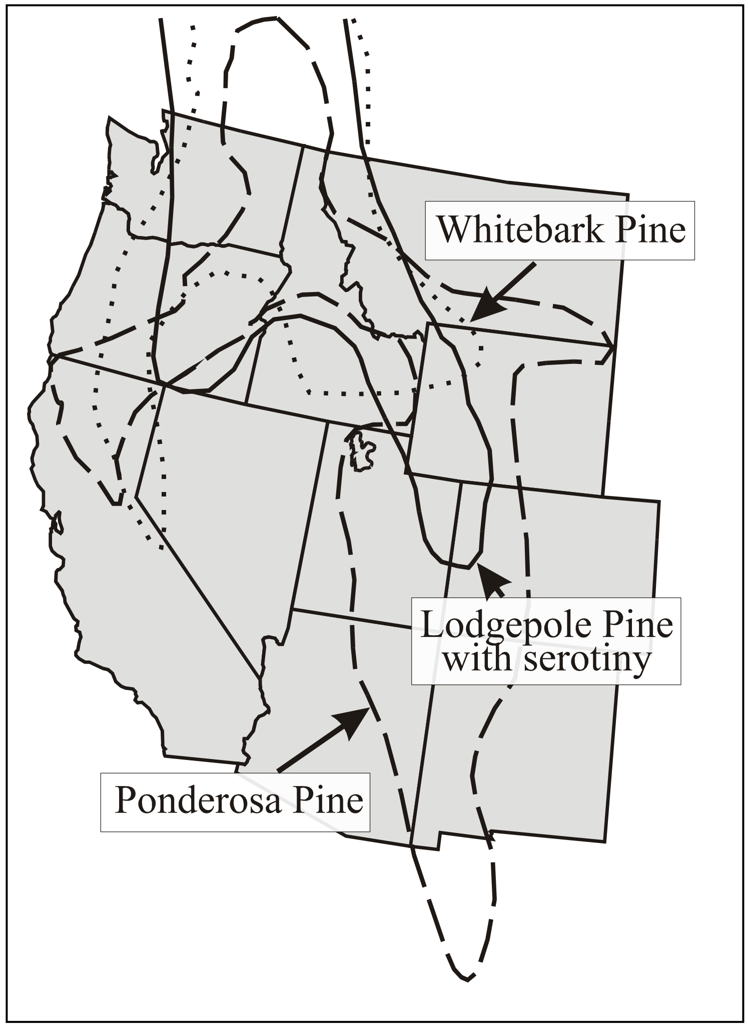


Figure 1—Map of the western United States showing the range of the kinds of forest featured in this curriculum. Ponderosa pine is widespread throughout the West. Whitebark pine occurs in the northern states. Lodgepole pine is widespread in the northern half of the West, but the kind of lodgepole featured in *FireWorks* (with a high rate of cone serotiny) is somewhat more limited.

Goals

FireWorks has been developed by the U.S. Department of Agriculture to increase student understanding

- of the physical science of combustion, especially in wildland fuels
- that a forest has many kinds of plants and animals, which change over time and influence one another
- that fire is an important natural process in many forests
- that native plants and animals have ways to survive fire or reproduce after fire, or both
- that people influence fire-dependent wildlands in the areas where they live and
- that people respond in different ways to fire-related questions.

[2]Appendix 3 lists other curricula for teaching about wildland fire.

Meeting these goals contributes to implementation of the recommendation from the Federal Wildland Fire Management Policy and Program Review (U.S. Department of Interior and U.S. Department of Agriculture 1995) to “transmit a clear message about the important role of fire as a natural process.”

To enhance scientific and literacy and critical thinking about science-related social issues among students, *FireWorks* aims to increase student skills in

- making observations
- classifying information
- measuring, counting, and computing
- stating and testing hypotheses
- describing observations, both qualitatively and quantitatively
- explaining reasoning
- identifying and expressing responses to science-related questions
- working in teams to solve problems and
- critical listening and reading.

These skills are crucial for developing an adult citizenry literate in science and attracting students to professional work in the sciences (National Research Council 1996).

Fire Ecology Background

Fire in North America

For thousands of years, fires have shaped the wildlands of North America. But wildland fires are not all the same, and they never have been. For instance, fires burned some grasslands nearly every year, while some forests and wetlands escaped fire for centuries at a time. In forests, some fires burned only grass and low shrubs under the large trees, others killed nearly every tree, and still others produced a mosaic of fire-killed trees and patches left unburned because of random changes in wind direction or other conditions (Brown and Smith 2000). Within large, severe burns, some patches remain unburned because of change changes in wind direction, weather, and other conditions. So the story of fire plays out differently in nearly every plant and animal community on the continent.

North American plants and animals persisted for thousands of years in the presence of fire. Many species thrived when their homelands burned at predictable intervals. Not surprisingly, some have developed traits that enable them to take advantage of fire to reproduce successfully or compete with other species (Miller 2000). You will investigate many of these traits in *FireWorks* activities. Some wild plants and animals are actually harmed if fire is **excluded** from their habitat, so land managers attempt to reintroduce fire and use naturally-occurring fires to benefit these landscapes. Professional work that includes preventing fires, putting them out where they are likely to produce damage, and using them to benefit the land is called *fire management.* Middle school and high school students using *FireWorks* have opportunities to try their hand at making fire management decisions.

The *FireWorks Library* and the *Teacher Box* (in the trunk) contain several references about fire ecology in North America. Here are general references:

- "Teacher Background Information" in the *Fire Ecology Resource Management Education Unit* (in the *Teacher Box*) provides a clear summary of principles of fire ecology that apply throughout the United States. This curriculum contains a concise, 3-page folder of "Fire Facts—Student Background Information," a "Glossary of Fire Terms," and a list of "Fire References."

- *Fire - a Force of Nature* (in the trunk's *FireWorks Library*) contains beautiful photographs and simple text about fire ecology in North America. This book devotes sections to fire in the Everglades, the giant sequoias of California, the area in and around Yellowstone National Park, southern California, and Alaska.
- *Fire and Vegetative Trends in the Northern Rockies* by George Gruell uses historic photos to show changes over time in forests, prairies, bogs, and other ecosystems.
- *Fire in Florida's Ecosystems* Educator's Guide (in the *FireWorks Library*) describes fire ecology in a very different region of the U.S. (pp. 4-13). You may find that the fire ecology of Florida is, in many ways, similar to that of the western states. Background information on fire in Florida is on pp. 14-16.

Fire in Forests Dominated by Ponderosa, Lodgepole, and Whitebark Pine

This version of *FireWorks* tells the fire story of three kinds of Western forests—those dominated by ponderosa pine, lodgepole pine, and whitebark pine. As you will see in the *FireWorks* activities, the three stories are quite different: In past centuries, ponderosa pine forests burned frequently in fires that consumed mainly grass and needles on the forest floor. Similar, "low-severity" fires burned occasionally in lodgepole pine forests, but every century or so, these forests were likely to burn with very severe fires that killed most of the trees. Whitebark pine forests at high elevations burned infrequently. Fires could be mild or severe, depending on the vegetation and weather; in fact, fires were so variable that we call them "rollercoaster fires." Table 1 summarizes the fire ecology of these forest types and shows where *FireWorks* covers each topic.

The *FireWorks Library* and the *Teacher Box* include many resources specific to the kinds of forest featured in the trunk. You can use them for background before teaching *FireWorks*, refer to them as questions arise, or have students use them as part of your instructional program.

- **About forests dominated by ponderosa pine:**
  - "The Essential Element of Fire" by Michael Parfit, pages 116 through 139 in the September 1996 issue, Vol. 190 (3) of *National Geographic,* describes the ecology of dry North American forests, including ponderosa pine
  - *Graced by Pines* is a popular science book about ponderosa pine.
- **About forests dominated by lodgepole pine:**
  - "The Great Yellowstone Fires" by David Jeffery, pages 252 to 273 in the February 1989 issue, Vol. 175 (2) describes the 1988 fires in the Greater Yellowstone Area, the fire suppression effort there, and the fires' effects on the ecosystem.
  - *Fire in the Forest* is a picture book about lodgepole pine.
- **About forests dominated by whitebark pine:**
  - *Made for Each Other* is a popular science book about the special relationship between whitebark pine and the Clark's nutcracker, the tree's main seed disperser.

The **Background** section, at the beginning of each chapter, lists further resources in the *FireWorks Library* and *Teacher Box* with information on the chapter theme.

Table 1—Summary of ecology and "fire story" of forests at three elevations, dominated by ponderosa, lodgepole, and whitebark pine. Column at right lists activities in *FireWorks* where the information is available.

		Low Elevation	Middle Elevation	High Elevation	*FireWorks* Activities
Pine species (grows well in sunny, open areas with bare soil)		ponderosa pine	lodgepole pine	whitebark pine	2-1, 2-2, 4-3, 4-4, Chapter 7
Shade-tolerant species (grows better than pine in shady places, on duff)		Douglas-fir	subalpine fir	subalpine fir	4-3, 4-4, Chapter 7
Pine traits for surviving or reproducing well after fire		open forest thick buds thick bark open, high crown	serotinous cones	trees in clusters open, high crown seeds planted by nutcrackers	2-1, 2-2, 3-4, 3-6, 3-7, 4-3, 4-4, 7-2, 7-3
Historic fire frequency	Crown fire	very infrequent	every 100 yr or so	every century or 2	2-1, 2-2, 3-4, Chapter 5, 6-5, 6-6, Chapter 7
	Surface fire	every 5-30 yr	1-2 per century	1-2 per century	2-1, 2-2, 3-4, Chapter 5, 6-4, 6-6, Chapter 7
Some animals		Pileated Woodpecker Flammulated Owl Elk (especially spring)	Black-backed Woodpecker Mountain pine beetle Elk (hiding cover in fall)	Clark's Nutcracker Grizzly bear Elk (summer)	6-7, Chapter 7
Traditional uses by Native Americans		Peeled bark	Tipi poles	Pine nuts	Chapter 7
Disturbances besides fire		Douglas-fir Dwarf mistletoe	Mountain pine beetle	White pine blister rust	Chapter 7
Management choices		"You Decide" #1, #5 “Living with Fire”	"You Decide" #2, #4	"You Decide" #3	Chapter 8

For Teachers

How to Select Lessons and Present an Integrated Program

FireWorks contains activities appropriate for students in grades 1-10. How can you select activities for a particular grade level or a particular school so students can synthesize the complex aspects of fire ecology and apply their knowledge in evaluative activities?

First, recommended grade levels are identified for each *FireWorks* activity in the Table of Contents and at the start of each activity. The levels used are Primary (grades 1-2), Elementary (grades 3-5), Middle (grades 6-8), and High (grades 9-10). Many activities can easily be used at more than one grade level; in those cases, adjustments for various levels are described in the "Procedures" section.

Teachers are welcome to weave the *FireWorks* activities together in the best possible way to meet their students' needs. Many *FireWorks* activities make sense by themselves, so they can be used in isolation from the others. However, use of isolated activities fails to take advantage of the interdisciplinary nature of fire ecology and the integrative nature of this curriculum, so it short-changes students and may not be very satisfying for teachers. **We strongly recommend that teachers use *FireWorks* as an extensive, integrated program**. We describe several such programs below, each program using several separate activities; these suggested programs take advantage of the potential for synthesis and integration provided by *FireWorks*.

The program for **primary** grades (table 2) focuses on forests as communities. Students discuss the nature of human and wildland communities. They learn about some of the trees growing in their geographic area. They view and discuss demonstrations of combustion, focusing mainly on scientific and personal-safety aspects of fire. Finally, they learn about fire, other changes, and succession in forest communities from a storyteller using a feltboard.

Table 2—Integrated program for using *FireWorks* in the primary grades (1-2). Activities are presented in a logical order for this age group.

Activ.	Title	Subject	Page
4-1	What's a Community?	Plants and animals in forest ecosystems	70
4-3	For Primary: Mystery Trees	Traits, life history of three pine species	79
3-1	For Primary and Elementary: Meeting the Fire Triangle	Fuel, oxygen, and heat source; safety	27
3-3	Testing the Fire Triangle	Fuel, oxygen, and heat source; convection	36
6-2	For Primary: Buried Treasure	Underground plant parts	113
7-3	Story Time	Feltboard stories of succession and fire	157

The program for **elementary** grades (table 3) also begins with a focus on communities and the "stories" told by fire in forested wildlands, but it emphasizes individual plants and animals and the characteristics that let them persist in places that have burned regularly for thousands of years. The elementary program also demonstrates basic principles of combustion. Ways to prevent and extinguish fires are discussed, and students model food webs and present a feltboard story of fire and succession.

The program for **middle school** students (table 4) uses laboratory experiments and physical models for investigating fire behavior. Students learn about fire history and

Table 3—Integrated program for using *FireWorks* in the upper elementary grades (3-5). Activities are presented in a logical order for this age group.

Act.	Title	Subject	Pg.
4-4	For Elementary and Middle School: Mystery Trees	Identifying 9 tree species	82
4-1	What's a Community?	Plants and animals in ecosystems	70
5-1	For Elementary: Tree Stories	Using tree rings to learn fire history	91
2-2	For Elementary: Visiting Wildland Fire	Survey of fire stories, fire feelings	20
3-1	For Primary and Elementary: Meeting the Fire Triangle	Fuel, oxygen, heat source; safety	27
3-3	Testing the Fire Triangle	Fuel, oxygen, heat source; convection	36
3-5	Bucket Brigade	Fuel size, shape, moisture, burning	49
8-2	Houses in the Woods	Safety around homes in forest areas	170
6-1	Dead or Alive!	Not all tissues in an organism have living cells	109
6-3	For Elementary and Middle School: Buried Treasure	Underground plant parts, survival	116
6-5	Recipe for a Lodgepole Pine Forest	Counting seed in serotinous cones	127
6-6	Designer Trees	Designing a fire-resistant tree	136
6-7	Great Escape	How do animals cope with fire?	140
7-1	In the Web	Food and energy web	144
7-3	Story Time	Feltboard stories of succession and fire	157
9-1	Burned Area Scavenger Hunt	Field trip to a recently burned forest	200

Table 4—Integrated program for using *FireWorks* in the middle grades (6-8). Activities are presented in a logical order for this age group.

Act.	Title	Subject	Pg.
2-1	For Middle and High School: Visiting Wildland Fire	Survey of fire in three forest types	18
3-2	For Middle School: Meeting the Fire Triangle	Fuel, oxygen, heat	30
3-3	Testing the Fire Triangle	Fuel, oxygen, heat, convection	36
3-4	The Fire Triangle in Wildlands	Slope, tree density effects on fire	43
8-2	Houses in the Woods	Fire safety near homes in forested areas	170
4-2	Tree Portrait, Plant Portrait	Tissues and structure of trees	74
4-4	For Elementary and Middle School: Mystery Trees	Identify, classify 9 tree species	82
6-3	For Elementary and Middle School: Buried Treasure	Underground plant parts, survival	116
3-5	Bucket Brigade	Fuel size, moisture, arrangement	49
6-4	Tree Skin	Insulating properties of tree bark	120
6-5	Recipe for a Lodgepole Pine Forest	Counting seed from serotinous cones	127
3-7	Tinker Tree Derby	Vertical fire spread, ladder fuels	62
5-2	For Middle and High School: Tree Stories	Fire history from tree rings	98
5-3	Repeating the Story?	Fire regimes in 3 forest types	103
7-2	Always Changing	Succession and fire, 3 forest types	150
7-4	Puzzling It Out	Jigsaw puzzles of 3 forest types	162
8-1	A Matter of Choice	12-minute videotape on fire management	167
8-3	Living with Fire	Computer game of fire management in ponderosa pine	176
8-4	Smoke: In or Out?	Smoke production, management	181
8-5	You Decide!	Role playing as fire managers	190
2-3	Revisiting Wildland Fire	Looking again at fire feelings	24
9-2	Woods Hunt	Field review and/or test	204

adaptations to fire. Students synthesize what they have learned in a drama that depicts fire and succession in forest communities. Then they apply their understanding by role-playing as fire managers in several forest management scenarios.

The **high school** program (table 5) emphasizes decision-making. A small number of *FireWorks* activities provide high school students with background information about fire; if teachers want more discovery-based learning, they can use the middle school program instead. High school students concentrate on issues and value choices regarding fire and forest management.

Table 5—Integrated program for using *FireWorks* at the high school level (grades 9-10). Activities are presented in a logical order for this age group.

Act.	Title	Subject	Pg.
3-4	The Fire Triangle in Wildlands	Effects of slope, tree density on fire behavior	43
2-1	For Middle and High School: Visiting Wildland Fire	Survey of fire ecology in 3 forest types	18
3-6	Will It Burn?	Ease of ignition of various fuels	53
8-4	Smoke: In or Out?	Smoke production, management	181
6-4	Tree Skin	Insulating properties of tree bark	120
3-7	Tinker Tree Derby	Vertical fire spread, ladder fuels	62
5-2	For Middle and High School: Tree Stories	Fire history from tree rings	98
5-3	Repeating the Story?	Fire regimes in 3 forest types	103
7-2	Always Changing	Fire and succession, 3 forest types	150
8-1	A Matter of Choice	12-min. videotape on fire management challenges	167
8-2	Houses in the Woods	Fire safety around homes in forested areas	170
8-3	Living with Fire	Computer game of fire management in ponderosa pine	176
8-5	You Decide!	Role playing as fire managers	190
8-6	Value Choices	Hard choices regarding fire management	195

FireWorks also provides a **school-wide integrated program** (grades 1-8), in which a small number of activities are completed at each of four grade levels (table 6). In the school-wide program, activities for grades 1-2 focus on forest communities and a basic understanding of fire. Grades 3-4 focus on adaptations and food webs, grades 5-6 on fire behavior and fire history, and grades 7-8 on fire behavior, succession, and fire management.

Links to Educational Standards

Classrooms are busy places, and teaching days are full of activities. How can teachers find room to teach a program like *FireWorks*?

FireWorks does not compete with core curriculum for classroom time. Instead, it helps teachers cover core concepts and improve student skills with hands-on materials and discovery-based lessons. To help teachers identify the ways in which *FireWorks* can be used to meet their curriculum requirements, each activity is prefaced by a list of educational standards met by the activity (not including extensions to the activity, which may meet additional standards). Because *FireWorks* is fundamentally a science program, these “Links to Standards” sections list the national science standards (National Research

Council 1996) and national environmental education standards (North American Association for Environmental Education 1999). Since

Table 6—Integrated school-wide program for using *FireWorks* in grades 1-8. Activities are presented in a logical order for each age group.

Lev.	Act.	Title	Subject	Pg.
1-2	4-1	What's a Community?	Plants and animals in ecosystems	70
	3-1	For Primary and Elementary: Meeting the Fire Triangle	Fuel, oxygen, and heat source; safety	27
	3-3	Testing the Fire Triangle	Fuel, oxygen, and heat source; convection	36
	7-3	Story Time	Feltboard stories of succession and fire	157
3-4	4-2	Tree Portrait, Plant Portrait	Tissues and structure of trees	74
	4-4	For Elementary and Middle School: Mystery Trees	Identifying 9 tree species	82
	6-1	Dead or Alive!	Not all tissues in an organism are comprised of living cells	109
	6-3	For Elementary and Middle School: Buried Treasure	Underground plant parts, survival	116
	6-5	Recipe for a Lodgepole Pine Forest	Counting seed in serotinous cones	127
	6-6	Designer Trees	Designing a fire-resistant tree	136
	6-7	Great Escape	How do animals cope with fire?	140
	7-1	In the Web	Food and energy web	144
5-6	2-1	For Middle and High School: Visiting Wildland Fire	Survey of fire in three forest types	18
	3-4	The Fire Triangle in Wildlands	Effect of slope, tree density on fire behavior	43
	3-5	Bucket Brigade	Fuel size, shape, moisture, burning	49
	5-2	For Middle and High School: Tree Stories	Fire history from tree rings	98
	5-3	Repeating the Story?	Fire regimes in 3 forest types	103
	7-4	Puzzling It Out	Jigsaw puzzles of 3 forest types	162
7-8	3-7	Tinker Tree Derby	Vertical fire spread, ladder fuels	62
	7-2	Always Changing	Succession and fire, 3 forest types	150
	8-2	Houses in the Woods	Fire safety around homes in forested areas	170
	8-1	A Matter of Choice	12-minute videotape on fire management challenges	167
	8-4	Smoke: In or Out?	Smoke production, management	181
	8-3	Living with Fire	Computer game of fire management in ponderosa pine	176
	8-5	You Decide!	Role playing as fire managers	190

FireWorks is interdisciplinary, it should not be limited to use in science instruction; a list of subjects and skills is also included for each activity.

Links to national standards are not commonly used in states where local standards are available, so local implementation of *FireWorks* requires links to state standards. To show how *FireWorks* meets state standards across disciplines, we have linked it to the educational standards of the state of Montana (Appendix 4). We chose Montana because the three forest types featured in the curriculum are widespread there (fig. 1), and educational standards are in place for all disciplines (Montana Office of Public

Instruction [no date]). We recommend that implementation in other states include links to state standards.

Organization

Each chapter of the curriculum begins with a brief description of the topic, background information and a list of resources for more information, educational goals (content and skills), and a list of activities. The activities provide ways for students to explore the chapter's theme in different ways, for different grade levels; use tables 2 through 6 to weave them together into a coherent, integrative program tailored for your particular students, facilities, and grade levels. Within the chapters, each **activity** is organized as follows:

Section	Content
Grade level(s)	Optimum grade levels for the activity
What's the Point?	summary of concepts and survey of activity
Teacher's Map	objective(s), subjects, duration
Links to Standards	National Science Teachers' Association North American Association for Environmental Education
Vocabulary	terms, all defined in Appendix 5 and in the *FireWorks Glossary* in the *Teacher Box*
Materials	what's in the trunk and what you must supply
Preparation	what you need to do before class
Procedure	steps in the activity
Evaluation	one or two students tasks that show objective is met
Closure	summarizing what has been learned, cleaning up
Extension(s)	additional activities relating to the main point of this activity

We suggest you read **"What's the Point?"** to review the activity and determine if it is a good fit for your program. Use **"Materials"** and **"Preparation"** to get ready, so the activity will go smoothly with students. Note that many *FireWorks* activities are designed for students to work in groups of various sizes. For most of the laboratory experiments, the trunk provides equipment for four teams of students. This information is provided in **"What's the Point?"** and **"Materials."**

"Procedure" provides step-by-step instructions. Opportunities for integrating *FireWorks* with your regular curriculum are identified in this section by frames like this:

> **INFO SPARKS:** Interesting or integrative information, not essential for getting across the main point of the activity.

"Evaluation" suggests ways to monitor student learning. Sample test questions for the whole curriculum are available in the *Evaluation Kit* in the *Teacher Box.* Teachers should feel free to add copies of any quizzes or tests that they develop.

FireWorks uses many student handouts, particularly at the upper grade levels. Masters for copying are provided in the *FireWorks Teacher Box*. Appendix 6 contains a complete list of handouts, which can be photocopied and used as an ordering form if your school does copying at a centralized location.

Safety

Safety is a big deal in *FireWorks*. Many of the experiments in this curriculum use fire and natural fuels in the classroom, providing a structured, well supervised environment in which students can make discoveries about fire and improve their habits regarding fire safety. Use of fire in the classroom, however, does increase teacher and student responsibilities for safety. In addition, the idea that fires are not always destructive to ecosystems is novel and intriguing to most students. Students need to learn that professional skills and years of experience are needed to use fire safely in wildlands. How does *FireWorks* address these issues? How can the teacher address them?

At the Primary and Elementary levels, *FireWorks* uses Smokey Bear. Nearly every child in the U.S. knows Smokey and has heard his message "Prevent Wildland Fire!" *FireWorks* takes advantage of this background by featuring "Smokeygrams" in several activities. Smokeygrams (fig. 2) are short messages that can be delivered, like telegrams, from the Principal, the Health and Safety teacher, an older student, or the teacher. They can also be delivered by Smokey himself, if you request someone from a local land management agency to visit your classroom. Smokeygrams greet the students, encourage them to learn more about fire, and caution them to continue doing their best to *not* begin a wildland fire.

One or two Smokeygrams can be included in the Middle and High School *FireWorks* programs, but repeated messages from Smokey are not likely to be effective at these levels. To introduce students to the use of fire by professional researchers and managers, use Activity 8-1 with its 12-minute videotape *Managing Wildland Fire—a Matter of Choice.* If you conduct burning demonstrations or experiments with your class, first discuss the information on the *Fire Safety* poster (in the trunk) presented in Activity 3-3, "Testing the Fire Triangle." Keep the poster up in your classroom and refer to it during other lessons as well. For each activity that uses fire, designate two "fire safety officers" from your class. Give them the spray bottles (from the *Hardware Box*), charged with water, and make it their job to "patrol" for unsafe practices during the burning portion of the activity. Most important, **model** and **insist on safe laboratory procedures** in your classroom or laboratory. The following additional steps will help your activities run smoothly and help your students grow in responsibility and competence regarding fire and laboratory safety:

- Inform your principal, local fire protection unit, and maintenance staff about activities in which you will use fire.
- Choose your work space carefully, especially if you will not be using a laboratory. Schools are equipped with sensitive smoke alarms, which are connected in a direct line to fire stations. Even if you are working in a laboratory, you may set off the smoke alarm, so check it out ahead of time. Fire protection staff and equipment must respond to every alarm, even if you tell them it's "only" smoke from an experiment. If you are working outdoors, watch carefully to prevent smoldering material from igniting schoolyard vegetation.
- Keep the *FireWorks* spray bottles filled with water. Have students use them to extinguish smoldering material at the end of each experiment; this will prevent trash-can fires. If you are working outdoors, keep a hose available and ready to use; have a bucket or two of water available as well.
- Keep the *FireWorks* fire extinguisher—and any other extinguishers in your classroom--ready for use. Know how to use them. If you discharge a fire extinguisher, have it refilled as soon as possible, and find a replacement to use in the meantime. **Don't conduct burning experiments without a charged fire extinguisher in the room.**

- If you or any of your students have asthma or respiratory problems, consider using a dust mask while working with fire.

Smokeygram #1

Dear Class,

Fire is really interesting, isn't it? It is also very powerful, you know. In your experiments, you are learning about matches and fuels. Please don't do any experiments in my homeland, our forests and grasslands. Don't do them in your homes or yards either! I hope your studies help you be even more careful about preventing wildland fires.

Sincerely yours,

Figure 2—One of four "Smokeygrams" used in *FireWorks* to remind students about fire safety and fire prevention. This Smokeygram is introduced in Activity 3-3.

Fire is both powerful and dangerous. Learning more about it should increase our understanding of and respect for both its power and its danger. Careless use of fire, including unsupervised use of fire by children, can cause terrible injuries and property damage. Please encourage your students to use what they learn in *FireWorks* to increase their safety at home and in wildlands.

Effectiveness

Researchers at the University of Montana have studied the effectiveness of the *FireWorks* curriculum used with 7th grade students in western Montana. Their results indicate that students who use *FireWorks* understood more about wildland fire than other students; they were able to transfer concepts learned in the classroom to a field setting; and they had more positive perceptions abut their teacher and classroom environment than students not using *FireWorks* (Thomas and others, in press). Field competencies and positive attitudes were still evident one year after using the curriculum (Thomas and Camp 2000).

Research on the effectiveness of FireWorks activities with adult audiences is currently underway at the University of Idaho (Parkinson 2000).

A Trunk of Your Own?

Students generally obtain the most realistic and compelling information about environmental science when it is applicable to ecosystems that they are familiar with—their own environmental and emotional "back yard" (Lindholdt 1999; North American Association for Environmental Education 1999). In addition, environmental education programs that incorporate field sites and support from local ecologists and managers are generally more successful than programs without links to the community (Knapp 2000, May 2000). The curriculum described here—featuring ponderosa, lodgepole, and whitebark pines—is likely to be most effective in areas where at least one of these tree species occurs. Educators or agency staff can produce the *FireWorks* trunk for use with this curriculum by using the list of supplies in Appendix 7 and the instructions in Appendix 8. We suggest consulting with local teachers and other environmental educators in your area before building a trunk, so you can develop a strategy for implementation. You may find it advisable to build a smaller version of *FireWorks,* focused on only one grade level and using just one of the programs suggested in tables 2 through 5, for your area. A smaller version of the trunk would be less expensive to develop and would focus marketing and teacher training efforts to a single grade level; it might be able to complement other environmental education programs at other grade levels. However, it would eliminate the possibility of "saturating" all grade levels of an elementary rural schools during the course of a trunk loan, the kind of program suggested in table 6.

Many activities in this curriculum could be used unchanged to teach about fire in any fire-adapted ecosystem in the world; the experiments testing the Fire Triangle and demonstrating smoke dispersion are examples. Activities that focus on particular species and ecosystems (for example, those in Chapters 2, 6, and 7) could be adapted to feature other fire-adapted ecosystems, using these activities as templates. The electronic files and examples of materials used in this trunk are available from the authors at the Fire Sciences Laboratory, Missoula, MT.

A new version of *FireWorks* is most likely to be widely used if an implementation plan is developed along with the new curriculum and trunk. We suggest including partners (local agency staff and teachers, environmental educators, and curriculum experts) in this process to:

- determine if the trunk should target a specific grade level
- identify educational standards met in each state where implementation is planned
- plan for copying, distributing, and maintaining trunks and
- plan for contacting and training teachers when the trunk and curriculum are completed.

Chapter 2. Getting Acquainted with Fire

Fire evokes strong feelings in all of us. It is also complex, particularly in regard to its role in ecosystems. The activities in this chapter provide an overview of the three “fire stories” that students explore throughout *FireWorks*—different species, ecology, adaptations, and fire history in forests dominated by ponderosa pine, lodgepole pine, and whitebark pine. These activities also provide a context for discussing students’ feelings about wildland fire, which can be revisited when students have completed the curriculum.

Background

All three activities in this chapter use the brief slide show *Visiting Wildland Fire*, in the *FireWorks* trunk (fig. 3). The slide show is used differently in the three activities. It is not necessary to “teach” the slide show using a detailed narrative, since all of the information in the slides is available to students through discovery-based activities in the curriculum. But information on the slides is provided, for your information, in table 7.

For additional background on the three pine forests, see these resources in the *FireWorks Library*:

- “The Great Yellowstone Fires” by David Jeffery, pages 252 to 273 in the February 1989 issue, Vol. 175(2) of *National Geographic*, describes the 1988 fires in Yellowstone National Park, which were mostly in lodgepole pine forests.
- “The Essential Element of Fire” by Michael Parfit, pages 116 through 139 in the September 1996 issue, Vol. 190(3) of *National Geographic*, describes the ecology of dry North American forests, including ponderosa pine forests.
- The fascinating story of whitebark pine forests, and their relationship to the Clark’s Nutcracker and fire, is provided in *Made for Each Other*, a book by Dr. Ronald Lanner.

Figure 3—Smoldering tree trunk from slide show used in Chapter 2.

Chapter Goals

1. Increase students’ understanding
   - that wildland fire is complex and variable
2. Increase students’ ability to
   - observe and record information from a visual image
   - identify and describe their feelings
   - show respect for one another’s feelings

Chapter Activities

2-1. For Middle and High School: Visiting Wildland Fire (M,H)
2-2. For Elementary: Visiting Wildland Fire (E)
2-3. Revisiting Wildland Fire (M)

Table 7--Detailed information about slides in the *Visiting Wildland Fire* slide show. This table is for reference rather than for explicit teaching, since information here is available in discovery-based activities throughout *FireWorks*. It can also be used for assessment if students prepare a narrative for the slide show, an extension suggested for Activity 2-3.

Slide No.	Topic	Notes
1	Flames, down log	***INTRODUCTION:*** This fire is burning in large woody debris during a prescribed fire in lodgepole pine forest.
		The first forest type is Ponderosa pine/Douglas-fir (PP/DF).
2	Surface fire, PP/DF	In past centuries, ponderosa pine/Douglas-fir forests usually burned in low-severity "understory" fires like this one. These were surface fires that kept the forests open and unlikely to burn with severe fire behavior.
3	Catface, PP	Large trees were not completely untouched by fire, however. Surface fires often killed the cambium part-way around the base of the tree, as occurred on this ponderosa pine. As the tree continued to grow, the damaged area showed as a triangular scar with living wood curving in from its sides. (Photo is from Onehorse Creek, Bitterroot National Forest, Montana.)
4	PP branches	We might say ponderosa pines have a “love-hate” relationship with fire. Typical historic fires, burning in surface fuels, killed many ponderosa pine saplings and some mature trees, and scarred the trunks of survivors. But without fire, ancient old trees like this one are likely to die prematurely. They can’t compete with dense Douglas-fir trees beneath them and may die of stress. They may be killed by fires that climb through the foliage of younger trees and burn their high, open crowns.
5	Pileated woodpecker	Each kind of forest in an ecosystem provides top-quality habitat for some animals. Pileated woodpeckers nest only in very large, old trees. The nest tree may be either living or dead, as long as it has a rotten center. This Pileated is feeding its family about 60 ft above the ground in a ponderosa pine. In historic forests, pines and western larches grew large and developed rotten centers. They were the woodpeckers' favorite nest trees. In many of today’s forests, however, Douglas-firs outnumber pines and larches, and few trees grow large because of competition for moisture and nutrients.
6	Arrowleaf balsamroot	Grasses and wildflowers are scorched and usually look dead the day after a surface fire, but the plants living in open ponderosa pine forests are perennials. This arrowleaf balsamroot grows back each year from a large, woody underground taproot. Surface fires provide a pulse of nutrients and reduce competition from young trees, so balsamroot often produces a lot of flowers a year or two after fire.
		The second forest type is Lodgepole Pine/Subalpine Fir (LPP/SF).
7	Lightning	In past centuries, forest fires were started by lightning and by Native Americans. Lightning still ignites most wildland fires in the our area.
8	Severe fire, lodgepole pine	Lodgepole pines grow at middle and high elevations in our area. Here the winters seem longer than at low elevations because snow stays on the ground much later. Although surface fires occur once in awhile in these forests, crown fires also occur every hundred years or so. This photo shows a prescribed fire in a lodgepole pine forest.
9	Postburn, lodgepole pine	Immediately after a crown fire, the forest looks completely dead. The fire has killed nearly all the trees. The soil is covered with ash. No longer held in place by living tree roots, it may erode rapidly from steep slopes if there's heavy rain. This photo shows the aftermath of crown fire in Rocky Mountain National Park, Colorado.

Table 7—cont'd.

Slide No.	Topic	Notes
10	Fireweed	The treasure that you don't see after the crown fire is what's in the soil: roots and stems of perennial plants and millions of seeds. The severe Red Bench Fire in Glacier National Park, 1988, failed to kill roots of fireweed. This photo, taken a year later, shows "mass flowering" of fireweed that sprouted from underground stems after the fire. Fireweed also reproduces from seed after fire. Seedlings are likely to "mass flower" two or three years after the burn.
11	Aspen sprout ("sucker")	Quaking aspens often grow in patches within pine forest. This aspen, in a stand surrounded by lodgepole pine forest, was top-killed by a prescribed fire. A year later, it is already sprouting back from its roots.
12	Lodgepole pine seedlings	Lodgepole pine stores some of its seeds in cones that are sealed by resin and opened by the heat of fire. These cones are called "serotinous." After the 1988 Red Bench Fire in Glacier National Park, MT, there were millions of lodgepole seedlings. This photo shows 10 to 20 seedlings per square foot four years after the fire.
13	Elk in lodgepole	Many animals use dense forests for warmth and to hide from predators and hunters. This elk is in a stand of lodgepole pine saplings that are just big enough to provide some hiding cover.
14	Lodgepole burn mosaic	Crown fires in lodgepole pine forests typically burn in a patchy pattern, called a "mosaic," across the landscape. In this photo, burned patches look like black islands on the largely unburned slope.
15	Lodgepole forest mosaic	Decades after fire, the fire-caused mosaic is still visible. The lobe-shaped stand in the upper right, which has an almost moss-like texture when viewed from this distance, is dense lodgepole pine that became established after a severe fire. Surrounding it is a taller, older forest that did not burn in the fire.
		The third forest type is Whitebark Pine/Subalpine Fir (WBP/SF).
16	Mixed severity fire, whitebark	Whitebark pine grows on dry sites at high elevations in our area, where the summers seem very short. Forest stands are interspersed with patches of rock and meadow, so fires spread unevenly and may even go out for lack of fuel. Where subalpine firs are growing beneath pines, however, foliage is continuous from the ground to the treetop, allowing fire to spread into the tree crowns.
17	Whitebark fire scars	Whitebark pines have thin bark, but these pines have survived at least one past fire. The same fire probably killed most of the subalpine firs here because they are very susceptible to fire damage.
18	Clark's Nutcracker	In late summer, flocks of Clark's Nutcrackers descend on groves of whitebark pine. They extract the large, nutritious seeds from the pine cones, then bury the seeds in the soil. Often they use open, windswept sites for these "caches." During much of the following year, Nutcrackers retrieve seeds from their caches to eat and feed to their young.
19	Whitebark seedling cluster	Nutcrackers don't retrieve all of the seeds from their caches though. New trees grow from seeds left in the ground. This cluster of saplings shows that several seeds were left here and then germinated.
20	Whitebark snags	Whitebark pines are killed by many things. This cluster of pines was probably killed by mountain pine beetles. White pine blister rust, a fungus accidentally introduced to North America from Europe, has killed large numbers of the whitebark pines in our area. Dead trees may stand for decades on these dry sites, however, providing habitat for cavity nesters like the Mountain Bluebird.
21	Fire inside pine bole	***CLOSING:*** Fire seems mysterious to humans—destructive yet creative, powerful but ephemeral, and fascinating to watch. Here a prescribed fire burns the rotten wood inside a lodgepole pine, leaving a shell of bark behind.

Activity 2-1. For Middle and High School: Visiting Wildland Fire

Grade levels:
X Middle
X High

What's the Point?

Fire evokes strong feelings in all of us. This slide show gives students an opportunity to reflect on their thoughts and feelings about wildland fire. Students respond to photos of fire and its effects in each of three forest types: ponderosa pine/Douglas-fir, lodgepole pine/subalpine fir, and whitebark pine/subalpine fir. These three forest communities, selected from a wide variety of forest types, illustrate the variation in "fire stories" that characterizes ecosystems in North America. *FireWorks* focuses on these three forest types often.

Re-use this slide show at the end of your study of wildland fire (using Activity 2-3), so students can reflect on their feelings about fire in the light of what they have learned.

For high school students, this slide show serves a somewhat different purpose; it is a survey of fire ecology, used as a part of an introduction to the challenges of fire management Chapter 8).

Teacher's Map:

Objective: During or after viewing a slide show, students will describe their thoughts and feelings about wildland fire.

Subjects: Science, Speaking and Listening

Duration: 30 minutes

Links to Standards[3]:

National Science Teachers' Association—Grades 5-8:
F3) Recognize sources and challenges of natural and human-induced hazards
F6) Recognize difference between science questions and other questions
G3) Recognize that uncertainty, debate… are part of science

National Science Teachers' Association—Grades 9-12:
C4) Recognize that energy flow underlies resource webs
F3) Recognize extent, sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades 5-8:
2.3B) Understand cultural perspective on environment and influence of environment on culture

North American Association for Environmental Education—Grades 9-12:
0B) Investigate short- and long-term environmental changes
2.2C) Understand the living environment as comprised of interrelated, dynamic systems

Vocabulary: species, wildland, wildland fire

[3]See Appendix 4 for links to Montana educational standards, grades 5-8 and 9-12.

Materials

In this trunk…	*…where?*[4]	*You must supply*
Visiting Wildland Fire slide carousel	Main/C	slide projector and screen flipchart paper and markers

Procedure

1. Explain that the class will be studying wildland fire in the coming week or two. Explain: Fire is a natural process in most wildlands of North America, and fires have occurred in the forests of the western states for tens of thousands of years.
2. Explain: In this slide show, students will see photos of fire and of burned areas in forests of the Rocky Mountains, Cascade Mountains, and the area between. Similar fires occur in other forests all over North America. They will see fire in three different kinds of forest, which they will study more thoroughly with later activities.

   For Middle School Students: After viewing the slides, they will be asked to write down and discuss their observations and feelings about wildland fire. Explain that people respond differently to dangerous and emotional issues but should try to be informed about them.
3. Start the slide show. Advance the slides every 8-10 seconds.

   For High School Students: At each slide, ask students to provide information on the kind of forest or severity of fire behavior. Supplement what they provide with information from table 7. It is not necessary to complete Steps 4 and 5; you can move on to the next activity.
4. When the slide show is over, give students time to write down their thoughts and feelings.
5. Gather student responses in a short brainstorming session. Encourage students to listen respectfully to others' thoughts and feelings. Explain that people's feelings about any one thing often differ without being "right" or "wrong." Record students' responses on flipchart paper.

Evaluation: Briefly describe one picture you remember well from the slide show. Describe why it is memorable to you.

Closure: Save students' responses and the flipchart pages to refer to later, when you "revisit" wildland fire near the end of your *FireWorks* use (Activity 2-3).

[4] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Activity 2-2. For Elementary:

Visiting Wildland Fire

Grade level:
X Elementary

What's the Point?

This slide show provides a survey of the three "fire stories" covered in *FireWorks* and asks students to reflect on their feelings about wildland fire. The three "fire stories" are those of forests dominated by ponderosa, lodgepole, and whitebark pine. Students observe and describe typical fire behavior in these forest types. Other kinds of forest in North America, and grasslands and shrublands as well, all have a fire story to tell; these three are just selected from our geographic area.

Teacher's Map:

Objectives: Given a series of photos and a sketch of three forest types, students can record the kind of flames typical of the three kinds of forest. They can also describe their feelings in response to photos that show wildlands and fire.

Subjects: Science, Writing, Speaking and Listening, Arts

Duration: 30 minutes

Links to Standards[5]:

National Science Teachers' Association—Grades K-4:

A1) Ask a question about the environment
F4) Understand that changes in environments can be natural or influenced by people
F5) Understand that changes in environments can be slow or rapid; rate of change has consequences

National Science Teachers' Association—Grades 5-8:

F3) Recognize sources and challenges of natural and human-induced hazards
F6) Recognize difference between science questions and other questions

North American Association for Environmental Education—Grades K-4:

0.A) Identify basic kinds of habitat and plants and animals living there
2.1A) Identify changes in physical environment
2.2C) Understand basic ways organisms are related to environment and other organisms
2.3B) Understand that experiences may be interpreted differently by different people
2.4B) Understand that places differ in physical and human characteristics
3.2A) Examine and express views on environmental issues

North American Association for Environmental Education—Grades 5-8:

2.1A) Understand most physical processes that shape the earth
2.2D) Understand how energy and matter flow in environment
2.4B) Explore meaning of places
3.2A) Understand range of environmental issues at local and global scales

Vocabulary: species, wildland, wildland fire

[5] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

Materials

In this trunk…	*…where?*[6]	*You must supply*
Visiting Wildland Fire slide carousel	Main/C	slide projector and screen flipchart paper and markers paper and art supplies copy of Student Page 1 for each student

Procedure

1. Explain that students will view a series of photos that describe the three kinds of forest they are learning about and the kinds of fires that occurred in these forests in the past. If you are following the suggested program in table 3 (see chapter 1), use the three feltboards and the fire history data from the last activity to remind students what these forests are and how they differ.
2. Explain that you will tell the students which kind of forest is being shown in each part of the slide show. They should be prepared to observe and record the kind of fire they see in each forest type.
3. Give a copy of Student Page 1 to each student. Explain that, when the photo of fire behavior is shown for each forest type, you will wait for a minute or two so students can look at it carefully and try to sketch or color it on their observation sheet.
4. Start the slide show. Loosely follow the narrative in table 8. If you want more information about the slides, see table 7, in the introduction to this chapter.
5. After viewing the slides, give students time to complete their sketches of fire behavior.
6. After the sketches are completed, ask students to write down, along the side of the page, one or two words describing their feelings about fires like these. Did any—or all—of the photos seem scary? surprising? beautiful? terrible?
7. Ask students to share their sketches, describing the three kinds of fire in words. Ask them to describe their feelings too. Encourage students to listen respectfully to others' feelings. Explain that people's feelings about any one thing often differ without being "right" or "wrong," so it is important to learn about one another's feelings.

Evaluation:

1. Describe or sketch three kinds of fire behavior.
2. List two different feelings from the class about wildland fire.

Closure: Post the flipchart page and the students' sketches in the classroom.

[6] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Table 8—Narrative sketch for *Visiting Wildland Fire* slide show. To be used at elementary grade level.

Slide No.	Topic	Notes
1	Flames, down log	***INTRODUCTION:*** These slides show how fires burn in different kinds of forest.
		Here are photos from *ponderosa pine* forests.
2	Surface fire	Look carefully at the fire. On your data sheet, write down the kind of forest. Then sketch or color the first diagram to show where the flames are burning and how high they reach on the trees.
3	Catface, ponderosa pine	This ponderosa pine tree has been scarred by many fires.
4	PP branches	Look up in the tree! It is very big, with many branches and needles. Fires have not killed it.
5	Pileated woodpecker	Here are some other things that live in ponderosa pine forests. We'll be learning more about them and how they can live in a place that burns often.
6	Arrowleaf balsamroot	
		Here are photos from *lodgepole pine* forests.
7	Lightning	Lightning starts many fires in wildland forests. This lightning strike may start a fire in a lodgepole pine forest.
8	Severe fire, lodgepole pine	Here's one kind of fire that can occur in lodgepole pine forests. Look at it carefully. On your data sheet, write down the kind of forest. Then sketch or color the second diagram to show where the flames are burning and how high they reach on the trees.
9	Postburn, lodgepole pine	Here's a forest a few weeks after the kind of fire in the last slide. How can things live here ever again?
10	Fireweed	Here are some photos taken a few years after such a fire.
11	Aspen sucker	
12	Young lodgepole	
13	Elk in lodgepole	Here is another inhabitant of a lodgepole pine forest—about ten years after fire.
14	Burn mosaic	Here is a patchy pattern caused by fire in lodgepole pine.
15	Lodgepole forest mosaic	Can you still find a patchy pattern in this forest, 50 years after fire?
		Here are photos from *whitebark pine* forests.
16	Mixed severity fire, whitebark	Here's a typical fire in a whitebark pine community. On your data sheet, write down the kind of forest. Then sketch or color the last diagram to show where the flames are burning and how high they reach on the trees.
17	Whitebark fire scars	The scars show that these whitebark pines have survived at least one fire.
18	Clark's Nutcracker	We'll be learning about these inhabitants of whitebark pine forests and how they plant new trees…
19	Seedling cluster	... like these.
20	Whitebark snags	We'll learn about something very small that kills whitebark pines and is much more damaging than fire.
21	Fire inside pine bole	***CLOSING:*** Fire is dangerous and powerful, and a part of these forest communities. Here a fire burns the rotten wood inside a lodgepole pine, leaving a shell of bark behind.

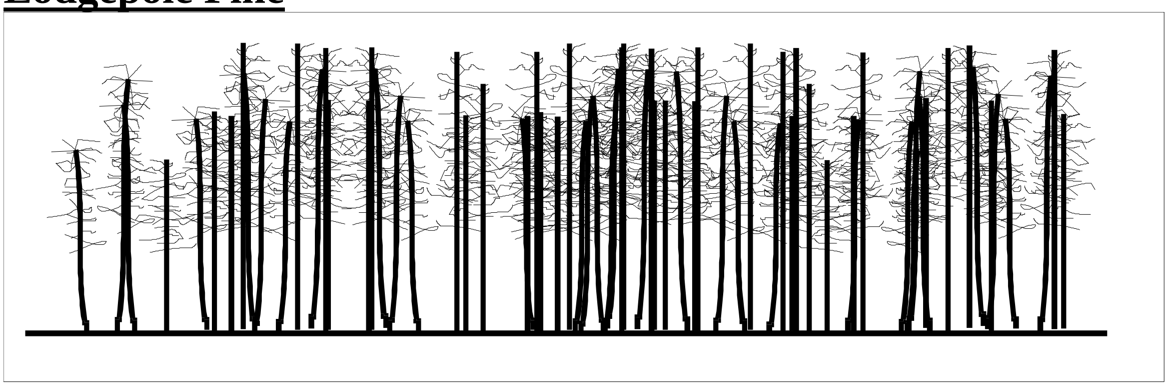
Student Page 1

Name: ___________________________

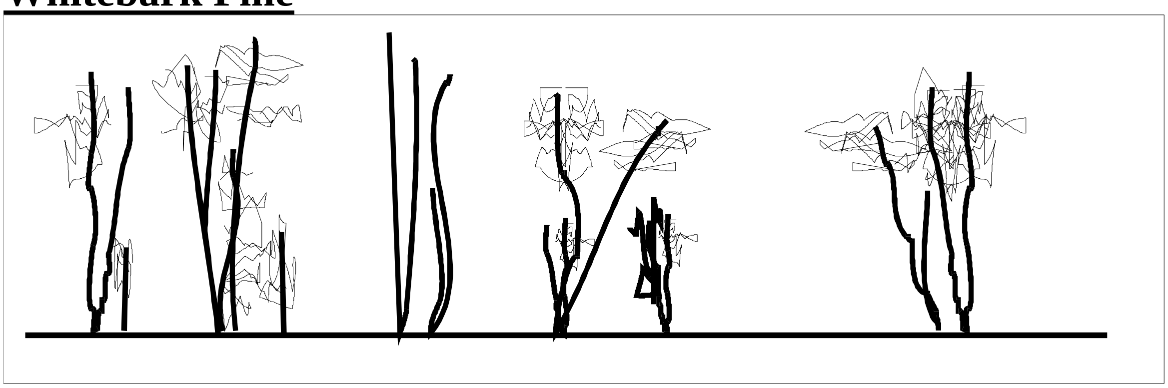
Draw and color a typical fire in each kind of forest.

Ponderosa Pine

Lodgepole Pine



Whitebark Pine



Activity 2-3. Revisiting Wildland Fire

Grade level:
X Middle

What's the Point?

Use this activity only if you did Activity 2-1 at the start of your *FireWorks* program. In that activity, students viewed and responded to a slide show with their observations and feelings about wildland fire. Now they can respond to the same photos again and consider whether their thoughts and feelings have changed in light of what they've learned.

Teacher's Map:

Objective: After viewing a slide show, students can describe their observations and feelings about wildland fire, and describe ways in which their thoughts and feelings have changed.

Subjects: Science, Writing, Speaking and Listening

Duration: 30 minutes

Links to Standards[7]:

National Science Teachers' Association—Grades 5-8:

F6) Recognize difference between science questions and other questions

North American Association for Environmental Education—Grades 5-8:

2.3B) Understand cultural perspective on environment and influence of environment on culture

Vocabulary: no new vocabulary

Materials

In this trunk…	***…where?[8]***	***You must supply***
Visiting Wildland Fire slide carousel	Main/C	slide projector and screen student notes and flipchart from Activity 2-1

Procedure

1. Explain: This is the same slide show that students viewed at the start of *FireWorks*, containing photos of fire and burned areas. They can now look at their earlier responses and think about ways in which their thoughts may have changed (or not) after studying fire ecology.
2. Start the slide show. Advance the slides every 2-4 seconds.

[7] See Appendix 4 for links to Montana educational standards, grades 5-8.

[8] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

3. Hand out the students' first responses to *Visiting Wildland Fire* and post the flipchart from Activity 2-1. Ask students to compare their current thoughts and feelings with the ones recorded earlier. Use the following questions:
    - What feelings are the same?
    - What feelings are different?
    - Pick one feeling that has changed. Can you explain why? If no feelings have changed, can you explain why?

Evaluation: Write a paragraph comparing your thoughts or feelings now about wildland fire with your thoughts or feelings when you began studying this subject.

Closure: Ask class members to describe an experience in their lives that caused them to change their beliefs or feelings about something. Ask them to describe why their beliefs or feelings changed.

Extensions

1. Write a narrative for the *Visiting Wildland Fire* slide show to be presented to first graders. Obtain specific information about the slides, if needed, from table 7.
2. Read and compare the two *National Geographic* articles on fire in the *FireWorks Library*:
    - “The Great Yellowstone Fires” by David Jeffery in the Feb. 1989 issue, vol. 175(2)
    - “The Essential Element of Fire” by Michael Parfit in the Sept. 1996 issue, vol. 190(3)

    How do the themes of the two articles differ? How are the authors’ attitudes toward wildland fire the same and how are they different?
3. Read the fire safety messages on pp. 76-77 in *Exploring Wood* (in the *Teacher Box*). Produce a different fire safety message for young children, a lesson that teaches about safety without teaching that all wildland fires are bad.

Chapter 3.
Burning Questions

Fire can occur only if oxygen, fuel, and heat are available. These three components are called the "fire triangle." In this chapter's activities, primary and elementary students learn about the three components of fire by making a physical model of the Fire Triangle. They investigate the geometric properties of a triangle and the nature of fire behavior by removing and adding legs of the triangle and observing the effects.

This chapter provides several laboratory experiments for investigating fire behavior and modeling the behavior of fire in wildland fuels. Students build model forests and model trees to learn how fires spread horizontally and vertically.

Background

For a quick survey of fire behavior and fire spread in wildlands, preview the 3-minute videotape *Kinds of Fire* in the *Teacher Box*. The tape is used in Activity 3-3. For additional background, see the following resources in the *FireWorks Library*:

- *The Book of Fire* by William Cottrell. This book provides detailed information and beautiful color diagrams about the chemistry and physics of wildland fire.
- pages 62-63 in *Wildfire* for a description of the fire behavior that occurs in a campfire. Clear color diagrams accompany this "Campfire Story."
- pages 8-13 in Jack deGolia's book *Fire - a Force of Nature.* This section describes the many ways a wildland fire can behave, depending on fuels, topography, and weather.
- pages 15-55 in *Yellowstone on Fire.* As fires grow large, especially if the weather becomes very windy, fires seem to take on a life of their own. They become extremely powerful and unpredictable. This kind of fire behavior occurred in Yellowstone National Park during the summer of 1988, and it is described photographically in *Yellowstone on Fire*.

Chapter Goals

1. Increase students' understanding
   - of chemical change
   - of combustion
   - of fire behavior in wildland fuels
2. Increase students' ability to
   - use physical models & analogies
   - make observations
   - interpret observations
   - apply new knowledge
   - describe their discoveries
   - use new information to solve problems

Chapter Activities

Activity 3-1. For Primary and Elementary: Meeting the Fire Triangle	(P,E)
Activity 3-2. For Middle School: Meeting the Fire Triangle	(M)
Activity 3-3. Testing the Fire Triangle	(P,E,M)
Activity 3-4. The Fire Triangle in Wildlands	(M,H)
Activity 3-5. Bucket Brigade	(E,M)
Activity 3-6. Will It Burn?	(H)
Activity 3-7. Tinker Tree Derby	(M,H)

Activity 3-1. For Primary and Elementary: Meeting the Fire Triangle

Grade levels:
X Primary
X Elementary

What's the Point?

In this activity, students make a physical model of the Fire Triangle as a geometric shape. They manipulate the model and discuss the components of the Fire Triangle in the context of things they are already familiar with—candle flames, campfires, and engines.

Teacher's Map:

Objective(s): Given toothpicks and gumdrops, students can construct a geometric triangle, name the components of the Fire Triangle, and explain that removal of one component of the Fire Triangle extinguishes the fire.

Subjects: Science, Mathematics, Speaking and Listening, Health, Workplace Competencies

Duration: 30 minutes

Links to Standards[9]:

National Science Teachers' Association—Grades K-4:
A1) Ask a question about the environment
A2) Plan and conduct simple imvestigation
A3) Use simple equipment and tools to gather information
A5) Communicate investigations and explanations
B1) Understand size, weight, shape, color, temperature; materials; states of matter
F1) Understand and make choices for safety and preventing injury

National Science Teachers' Association—Grades 5-8:
A1) Identify questions that can be answered scientifically
A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A6) Use mathematics in science
B1) Understand properties of matter
B2) Describe physical and chemical changes
B4) Identify ways in which energy moves in and out of a system

North American Association for Environmental Education—Grades K-4:
1A) Develop questions to learn about environment
1B) Design simple investigations
1E) Describe data, organize information to search for patterns
2.1C) Be aware of basic behavior of some forms of energy

North American Association for Environmental Education—Grades 5-8:
1A) Develop, focus and explain questions about environment
1B) Design investigations to answer questions
1G) Synthesize observations into coherent explanations
2.1A) Understand most physical processes that shape the earth

[9] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

cont'd.

2.1C) Be aware of basic behavior of some forms of energy 2.2D) Understand how energy and matter flow in environment 4D) Understand and accept personal responsibility for actions

Vocabulary: Fire Triangle, fuel, heat, oxygen, triangle

Materials:

In this trunk...	*...where?*[10]	*You must provide*
Fire Triangle poster	Main/B	gumdrops (12+ per student team)
		toothpicks (12 per student team)

Procedure:

1. Explain: In previous activities (if you are following one of the suggested curriculum programs described in table 2 or 3), students have learned about three forest communities. They have learned that fire has occurred in those forest communities for hundreds of years. How can the plants and animals in those communities survive fire? Students will soon do research on some amazing ways in which forest inhabitants "deal with fire." To understand better, they will first learn more about fire itself.
2. Ask students to work in groups of three or four.
3. Explain: Each student team should build three or four shapes out of gumdrops and toothpicks. Write them on the board: 3-sided (triangle), 4-sided (in this case, a square), 5-sided (pentagon), and 6-sided (hexagon). Use the toothpicks for the sides and gumdrops for the corners.
4. Ask students to find out which shape is the most "stable" one, that is, it keeps its shape even when you push on a side or a corner. Unless they eat all the gumdrops, it won't take long for them to decide that the triangle is the most stable.
5. All students can convert their shapes to triangles. Ask students what happens when one leg of a triangle is removed. It collapses into a single line.
6. Explain: Scientists use the idea of a "triangle" to describe fires because a fire needs three things to be stable, that is, to keep burning. Can they think of what is needed? List their thoughts on the board. Look for items relating to ignition sources, fuel, and oxygen.
7. Display the *Fire Triangle* poster (fig. 4). Explain that these are the three things needed to start a fire and keep it going, and relate the

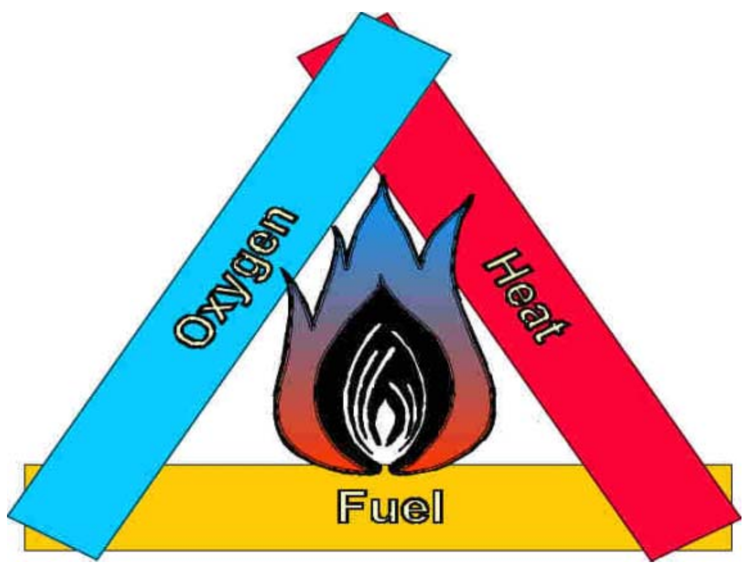


Figure 4—*Fire Triangle* poster.

[10] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

components on the triangle to students' ideas on the board.
8. Ask what happens when one of these components is removed from a fire. (It stops burning.) Ask: **Burnable things surround us every day. Why aren't they on fire?** (An external source of heat is usually needed to start a fire. Once a fire has started, it produces the heat needed to continue burning. A fire can be put out if fuel, oxygen, or heat is removed.)
9. Ask how people can use this knowledge to stop a fire that occurs in their homes and in wildlands. (When you throw water on a fire, you cut off oxygen and remove heat. You can also cut off oxygen by throwing dirt on a fire. "Stop, drop, and roll" reduces the supply of oxygen to a fire. Running away would do the opposite—add more oxygen—so it is a bad idea. Fire extinguishers remove heat and deprive a fire of oxygen. Fire retardant dropped from airplanes removes heat and cuts off oxygen from wildland fires. When all the wax is gone from a candle or all the fuel is burned in a campfire, it goes out.)

Evaluation:
1. Name the three things needed for a fire to occur.
2. Explain to a partner and demonstrate how "stop, drop, and roll" removes something from the Fire Triangle and puts a fire out.

Closure: Collapse the triangles completely by eating the gumdrops and throwing the toothpicks away.

Extensions:
1. Play "Fire Tag" (in *Ecosystem Matters* in the *Teacher Box*, pp. 60-61) to learn about how fires spread in wildlands and how people can protect some areas from fire.
2. Make and decorate your own paper fire triangles using Activity 3.2.
3. Read about people's feelings about fire in *Legends of Earth, Air, Fire and Water.* These stories would be fun to read to the whole class.
4. Learn more about the Fire Triangle and home safety from Smokey Bear's Internet site: www.smokeybear.com

Activity 3-2. For Middle School: Meeting the Fire Triangle

Grade level:
X Middle

What's the Point?

This activity is a brief **guided discussion** that describes combustion and wildland fire in terms of science concepts and things that students already know about fire. It may be possible to proceed to Activity 3-3 without using this discussion, then challenge the students to construct the Fire Triangle from their own observations.

Teacher's Map:

Objective: Given materials for a paper model, students can construct a model of the Fire Triangle and explain how extinguishing a fire is analogous to removing one leg of a triangle.

Subjects: Science, Mathematics, Writing, Speaking and Listening, Health

Duration: 30 minutes

Links to Standards[11]:

National Science Teachers' Association—Grades 5-8:

A6) Use mathematics in science
B1) Understand properties of matter
B2) Describe physical and chemical changes
B4) Identify ways in which energy moves in and out of systems
F1) Identify potential for accidents, make choices to minimize risk of injury
F3) Recognize sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades 5-8:

2.1C) Understand energy transfer
2.2D) Understand how energy and matter flow in environment

Vocabulary: Fire Triangle, fuel, heat, hypothesis, model, oxygen, prescribed fire, tree crown

[11] See Appendix 4 for links to Montana educational standards, grades 5-8.

Materials:

In this trunk...	*...where?*[12]	*You must provide*
Fire Triangle poster	Main/B	*Fire Triangle* transparency (class page 1)—optional
Tree Portrait poster	Main/B	For Middle-school level, provide each student a copy of *Fire Triangle Kit* (Student Page 2), three brads, and several hole punches for the class.
"Fuels... Tree & Soil Parts, and Fire Targets" kit	Teacher/C	Tape or sticky-tack to attach labels to *Tree Portrait*

Procedure:

Post the *Fire Triangle* poster in the classroom (fig. 4). Ask students what is needed for a fire. Write answers on the board. Then use the answers to discuss the three parts of the Fire Triangle: heat, fuel, and oxygen. **This discussion can be brief** and still prepare students adequately for the *FireWorks* activities. The Fire Triangle transparency (class page 1) can be used as a transparency to guide discussion, but may not be necessary. At the end of the discussion, ask students to construct a paper model of the Fire Triangle Kit (student page 2); use this as an evaluative tool.

Discussion Points (also listed on class page 1):

1. **What is fire?** Fire is a rapid chemical reaction that combines fuel and oxygen to produce heat and light.

> **INFO SPARK—Integrating with physical science:** You can use either of the formulas below to describe the chemical reaction for combustion. Information about photosynthesis and respiration or the oxygen and carbon cycles, presented in many science texts, can also be used here.
>
> carbohydrate + oxygen + heat → carbon dioxide + water vapor + heat + light
>
> $C_6H_{12}O_6 + 6\ O_2 + \text{heat} \rightarrow 6\ CO_2 + 6\ H_2O + \text{heat} + \text{light}$

2. **Burnable things surround us every day. Why aren't they on fire?** An external source of heat is usually needed to start combustion. Once a fire has started, it produces the heat needed to continue burning. A fire can be put out if fuel, oxygen, or heat is removed. This idea is often depicted using a triangle (refer to the *Fire Triangle* poster). Remove any one of the three legs of a triangle, and it will collapse; remove any one of the required components of fire, and it will go out.
3. **What is the fuel in fires we are familiar with?** Most cars are fueled by gasoline, using an "internal combustion" engine; candles are fueled by melted wax, furnaces by natural gas or fuel oil, and campfires by wood.
4. **What fuels a wildland fire?** In nature, fire's ***fuel*** is plant material. Use the *Tree Portrait* poster to discuss nature's fuels. Tape the colored labels from the *Fuel Labels* envelope to the tree portrait to illustrate these points:
    - ***Tree crowns,*** high above the ground (red label), provide some fuel; these include tree *branches*, *leaves* (*needles* are a kind of leaf), and *trunks*.

[12] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

- Fuels that lie on or right above the ***surface*** of the ground (colored orange) include *dead and fallen needles, leaves, grass, dead wood, stumps,* and *low shrubs*.
- The main ***ground fuel*** is *duff*, the layer of dead, decaying plant material that makes up the top layer of soil (colored purple). It contains *decaying leaves, decaying wood,* and *roots*. Sometimes it is mixed with mineral soil (very fine rock particles), which won't burn.

5. **Where does the oxygen for fire come from?** Oxygen is plentiful in air. Students may be able to relate the "oxygen" part of the fire triangle to their fire-safety education: "Stop, drop, and roll" is one way to reduce the oxygen available to burning clothing. If a person runs with clothing on fire, the oxygen supply increases and the fire burns more intensely.

> **INFO SPARK—Integrating with Life Science, Mathematics, and Physical Science:** Oxygen comprises about 21 percent of the air we breathe. Nitrogen gas comprises 78%. Argon, carbon dioxide, and other gases comprise the remaining 1%. Oxygen is so plentiful that we use only about 20% of the oxygen in every breath we take. If we used it all, artificial resuscitation wouldn't work! Students can make a pie chart showing the chemical composition of air. This discussion point also provides an opportunity to refer to the oxygen and carbon cycles, photosynthesis, and respiration.

6. **What heat sources do we use to start fires?** Spark plugs in cars, pilot lights in appliances, and matches are some examples.
7. **What provides heat for forest fires?** In wildlands, nature provides heat in lightning and volcanoes. Matches, untended campfires, and cigarettes are the sources of heat for many human-caused wildland fires. During the thousands of years when Native Americans were the only people living in North America, they often started fires to change the plant communities that provided their food and shelter. They used fire to make their campgrounds safe from fire and enemies, to improve grazing and berry supplies, and for many other reasons. After they obtained horses, Native Americans used fire to improve forage for their herds. Today, we would call these *prescribed fires.*
8. **How does wind influence fire?** Wind influences fire in many ways. Think about starting a campfire. If you blow on it, you provide extra oxygen and blow the heat toward the fuels, getting the fire to burn more intensely. If you blow too hard, especially across a small flame like a candle, you scatter the heat so much that the fire goes out. Wind helps forest fires spread by drying out fuels and carrying burning embers ahead of the fire.
9. **Use the fire triangle to describe some ways to put out a fire.** To slow down a fire or put it out, at least one of the three components of the fire triangle must be changed. Think about ways that both large and small fires are controlled. When all the wax is gone from a candle or all the fuel is burned in a campfire, it goes out. A fireline, used to control forest fires, is simply a path cut through all of a forest's fuels—down to mineral soil. When the fire gets to the fireline, it runs out of fuel. When you throw water on a fire, you cut off oxygen and remove heat. You can also cut off oxygen by throwing dirt on a fire. Fire extinguishers and fire retardant dropped from airplanes remove heat and cut off oxygen from wildland fires.

Evaluation: Provide each student with a Fire Triangle Kit (Student Page 2). Ask students to construct a Fire Triangle and label the parts correctly. Ask them to write a paragraph in which they do the following:

1. describe a fire (candle, engine, campfire, and forest fire are all possibilities)
2. tell one way to put it out
3. explain what part of the Fire Triangle is removed when that method is used to put it out

Closure: Explain: this discussion has provided a *model* for how fires work. A *model* is like a *hypothesis* because it is an explanation for something observable, and it can be tested. Students will test the Fire Triangle model in activities to come.

Extensions:

1. Make a collage of familiar things that use combustion. Examples: Cars and gas appliances contain "burning chambers." Electrical appliances may rely on combustion of coal to produce power. Barbecues, lanterns, and candles use fire. So do “real” fireworks displays. Use the components of the Fire Triangle to describe how combustion is controlled in these items.
2. Learn about causes of fires in your local area by doing the “Cause and Effect” activity at the top of p. 60 in *Ecosystem Matters* (in the *Teacher Box*).

Fire Triangle

1. What is fire?

2. Burnable things surround us every day. Why aren't they on fire?

3. What is the fuel in fires we are familiar with?

4. What fuels a forest fire?

5. Where does the oxygen for fire come from?

6. What heat sources do we use to start fires?

7. What provides heat for wildland fires?

8. How does wind influence fire?

9. Use the fire triangle to describe some ways to put out a fire.

Student Page 2

Fire Triangle Kit

1. Cut along the lines to make the three "legs" of your Fire triangle.
2. Mark one leg "Fuel." Mark another "Oxygen." Mark another "Heat." Decorate the pieces.
3. Punch holes on the X marks at the ends of each leg.
4. Put brads or other connectors through the holes and connect the legs of the triangle. Write your name on the back.
5. If you remove one leg of a paper triangle, what happens to it?
6. If you remove one leg of the Fire Triangle, what happens to the fire?

X	**X**	**X**
X	**X**	**X**

Activity 3-3. Testing the Fire Triangle

Grade levels:
<u>X</u> Primary
<u>X</u> Elementary
<u>X</u> Middle

What's the Point?

This activity uses fires that students are familiar with—a burning match and a candle—to see if fire can occur without the components of the Fire Triangle. **For Primary and elementary students,** conduct the activity as a demonstration. **For students in the middle grades,** assign students to four teams, set up four lab benches for them to work at, and ask them to follow the directions that you provide.

This is the first of many activities that uses matches and fire. It is important to emphasize safety. Prepare the students the day before the experiments by going over safety procedures and using **Smokeygram #1** (see fig. 2, chapter 1), both described in ***Preparation*** below.

In **Demonstration/Experiment 1**, a downward-pointing match and an upward-pointing match are burned (fig. 5). The downward-pointing match sustains fire until all of its fuel is burned to ash. (Ash is the mineral portion of wood, which doesn't burn.) Lack of fuel, then, is what puts the fire out. In contrast, the upward-pointing match goes out before its fuel is all consumed. The heat from the match disperses upward, so it heats the air above the flame but not the remaining fuel, which is beneath the flame. The upward-pointing match does not sustain fire as well as the downward-pointing one because of lack of heat.

In **Demonstration/Experiment 2,** students try to light a candle that is surrounded by carbon dioxide. The carbon dioxide is supplied by dry ice sublimating in a beaker; because it is cold and CO_2 is denser than air, oxygen is displaced and the candle cannot be lit.

Figure 5—Eighth graders ask, "Where does the heat go?"

Teacher's Map:

Objective: Given experimental materials, students can demonstrate and describe the effects of depriving a fire of heat, fuel, and oxygen.

Subjects: Science, Mathematics, Speaking and Listening for all grade levels. These additional subjects are included at the Middle School level: Reading, Writing, Health, Workplace Competencies

Duration: 20 minutes (Primary and Elementary); 40 minutes (Middle)

Links to Standards[13]:

National Science Teachers' Association—Grades K-4:

A1) Ask a question about the environment
A2) Plan and conduct simple investigation
A3) Use simple equipment and tools to gather information
A4) Use data to construct an explanation
A5) Communicate investigations and explanations
B1) Understand size, weight, shape, color, temperature; materials; states of matter
B3) Demonstrate production of heat, conduction and convection

National Science Teachers' Association—Grades 5-8:

A1) Identify questions that can be answered scientifically
A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations
A5) Communicate procedures and explanations
A6) Use mathematics in science
B1) Understand properties of matter
B2) Describe physical and chemical changes
B3) Identify ways in which energy moves in and out of a system
F1) Identify potential for accidents, make choices that minimize risk of injury
G1) Understand that scientists work alone and in teams
G2) Understand that science results must be communicated
G3) Recognize that uncertainty, debate, further investigation, and evaluation are part of science

North American Association for Environmental Education—Grades K-4:

1B) Design simple investigations
1C) Collect information about environment
1E) Describe data, organize information to search for patterns
2.1B) Identify characteristics of and changes in matter
2.1C) Be aware of basic behavior of some forms of energy

North American Association for Environmental Education—Grades 5-8:

1G) Synthesize observations into coherent explanations
2.1C) Understand energy transfer
2.2D) Understand how energy and matter flow in environment

Vocabulary: carbon dioxide, chemist, combustion, condensation, convection, gas, liquid, solid, sublimation

[13] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

Materials

In this trunk…	*… where?*[14]	*You must supply*
Fire Safety poster	Main/B	For **Middle School** level: Copy of Student Pages 3 and 4 for each team
Smokeygram #1	*Smokeygram kit*, Teacher/C	
Fire extinguisher	Main/B	
Spray bottles with water (2)	*Hardware Box*, Main/A	
Demonstration/Experiment 1:		
Support stand post & base (1 for **Elementary** level, 4 for **Middle School** level)	Main/A	Wooden matches Paper towels for cleanup
Clamp for support stand (1 or 4)	All in *Hardware Box*, Main/A	
Rod segment with alligator clip (1 or 4)		
Burning tray (cookie sheet) (1 or 4)		
Ashtray for burnt matches (1 or 4)		
15-cm rulers (**Middle School** level only)		
Demonstration/Experiment 2:		
Tongs for handling dry ice Votive candle (1 or 4) Ashtray for burnt matches (1 or 4) Beaker, 500 mL 1 or 4)	All in *Hardware Box*, Main/A	Dry ice (1-2 pieces about ping-pong ball size for each group)—available in most supermarkets[15]
Votive candle (1 or 4)		Wooden matches
Ashtray for burnt matches (1 or 4)		Paper towels

Preparation

Because this activity uses fire, you'll need to make some special preparations. Follow the precautions listed in Chapter 1. The day before doing this activity go over the rules on the *Fire Safety* poster, or follow the lab rules for your school. If students come to class unprepared (wearing loose sleeves or sandals, for instance), do not allow them to handle burning materials. Use **Smokeygram #1** (see fig. 2, chapter 1) as a reminder just before students begin the experiments. Read it to the class and post it in the classroom, or have it "delivered" from another room by "special courier" (perhaps a student from another class).

[14] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

[15] If you can't find dry ice, do this experiment using baking soda and vinegar: Place the candle in a 1-qt freezer container (in the Hardware Box). Mix vinegar with baking soda. Immediately pour the resulting CO_2 gas (not the foam or liquid) over the burning candle.

Procedure

1. For **Demonstration** (at **Elementary level),** set up a demonstration table with all materials on it. For **Experiment** (at **Middle School** level), set up 4 work stations. The following instructions are written for the **Middle School** level; **elementary** teachers can follow them for their demonstrations.
2. Before having students start their own experiments, place some dry ice in an extra beaker and discuss it with the students. It is frozen carbon dioxide (one of the parts of air), and it's <u>very</u> cold—much colder than ice. Then ask the students what is happening to the dry ice in the beaker. It doesn't <u>look</u> like it is changing, but it is; the solid carbon dioxide is *sublimating*—going right from solid to gas form—in the beaker. In a few minutes, it will all have disappeared. The fog in the beaker is actually water vapor condensing out of the room's air because the temperature is so cold next to the dry ice.

   > **INFO SPARK—Integrating with physical science:** This would be a good time to discuss or review states of matter (solids, liquids, gases), physical changes (such as evaporation, condensation, and sublimation), and chemical changes with the class.

3. Have the students set up their beaker and candle for Experiment 2 before beginning Experiment 1. Then they can set up Experiment 1. While they conduct Experiment 1, circulate to all stations, placing dry ice next to the votive candles inside the beakers. Use several pieces of dry ice (3-5) in each beaker, and caution the students not to touch it or disturb the beaker in any way while doing Experiment 1.
4. Have students conduct Experiment 1, following the instructions and recording their observations on Student Page 3.
5. Have students conduct Experiment 2, following the instructions and recording their observations on handout Student Page 4.
6. After all experiments and data sheets are completed, ask students about their results. In particular, what component of the Fire Triangle was removed in each part of the experiments? The downward-pointing match goes out for lack of fuel. The upward-pointing match goes out because the heat produced by the flames is rising, so the fuel that is available is not heated (lack of heat). The candle can't be lighted because oxygen is not available. (Ignition might be slowed by the cold conditions in the presence of dry ice "fog," but it probably wouldn't stop ignition altogether.)

   > **INFO SPARK—Integration with physical science at advanced Middle School or High School level:** In Experiment 2, carbon dioxide stays in the beaker and does not disperse throughout the room. Why? One reason is that it is cold, and cold gases are more dense than warm gases. A second reason is that carbon dioxide is heavier than air. Students can check out the relative weights of the two gases by comparing the weight of a mole of the two molecules. Use the atomic weights below.
   >
   > | ***element*** | ***atomic weight*** |
   > |---|---|
   > | Carbon (C) | 12 g |
   > | Oxygen (O) | 16 g |
   >
   > A mole of CO_2 weighs 12 g + 2(16 g) = 44 g
   > A mole of O_2 weighs 2(16 g) = 32 g

Evaluation:

1. Describe or draw a picture to show where the heat from a candle goes.
2. What evidence do you have to show that a fire cannot burn without oxygen?

Closure: Lots of things can happen when you blow on a fire. Here's a chance to discuss some of them. You can blow a candle out, but you can also blow on a campfire to get it to burn better. What makes the difference? [When you blow on a candle, you add oxygen to it, but you also bend the flame and disperse the heat away from the wick. The result is to remove so much heat from the fuel that the fire goes out. When you blow on a campfire, you bend the flames and disperse the heat over the unburned fuel that is "downwind," spreading the fire. Most campfire builders can remember a few times when they blew too hard and put the fire out.]

Explain that research on combustion, like the experiments in this activity, is the work of *chemists.*

Extensions

1. In Step 6 above, we claim that the atmosphere around the dry ice is not dry enough to keep us from lighting a candle—that the candle will not light because oxygen is not available. Design an experiment that tests this claim.
2. Use a different procedure to test the Fire Triangle, from Discovery Channel's Internet site:

   pictures.discovery.com/dppages/wildfire/teacher/lesson4.html
3. Apply what you've learned about the Fire Triangle to personal safety using Discovery Channel's Internet site:

   pictures.discovery.com/dppages/wildfire/teacher/safety.html

Student Page 3

Names: ________________________

Testing the Fire Triangle—Experiment 1.

Organize your team. On a team of 4, one person should light matches and observe heat; one should measure time, one should measure flames, and one should record data. Change jobs if you repeat the experiment.

Procedures:

1. Place the burning tray on a heat-resistant surface. Set the support stand in the center of the burning tray. Attach the clamp near the top of the ring stand. Attach the rod with alligator clips to the clamp, so it forms a "T" with the stand.
2. Clip a wooden match to each alligator clip. Clip in one match so the ignitable tip points straight up. Clip in the other so the ignitable tip points down.
3. Light a third match and use it to ignite the downward-pointing match. Record your observations in the first column below, lines 1 and 2.
4. Use another match to ignite the upward-pointing match. Record your observations in the second column below, lines 1 and 2.
5. Do the experiment with two fresh matches. Have one person on the team carefully place her or his hand above, below, and next to the flame to see if any areas are hot. Record observations in line 3 below, both columns.
6. Do the experiment again, if necessary, so you can answer questions 3 and 4 below.

Match is pointing...	DOWN	UP
1. Without putting the ruler in the flame, estimate how long the flame is (cm).		
2. How long did the fire burn (seconds)?		
3. What direction did most of the heat go?		
4. Why do you think the match went out? What part of the Fire Triangle was removed?		

Student Page 4

Names: ___________________________

Testing the Fire Triangle - Experiment 2.

Organize your team. One person should set up the experiment. One should try to light the candle. One should record observations. Change jobs if you repeat the experiment.

Procedures:

1. Place the candle inside a beaker.
2. Ask your teacher to place 1 or 2 pieces of dry ice into the beaker, next to the candle.
3. Leave the beaker alone for a few minutes. Don't bump or move or stir the beaker.
4. After 5 minutes, answer question 1 below.
5. Try to light the candle.
6. Answer questions 2 and 3.

1. Describe any changes that occurred in the beaker during the minutes before you light the candle.	
2. Describe what you observe when you try to light the candle.	
3. Use the Fire Triangle to explain what you observe.	

Activity 3-4. The Fire Triangle in Wildlands

Grade levels:
X Middle
X High

What's the Point?

The Fire Triangle tries to capture the concepts underlying wildland fire behavior—a powerful, highly variable force of nature. When you're looking at a match or a candle, it looks simple. In wildlands, it usually isn't. Instead, it is complicated, intriguing, and dramatic.

In this activity, students construct and demonstrate some principles of fire behavior for the class. They use matches to model trees and a matrix of matches to model a forest. They compare fire behavior on different slopes and with different arrangements of trees. They also view a 3-minute videotape of wildland fires burning in three layers of the forest—surface, crown, and ground fuels. They interpret the fires in the videotape in terms of what they have learned about fire behavior and the Fire Triangle.

Teacher's Map:

Objectives: Given a physical model of a forest stand, students can describe effects of slope and tree density of fire spread. After viewing a videotape, students can identify three kinds of fire behavior—surface, crown, and ground fire.

Subjects: Science, Math., Writing, Speaking and Listening, Workplace Competencies

Duration: 50 minutes

Links to Standards[16]:

National Science Teachers' Association—Grades 5-8:

A1) Identify questions that can be answered scientifically
A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations
A5) Communicate procedures and explanations
B2) Describe physical and chamical changes
B3) Understand that energy is transferred in many way
B4) Identify ways in which energy moves in and out of a system
F1) Identify potential for accidents, make choices that minimize risk of injury
F3) Recognize extent, sources and challenges of natural and human-induced hazards

National Science Teachers' Association—Grades 9-12:

A2) Design and conduct experiment, use models to explain results
B3) Understand basic chemical reactions
F1) Identify hazards, make choices that minimize risk of injury
F3) Recognize extent, sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades 5-8:

1B) Design investigations to answer questions
1D) Judge weaknesses and strengths of information being used
1G) Synthesize observations into coherent explanations

[16] See Appendix 4 for links to Montana educational standards, grades 5-8 and 9-12.

cont'd.

2.1C) Understand energy transfer
2.4A) Understand that human-caused changes affect environment
North American Association for Environmental Education—Grades 9-12:
1B) Design investigations to answer particular questions
1D) Apply logic to assess completeness and reliability of information
1G) Use evidence and logic to develop hypotheses
2.2C) Understand the living environment as comprised of interrelated, dynamic systems

Vocabulary: chemist, crown fire, density, ecologist, firestorm, forester, ground fire, model, physicist, range manager, slope, spot fire, surface fire, wildlife biologist

Materials

In this trunk...	***...where?***[17]	***You must supply***
Kinds of Fire videotape (3 min.)	Teacher/C	VCR and monitor
Tree Portrait poster	Main/B	Wooden matches (lots)
*Fuels, Tree Parts…*kit	Teacher/C	Metal trash can without liner
Matchstick forest kits (4)	*Hardware Box*, Main/A	overhead projector
Fire extinguisher	Main/B	Copy of Student Page 5 for each team
Burning trays	Main/A	
Class Page 2 (transparency in *FireWorks Visual Aids/Handouts*)	Teacher/C	
spray bottles with water (2)	*Hardware Box*, Main/A	

Procedure

1. Set up the class with four student teams. Explain that this activity is similar to research done by chemists and physicists. Results from research like this are used by foresters, firefighters, range managers, wildlife biologists, and ecologists.
2. Explain that each team will set up different experiments, but the whole class will observe every fire. So, in effect, the student teams are setting up demonstrations for the whole class.
3. Review safety procedures in the laboratory; use the *Fire Safety* poster or other lab rules.
4. Give each student team a matchstick forest model (drilled square of masonite, 2 bolts, 1 nut-and-washer set, 1 nail) and 50-100 matches. Ask students to insert a match in every hole of the matchstick forest model, tips pointing up.
5. Set these "matchstick forests" in burning trays on a heat-resistant surface. If you don't have laboratory facilities, one really good surface to use is a trash-can lid filled with sand. Let the first "forest" be level; to the second and third, attach a short bolt so the slope is about 20 degrees. To the fourth, attach the long bolt so slope is about 40 degrees. Have a spray bottle and fire extinguisher nearby.
6. Explain to students that the individual matches represent trees that have flammable crowns, like the conifers in local forests. In this demonstration, students will observe how slope and

[17] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

tree density affect fire spread through tree crowns. Before lighting the matches, ask students for their guess (hypothesis) about how the fires will differ.

Figure 6—Middle school students ignite their “matchstick forest” while younger students “patrol” for unsafe practices.

7. Light the match tips along one edge of the flat "forest" and observe fire behavior. Then light the match tips along the top edge of a medium-slope forest and observe. Then light the bottom row of matches on the other medium-slope forest and observe. Finally, light the bottom row of matches on the steep forest and observe (fig. 6). Ask for descriptions of what the students observe and interpretations in terms of the Fire Triangle. (Heat travels upward, so the matches and trees uphill from a fire receive more heat than those below and are easier to ignite.) Optional: Ask students to answer Questions 1-3 on Student Page 5.
8. Ask students to remove whatever remains of the matches from each board. They can use the nail in the kit to poke the burned matches out, if necessary.
9. Explain that the arrangement of "trees" in the matchstick forests studied so far resembles the arrangement in lodgepole pine/subalpine fir forests. Show Class Page 2 on the overhead projector. This table describes the number and arrangement of trees in ponderosa pine/Douglas-fir forests and whitebark pine/subalpine fir forests. Ask students to set up matchstick forests resembling these two forest types—using the long bolts to make "steep" forests. Ask how they expect fire behavior to differ.
10. Light these matchstick forests, one at a time, and discuss or record observations on Student Page 5, lines 4 and 5.
11. Ask each student team to construct a matchstick forest to solve a problem. Here are two possibilities: (1) Your matchstick forest is on a steep slope. You can remove 12 trees from it. Find the best arrangement of 12 fewer trees (a total of 37 remaining) to reduce the risk of fire spread. (2) You are in the timber business, and most of your land is on moderate slopes. You need to reduce the risk of fire spread on your land, but you want to raise as many trees as possible. What’s the best density and arrangement for your trees?
12. Light these matchstick forests, one at a time, and discuss how well each team solved the problem.
13. Ask the students to compare the model forests used in this experiment to real forests. What are the similarities? What are the differences? How would they expect wildland fires to differ from matchstick fires?

14. Explain: Real wildland fires are much more complicated than model fires. Show the 3-minute videotape *Kinds of Fire*. Ask students which kind of fire (surface, crown, or ground) was modeled in their matchstick forests? (crown fire)
15. Explain**: Spot fires** (mentioned in the videotape) can be started by small fires, including slash burns, as well as large, severe fires; the spot fires started by large fires, however, may start a long distance from the main fire. Any time there are several fires in an area, caused by numerous spot fires or lightning strikes or any other source, they can influence one another and even merge into a large, severe "**firestorm**."

Evaluation:
1. Use a sketch to show how slope affects fire spread.
2. If you double the number of trees in a forest, what happens to the fire danger?

Closure: On the *Tree Portrait* (poster from the trunk), attach the laminated cards identifying the locations where fires can burn (ground, surface, and crown).

Extensions
1. Read and report to the class on the 1997 *Discover* article about lightning, in the *FireWorks Library*.
2. View the videotape *International Crown Fire Modeling Experiments* (in the *Teacher Box*) to see what researchers are doing to learn more about very severe fires and safety measures.
3. Learn about wildland fires on a national scale by consulting the U.S. "National Fire Occurrence Maps" on the Internet at
   www.fs.fed.us/fire/fuelman
4. What's going on right now in the firefighting business? To find out, visit the National Interagency Fire Center's Internet site:
   www.nifc.gov

Class Page 2

Arranging Trees in the Forest 100 Years Ago

Three kinds of forest, three arrangements of trees.

What kind of forest?	How many trees in a matchstick model?	How are the trees arranged?
Lodgepole pine/subalpine fir	49	Trees are dense and quite evenly spaced.
Ponderosa pine/Douglas-fir	5	Trees occur singly, occasionally in pairs.
Whitebark pine/subalpine fir	13	Trees occur in clusters of 2 to 5.

The matchstick model represents 1/40 hectare (1/15 acre),
a square 16 m (about 50 ft) on a side.
Is this bigger than your classroom?

Student Page 5

Names: ______________________________

The Fire Triangle in Wildlands

In this demonstration, you watch fires on three slopes--flat, medium, and steep. Answer questions 1-3 using the demonstration fires as examples.		
1	How does the steepness of a hillside affect a fire's spread?	
2	How well do fires burn downhill?	
3	How does slope affect fire spread? Use the Fire Triangle to explain.	
Now you will burn two more "matchstick forests" to explore how the arrangement of trees affects fire spread. Answer the questions below.		
	Description of matchstick forest	How well did this arrangement resist crown fire?
4	Ponderosa pine/Douglas-fir forest 100 years ago (5 large trees in area where lodgepole pine might have 50 trees)	
5	Whitebark pine/subalpine fir forest (13 trees, growing in clusters of 2-5 trees, in area where lodgepole pine might have 50 trees)	
6	Use the Fire Triangle to explain.	

Activity 3-5. Bucket Brigade[18]

Grade levels:
X Elementary
X Middle

What's the Point?

Candles and matches, contained in clips and beakers, make tidy fires. Wildland fires are anything but tidy. In this activity, teams of students try to start a fire using branches, leaves, and needles (fig. 7)—some of which have been partially burned. Then they try to explain what happens in terms of the Fire Triangle. Finally, they view a short videotape that describes how fires burn in various layers of wildland fuels (tree crowns, forest floor surface, and ground).

This is an outdoor activity. Select a place far from dry grass, bark chips, and other fuels. Make sure a hose is available and ready to use. Because the students will be using matches, **you may want to ask some parents or other volunteers to help. Also, please note that you have to gather the following fuels yourself for this experiment:** green pine needles (it's OK to leave them on small twigs), and charred material (from a fireplace or campfire).

Figure 7—Elementary students evaluate the flammability of their fuel recipe.

Teacher's Map:

Objective(s): Students can select fuels that are likely to burn well and arrange them so they are most likely to burn.

Subjects: Science, Mathematics, Writing, Speaking and Listening, Health, Workplace Competencies

Duration: 50 minutes

Links to Standards[19]:

National Science Teachers' Association—Grades K-4:

A1) Ask a question about the environment
A2) Plan and conduct simple investigation
A3) Use simple equipment and tools to gather information
A4) Use data to construct an explanation
A5) Communicate investigations and explanations
B1) Understand size, weight, shape, color, temperature; materials; states of matter
B3) Demonstrate production of heat, conduction and convection
E3) Communicate a problem, design and solution

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[18] Adapted from *Getting to Know Wildland Fire* (see Appendix 3 for more information).
[19] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

cont'd.

E4) Understand that scientists and engineers often work in teams to solve problems
F1) Understand and make choices for safety and preventing injury
F4) Understand that changes in environments can be natural or invluenced by people
F5) Understand that change in environments can be slow or rapid, rate has consequences

National Science Teachers' Association—Grades 5-8:

A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations
A5) Communicate procedures and explanations
A6) Use mathematics in science
B2) Describe physical and chemical changes
B4) Identify ways in which energy moves in and out of a system
F1) Identify potential for accidents, make choices that minimize risk of injury to self or others
G1) Understand that scientists work alone and in teams
G2) Understand that science results must be communicated
G3) Recognize that uncertainty, debate, further investigation and evaluation are part of science

North American Association for Environmental Education—Grades K-4:

1B) Design simple investigations
1C) Collect information about environment
2.1B) Identify characteristics of and changes in matter
2.1C) Be aware of basic behavior of some forms of energy

North American Association for Environmental Education—Grades 5-8:

1B) Design investigations to answer questions
1G) Synthesize observations into coherent explanations
2.1C) Understand energy transfer
2.2D) Understand how energy and matter flow in environment
2.4D) Understand ability to control environment as function of knowledge and technology

Vocabulary: charred fuel, flammability, fuel, fuel moisture, surface area, volatile, volume

Materials

In this Trunk…	***… where?***[20]	***You must supply***
Fire extinguisher	Main/B	Aluminum pie tins (5)
Spray bottles, filled with water (2)	*Hardware Box*, Main/A	Wooden matches Metal trash can *without* plastic liner
"Bucket Brigade" Kit	Teacher/C	large bucket of water
dead ponderosa pine needles[21] dead & dry branches, small dead & dry branches, large	Teacher/C	Two grocery bags, one containing **green pine needles & small branches**, the other containing **charred fuels** from a fireplace or campfire
	Fuels Box, Main/B	Three grocery bags, each one containing one of the fuels listed at left (from the *Fuels Box*)

[20] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).
[21] This experiment doesn't require a lot of fuel to make its point. The *Fuels Box* in the main *FireWorks* trunk contains small amounts of each of these fuels; you can supplement this supply if you want to use more.

Preparation

Collect green pine foliage (you can leave small branches attached) in the field (fig. 8). If you think you will need more of the fuels provided in the *Fuels Box* (dead pine needles, small and large branches), collect those as well. Store the green needles in a plastic bag in the refrigerator until the day you use them. They can be stored for a week or two.

Place fuels in five grocery bags and attach the fuel labels from the *Bucket Brigade* kit.

Procedure

1. Explain: Five teams of students will try to start small fires in the aluminum pie tins. It may not be easy! Each team will assemble a pie tin with a certain mixture of fuels, specified on their Fuel Recipe. They must carefully plan a strategy to get as much of their fuel as possible to burn within 15 minutes. Remind students that fires will not burn unless all three parts of the fire triangle are present.
2. Divide the students into five teams. Give each team a Fuel Recipe card from the *Bucket Brigade* kit, plus an aluminum pie tin.

Figure 8—Small branch of ponderosa pine, with bud at tip. Circles in photo are 2 cm across.

3. Give seven matches to each team. Seven is all they get.
4. Have the students follow the team's recipe to place the right combination of fuels in their pie tin. The fuels have to fit *inside* the pie tin, not be hanging over the edges and spilling out. Here are the Fuel Recipes:
   - Recipe #1 green needles (attached to twigs)
   - Recipe #2 dead & dry branches, small diameter (< 0.5 cm), mixed with green needles
   - Recipe #3 small dead & dry branches, plus dry needles
   - Recipe #4 large dead & dry branches, mixed with small-diameter branches
   - Recipe #5 charred fuels from campfire or fireplace, mixed with small branches
5. Go over the following rules with the students:
   - Each team must work together.
   - The whole team is responsible for safety. If any student is injured, the experiment stops.
   - All fires must be built within the pie tin on the designated surface (pavement or gravel, away from cars, buildings, and dry vegetation).
   - Each team must stick to its recipe. No other fuels may be added.
   - Each team gets only 7 matches; no more may be used.
   - Each team MUST use a 2-minute group planning session before lighting any matches; they can arrange the fuels in the pie tin in any way they wish.
6. Go outside to the location where students will build their fires.
7. Tell students to begin planning
8. After two minutes, tell students that they may begin lighting their fires.
9. After 15 minutes, stop the activity.
10. As a class, take a "tour" of the work sites. Discuss how successful each fire was and why it burned well or didn't. Here are some **discussion points**:

Green fuels have much more moisture than dead fuels, unless it's been raining lately. Moisture affects the Fire Triangle in two ways: First, you have to evaporate the moisture before you can heat the fuel to the ignition point (about 600^{o} Fahrenheit, 320^{o} C). If things are really wet, the water also keeps oxygen from the fuel.

Green fuels usually contain about as much water (by weight) as the plant tissue itself! The moisture of dead, dry vegetation depends on its environment but can be as low as 3 percent of the material's weight. So green fuels may be difficult to *start* on fire.

Once green fuels start to burn, however, they may produce more heat than dead ones. Green pine needles contain more stored energy than dead ones because they contain oils and other "volatile" compounds that deteriorate after the needles die.

Large particles, like the big twig, are much harder to ignite than small particles. That's because the small pieces have much more surface area exposed to oxygen and to the heat of the match than the large pieces do. (Scientists call this the "surface-area-to-volume ratio; as this number increases, fires burn more readily.)

Plant matter is a mixture of burnable "stuff" (carbon compounds that combine readily with oxygen in the presence of heat) and unburnable minerals such as silicon, which glass is made of. Charred wood from an old campfire has had much of its carbon burned off, especially from the surface of the fuel, so it is harder to ignite than unburned wood.

11. Ask the students what factors other than fuel condition came into play as they built their fires. What strategies did they use to try to get the fires to burn?

Evaluation: Using the five kinds of fuels provided in this activity, write a recipe for a fire that would burn really well. Write a paragraph that uses the Fire Triangle to explain why you think your recipe is a good one.

Closure: If time permits, let students assemble their own combination of fuels to make a really good fire. Give them seven matches again and see how well the new "fuel recipes" burn.

For Elementary students: Students at the elementary level should take a few minutes to view the 3-minute *Kinds of Fire* videotape; older students have already seen it (Activity 3-4).

Ask students to clean up materials and put equipment away.

Extensions

1. The **discussion points** in #10 above mention that the moisture content of fuels is very important in determining how well they burn. Design an experiment to measure the moisture content of various fuels and express it as a percent of dry weight. If equipment is available (an oven for drying and a balance for weighing), do the experiment and report results to the class.
2. The **discussion points** also mention that surface-area-to-volume ratio affects how well fuels burn. Design and carry out an experiment to determine whether high or low surface-area-to-volume ratios favor better burning. You will need to measure some large twigs and small twigs, estimate their total surface area and volume of each, calculate their surface-area-to-volume ratios, and attempt to burn them.
3. Read pp. 87-127 in *Yellowstone on Fire* (in the *FireWorks Library*), a photojournalist's description of fire behavior in the 1988 Yellowstone fires.

Activity 3-6. Will It Burn?

Grade level:
X High

What's the Point? _______________

In four experiments, the class investigates the "burnability" of fuels that occur in wildlands. The class is divided into four teams. Each team conducts one experiment, then reports results and conclusions to the class. The four experiments investigate the effects of fire on four different parts of a tree:

Experiment 1	Needles
Experiment 2	Buds
Experiment 3	Branches
Experiment 4	Roots

In each experiment, students *try* to burn two kinds of natural fuels; they decide which kind is harder to burn and explain why (fig. 9). Students use the Fire Triangle in their explanations.

"Burnability" is related to the mixture of oxygen and fuel and the intensity of heat. In these experiments, roughly the same amount of heat is provided to each set of material—the flame from a single wooden match, applied to two or more layers of crumpled newspaper. The moisture content and "fluffiness" of the fuels determine how well they burn.

Figure 9— Do branches burn more readily than pine needles? These eighth graders are finding out.

Teacher's Map:

Objective: Given experimental materials, students can demonstrate or describe the effects of fuel greenness, fuel particle size, and fuel "fluffiness" on how well a fuel burns.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Workplace Competencies

Duration: 50 minutes

Links to Standards[22]:

National Science Teachers' Association—Grades 9-12:

A1) Formulate a testable hypothesis and obtain relevant knowledge
A2) Design and conduct an experiment, using mathematics and models to explain results
A3) Communicate and defend a scientific argument
A4) Use technology, mathematics, logic and previous research in investigations

[22] See Appendix 4 for links to Montana educational standards, grades 9-12.

cont'd.

B3) Understand basic chemical reactions

North American Association for Environmental Education—Grades 9-12:

0B) investigate short- and long-term environmental changes
1B) Design investigations to answer particular questions
1G) Use evidence and logic to develop hypotheses
2.1B) Apply understanding of chemical reactions to explain environmental phenomena
2.2D) Use interaction of matter and energy to explain environmental characteristics

Vocabulary: bud, duff, mineral soil, needle, soil, surface area, volume

Materials

In this trunk...	***...where?***[23]	***You must supply***
Burning tray (4)	Main/A	Wooden matches
Oven mitts (4)	All in *Hardware Box*, Main/A	Metal trash can, without plastic liner
Spray container, filled with water (2)		Paper towels for cleanup
Rulers, 15-cm (4)		Newspaper cut into sheets about 24 X 35 cm (1/4 of unfolded, open "page")
Safety goggles (4) Ashtray for burned matches (4)		Overhead projector
Fire Extinguisher	Main/B	1 copy of Student Pages 6-9 (Each team gets one Student Page & conducts one experiment
Transparency of Class Page 3 in *Visual Aids & Handouts*	Teacher/C	
Fuels Box[24]	Main/B	

Preparation

Collect green conifer foliage in the field. You don't need much; 10 to 15 needles will do for Experiment 1, and 3 to 5 buds for Experiment 2. Use fig. 8 (see Activity 3-5) and fig. 10 to help identify the needles and buds needed. We suggest using ponderosa pine and Douglas-fir, but if they are not available in your area, other pines and true firs will be interesting to investigate instead.

FireWorks provides enough materials (dead pine needles, small and large branches) for two to four replications of these experiments. If you think you will need more, collect them. Store the green needles in a plastic bag in the refrigerator until the day you use them; they die and dry out rapidly after being picked.

Please note that availability of tree buds depends on season. If it is spring and conifer leaves have just emerged, the brand-new tree buds may not be large enough to demonstrate the

[23] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

[24] This experiment doesn't require a lot of fuel to make its point. The *Fuels Box* in the main *FireWorks* trunk contains small amounts of dead pine needles, small twigs, and large twigs; you can supplement this supply if you want to use more.

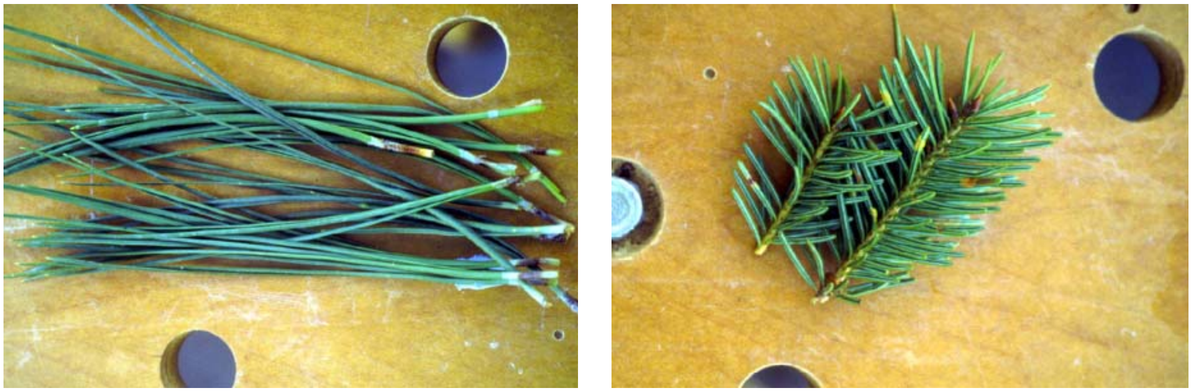


Figure 10—Pine and fir foliage to be collected. Left, green needles of ponderosa pine. Right, bud and branch tips of Douglas-fir. Circles in photos are 2 cm across.

point made in Experiment 2 below. In the northern Rocky Mountains, for instance, ponderosa pine buds usually burst sometime in May, and new buds are not well developed until mid-July.

These experiments use fire. Prepare students the day before the activity by going over the *FireWorks Safety* poster. Conduct experiments on a working surface that cannot be damaged by heat or fire. Make sure that ventilation is sufficient for smoke. Keep the fire extinguisher nearby. Fill the spray bottles with water and place them in an accessible location. If you do the experiments outdoors, stay away from dry vegetation and bark chips. Be sure that burning embers do not reach flammable materials. Everyone working directly with fire should wear safety goggles (in the *FireWorks* supplies).

Procedure

1. Ask students to set up their work stations. Each team needs
   - at least one pair of goggles
   - one burning tray
   - one oven mitt
   - one ashtray
   - one ruler
   - one Student Page (6, 7, 8, or 9)
   - at least two sheets of newspaper, 24 X 35 cm
   - **one** of these sets of materials, to correspond with their Student Page:

Exp. 1—dead, dry pine needles	**AND**	green pine needles
Exp. 2—buds of fir tree	**AND**	buds of pine tree
Exp. 3—small twigs (<0.25 cm thick)	**AND**	thick twigs (> 2 cm)
Exp. 4—“duff” (peat)	**AND**	mineral soil (sand)
	AND	cotton string

2. Show students how to crumple the layers of newspaper separately and lay them on the burning tray. Class Page 3, a transparency, illustrates this. Show them how to ignite the newspaper for their experiments (two corners on a "long" edge).
3. Ask students to do their experiments and prepare to show/ report their results to the class. Procedures for the four experiments are written on Student Pages 6-9.
4. After the experiments are completed, ask each team to report to the class.

INFO SPARKS on the experiments:

Experiment 1. Dead vs. Green Needles. Because a lot of heat is needed to dry fuels out before they can burn, we expect dry material to burn more easily than moist material. The dead needles in Experiment 1 will have about the same moisture as their surroundings. In your warm, dry classroom, this may be as little as 5% of their weight. In a forest after heavy rain, it may be much more. Green needles, on the other hand, usually contain moisture at least equal to their own weight because they are constantly using water to stay alive.

Experiment 2. Tree Buds. In general, the more fuel surface exposed to oxygen and heat, the more easily the fuels burn. That's why people use crumpled newspaper instead of piles of newspaper to start a campfire. This idea leads us to expect thick buds to burn less easily than narrow, tiny buds.

Experiment 3. Large vs. Small Twigs. As in Experiment 2, the more fuel surface exposed to oxygen and heat, the more easily the fuels burn, so we expect thick twigs to burn less easily than tiny, narrow twigs.

Experiment 4. Pure mineral soil (including sand) does not burn because it contains no organic matter—that is, no fuel. When mineral particles are mixed with duff, however, the "soil" can burn. Roots growing deep in pure mineral soil are less likely to be damaged by fire than roots growing in dry duff or in a soil-duff mixture.

Evaluation: Write instructions for an 8-year-old, explaining how to collect fuels and arrange them for a campfire that will be easy to start on fire. Include only wildland fuels, no petroleum products! If possible, "borrow" a child and go through your directions with him or her, then revise your first draft accordingly.

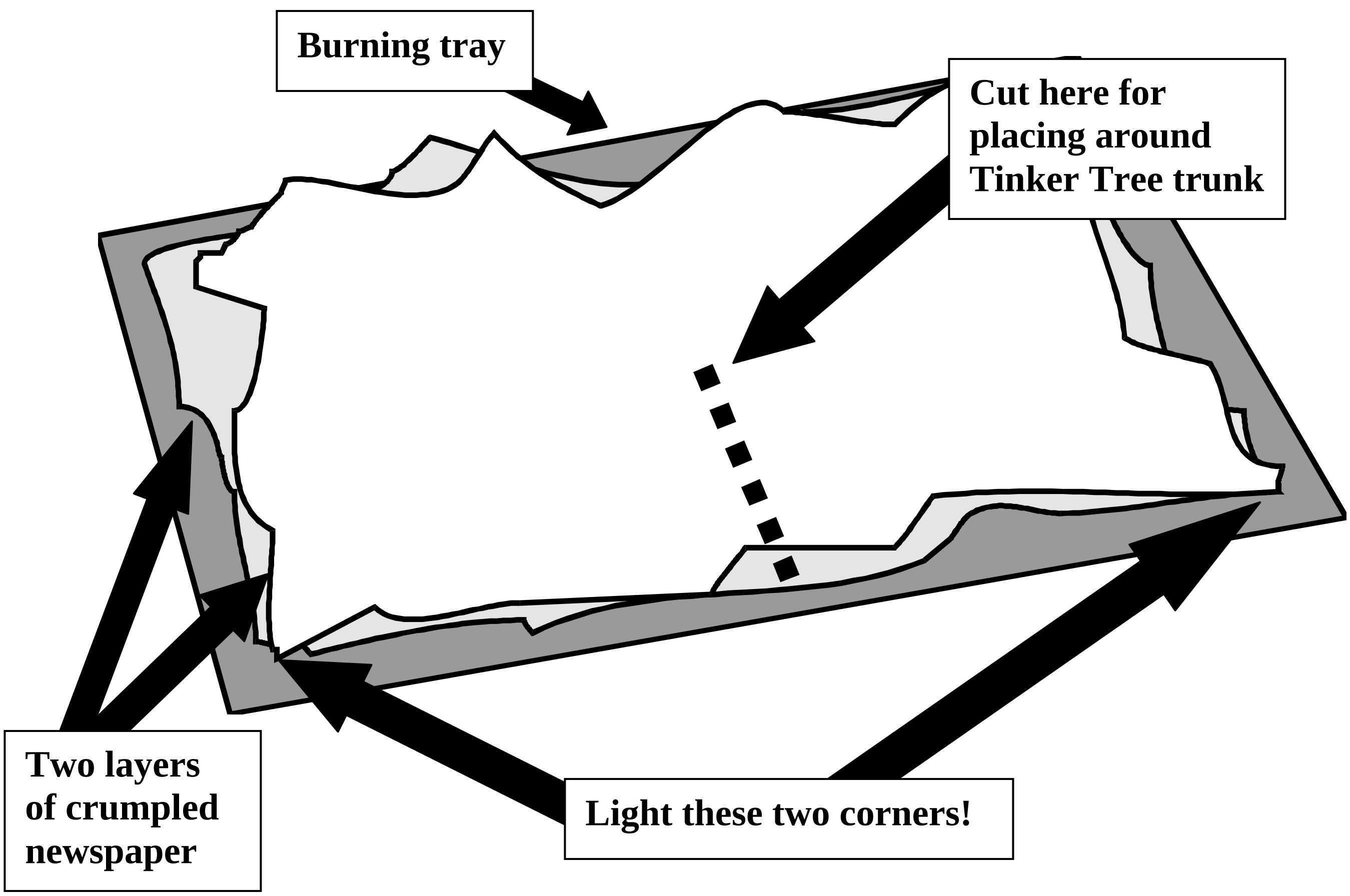
Closure: Ask students to clean the laboratory and put materials and equipment away.

Extensions

1. Fire behavior is strongly influenced by how much surface area of the fuel is exposed to oxygen. Re-do Experiment 3 but come up with a way to measure the effects of surface area on combustion, then analyze and display your results. How will you measure the surface area and volume of each twig? How will you calculate surface area and volume? How will you estimate how completely the fuels burn? Can you account for the moisture content of the fuels?
2. Find out how to calculate the surface area and volume of a cylinder. Calculate the surface area and volume of 10 cylinders with radii ranging from 0.2 cm to 40 cm in diameter. Show your results some kind of graph. Assuming that most fuel particles are roughly cylindrical in shape, explain how your graph can be used to explain some aspect of fire spread.

Class Page 3

Burning Tray Setup
For Activities 3-6 and 3-7,
"Will It Burn?" and "Tinker Trees"



Student Page 6

Names: ________________________

Exp 1. Dead *vs.* Green Needles

1. Organize your team. Everyone should observe the fires. One person should record information on the data sheet AFTER the whole team has talked over what to write.
2. Get your materials together and set up your work station.
3. Use what you already know about fire, including the Fire Triangle, to guess which needles (green or dead) will be easier to burn. Write this *hypothesis* on line 1.
4. Place the burning tray on a flame-retardant surface in a laboratory or on a paved surface outdoors with little wind.
5. Crumple up two quarter-page sheets of newspaper. Flatten them out a bit, so some air gets between the layers. Place them, one on top of the other, on the burning tray (as shown on Class Page 3).
6. Lightly spread the dead pine needles on top of the newspaper in the burning tray. Scatter them around on the paper; don't leave them in a single pile.
7. Use a match to ignite two adjacent corners of newspaper.
8. Observe the fire.
9. Describe how well the dead needles burned on line 2.
10. Shake the burned and partly burned materials into a metal trash can. Spray water on them, if necessary, to put out any smoldering. (Fire is not completely out until there is no smoke.)
11. Repeat steps 3 through 8 with the live ponderosa pine needles. Record observations on line 3.
12. Answer the questions on lines 4 and 5.

1. **Hypothesis:** Which needles do you think will be easier to burn?	
2. How well did the **dead needles** burn?	
3. How well did the **live needles** burn?	
4. Was your hypothesis correct?	
5. Use the three legs of the **Fire Triangle** to explain your results.	

Student Page 7

Names: __________________________________

Exp 2. Tree Buds—Pine *vs.* Fir

1. Organize your team. Everyone should observe the fires. One person should record information on the data sheet AFTER the whole team has talked over what to write.
2. Get your materials together and set up your work station.
3. Use what you already know about fire to guess which bud will be easier to damage with fire. Write your *hypothesis* on line 1.
4. Place the burning tray on a flame-retardant surface in a laboratory or on a paved surface outdoors with little wind.
5. Crumple two quarter-page sheets of newspaper into two balls. Flatten them out on the tray but leave room so some air can get between the layers (as shown on Class Page 3).
6. Place the two to four tree buds of each species on top of the newspaper. Don't bunch them together; spread them out over the newspaper.
7. Use a match to ignite two adjacent corners of the newspaper.
8. Observe the fire.
9. Look at the burned buds. Try to scrape away the burned outside.
10. Answer questions 2-5.

1. **Hypothesis:** Which bud do you think will be easier to damage with fire?	
2. Describe the burned **Douglas-fir** bud. Do you think the cells inside it survived?	
3. Describe the burned **ponderosa pine** bud. Do you think the cells inside it survived?	
4. Do you think your hypothesis was correct?	
5. Use the **Fire Triangle** to explain your results.	

Student Page 8

Names: ___________________________

Exp 3. Large *vs.* Small Twigs

1. Organize your team. Everyone should observe the fires. One person should record information on the data sheet AFTER the whole team has talked over what to write.
2. Get your materials together and set up your work station.
3. Use what you already know about fire, including the Fire Triangle, to guess which twigs will be easier to burn. Write this *hypothesis* on line 1.
4. Place the burning tray on a flame-retardant surface in a laboratory or on a paved surface outdoors with little wind.
5. Crumple two quarter-page sheets of newspaper into two balls. Flatten them out a bit on the burning tray, so some air gets between the layers (as shown on Class Page 3).
6. Spread the small twigs on top of the newspaper. Spread the twigs around on the paper; don't leave them in a single pile.
7. Use a match to ignite two adjacent corners of newspaper.
8. Observe the fire.
9. Describe how well the twigs burned on line 2.
10. Shake the burned and partly burned materials into a metal trash can. Spray water on any smoldering materials. (Fire is not completely out until there is no smoke.) Then dry the tray.
11. Repeat steps 4 through 10 with the large twigs. Record observations on line 3.
12. Answer the questions on lines 4-5.

1. **Hypothesis:** Which twigs do you think will be easier to burn?	
2. How well did the **small twigs** burn?	
3. How well did the **large twigs** burn?	
4. Was your hypothesis correct?	
5. Explain your results using the **Fire Triangle**.	

Student Page 9

Names: ________________________

Exp 4. "Root Sandwich"

1. Organize your team. Everyone should observe the fires. One person should record information on the data sheet AFTER the whole team has talked over what to write.
2. Get your materials together and set up your work station.
3. Use what you already know about fire, including the Fire Triangle, to guess which material (duff or mineral soil) will protect plant roots in the soil better. Write your *hypothesis* on line 1 below.
4. Place the burning tray on a flame-retardant surface in a laboratory or on a paved surface outdoors with little wind.
5. Crumple two quarter-page sheets of newspaper into balls. Flatten them out a bit on the burning tray but leave room so air can get between the layers (as shown on Class Page 3).
6. Cut five pieces of cotton string about 10 cm long. The string represents plant roots. Place it on the newspaper. Sprinkle a handful of duff loosely around the string without covering it completely.
7. Place three layers of newspaper on top of the duff and string. This makes a "root sandwich."
8. Use a match to ignite two adjacent corners of newspaper.
9. Observe the fire.
10. After the fire goes out, describe the cotton string on line 2.
11. Shake the burned and partly burned materials into a metal trash can. Spray water on any smoldering materials. (Fire is not completely out until there is no smoke.) Dry the tray.
12. Repeat steps 4 through 11 with more strands of string and a handful of mineral soil rather than duff. Record observations on line 3.
13. Answer the questions on lines 4-5.

1. **Hypothesis:** Will **duff** or **mineral soil** protect plant roots better?	
2. How well did **duff** protect the "root"?	
3. How well did **mineral soil** protect the "root"?	
4. Was your hypothesis correct?	
5. Use the **Fire Triangle** to explain your results.	

Activity 3-7. Tinker Tree Derby

Grade levels:
X Middle
X High

Figure 11—Middle school students observe surface fire approaching their tinker tree.

What's the Point?

The arrangement of branches and needles on a tree and the arrangement of trees in a forest influence the way forest fires spread. Let's call these arrangements the "architecture" of the forest. In the ***Tinker Tree Derby***, students investigate forest architecture in relationship to fire.

The Tinker Tree Derby sets up a competition among student teams. Each team constructs a "tinker tree" from a chemistry support stand, wire rods, and newspaper. Their goal is to design a tree that can withstand fire passing beneath it (fig. 11). Such an "underburn" or low-severity surface fire was shown in the *Kinds of Fire* video in Activity 3-4. While attempting to make a fire-resistant tree, however, they must also make sure that their tinker tree has plenty of leaves to photosynthesize so the tree can grow and produce seed. A team's success is tested by experimental burning.

This activity should be done in an area with good ventilation. If you do not have a laboratory with good ventilation, you probably should ignite the Tinker Trees outdoors. Even if you do have a good laboratory, a student team may choose to build a Tinker Tree with very heavy fuels (thus forfeiting the Tinker Tree victory but getting to see a really "hot" fire). In this case, you should also ignite it outdoors.

Teacher's Map:

Objective: Given equipment and supplies, students can describe features of a tree that enable it to survive surface fire.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Technology, Library Media, Arts, Media Literacy, Health, Workplace Competencies

Duration: 40 minutes

Links to Standards[25]:

National Science Teachers' Association—Grades 5-8:

[25] See Appendix 4 for links to Montana educational standards, grades 5-8, 9-12.

cont'd.

A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations
B1) Understand properties of matter
E3) Demonstrate risks and tradeoffs in technological design
F1) Identify potential for accidents, make choices that minimize risk of injury
F3) Recognize extent, sources and challenges of natural and human-induced hazards
G3) Recognize that uncertainty, debate, further investigation, and evaluation are part of science

National Science Teachers' Association—Grades 9-12:

A2) Design and conduct experiment, use mathematics and models to explain results
A4) Use technology, mathematics, logic and previous research in investigations
F1) Identify hazards, make choices that minimize risk of injury to self and others
F3) Recognize extent, sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades 5-8:

1B) Design investigations to answer questions
1G) Synthesize observations into coherent explanations
2.1C) Understand energy transfer
2.2A) Understand biotic communities and adaptations

North American Association for Environmental Education—Grades 9-12:

1D) Apply logic to assess completeness and reliability of information
2.2D) Use interaction of matter and energy to explain environmental characteristics

Vocabulary: crown fire, foliage, ladder fuels, sapling, succession, surface fire

Materials

In this trunk...	***...where?[26]***	***You must supply***
Burning tray (4)	Main/A	Metal trash can *without liner*
Spray containers, filled with water (2)	All in *Hardware Box*, Main/A	Newspaper cut into sheets about 25 X 35 cm (1/4 of unfolded, open "page")
Safety goggles (4)		Scissors
Ashtray (1)		Wooden matches
Measuring tape		Hole punches (4)
Oven mitts (4)		One copy of Student Page 10, "Derby Rules" for each team
Fire extinguisher	Main/B	Paper towels for cleanup
"Tinker Trees" kit (has badges, rosettes)	Teacher/C	Overhead projector & markers
Support stands (4)—each has post, base, & several rod segments	Main/A	One copy of Student Page 11, "Perfect Ten?"
Class Page 3 (see Activity 3-6) illustrating newspaper setup	Both in *Visual Aids & Handouts*, Teacher/C	
Class Page 4, "Derby Results" transparency		

[26] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Preparation

This activity uses fire. Prepare the students in the same way you have done for other burning activities.

Get student helpers to set up four work stations. Each station should have

- safety goggles
- ashtray
- oven mitt
- a burning tray with a support stand on it
- 10-20 segments of wire rod
- 4 half-sheets of newspaper 25 x 35 cm
- about 20 strips of newspaper—cut into strips about 50 cm long and 5 cm wide
  Fold the newspaper strips accordion-style, then punch so a hole goes through all layers. (See the newspaper pieces in the Tinker Tree kit for examples.) **WARNING:** This step is quite time consuming. You may wish to set up an activity center and get student volunteers to work on this 2-3 days ahead of time.
- Student Page 10, Derby Rules

Equip the demonstration area with a water-filled spray container and fire extinguisher. Have the measuring tape handy. Set up an overhead projector with the Class Page 4 transparency on it.

Procedure

The Tinker Tree Derby has two phases.

In Phase 1, the **Qualifying Round**, every team underburns a tinker tree to see which design withstands surface fire with the most “foliage” (accordion-folded newspaper) left intact. It would be most logical to determine the most foliage by weight. However, that’s slow and very messy, so we recommend instead that you measure the total length of branch that has foliage remaining after the fire.

In Phase 2, the **Grand Championship**, "surviving" tinker trees from the Qualifying Round are tested to see if they can survive fire even if "tinker saplings" are growing under them. This is what typically happens in forests after many years without surface fire.

PHASE 1—QUALIFYING ROUND:

1. Explain the objective of the Tinker Tree Derby: Design a tree with foliage high enough to withstand surface fire and at the same time maximize the length of branch covered by foliage. Ask each team to follow the Derby Rules (Student Page 10) to construct a tinker tree. Give them 10-15 minutes to construct their trees.
2. On the Class Page 4 transparency, write each team’s name.
3. Burn the Tinker Trees one at a time, either by moving the class from station to station or by bringing them all to a central location. Ask a team member to light two adjacent corners of newspaper along the “long” edge (as shown on Class Page 3, shown in Activity 3-6).
4. If the tree's foliage burns completely, erase the team’s name from the transparency; they didn’t qualify. If the tree has some unburned foliage, measure and record the length of branch still covered by unburned newspaper (cm) on the Class Page 4 transparency, first column. **The entry with the greatest total branch length with foliage wins the Qualifying Round.**
5. Award **Tinker Tree Derby Champion** badges to the winning team.

PHASE 2—GRAND CHAMPIONSHIP ROUND:

1. **This phase is only for teams whose tinker trees that survived the Qualifying Round. Assign other work to teams whose trees have burned. Instructions for the Qualifying teams:**
2. Have students leave the surviving foliage intact but remove the ash of the burned surface fuels and replace it with four new layers of surface fuel. Explain that this accumulation of surface fuel is typical in forests after 50 or more years without surface fire.
3. Have each team cut two pieces of newspaper about 20 X 20 cm, crumple them up, and place one on each side of their tinker tree trunk, under the branches. These are “tinker saplings,” young trees that grow up under the old survivor. Explain that this, too, is typical of forests after many years without surface fire. It is part of the process of change after disturbance known as *succession.*
4. Have the class go to each work station and observe these finalist trees being underburned. If a tree has some unburned foliage after the fire, measure and record the length of branch still covered in the second column of the Class Page 4 transparency. **The tree that survives this fire with the greatest length of leafy branch wins the grand championship.**
5. Award **Tinker Tree Grand Champion** badges to the winning team.

Evaluation:

Middle School level: If you were starting the Tinker Tree Derby over again, how would you design your tree differently? Why?

High School level: Use Student Page 11 (“Perfect Ten?”) to rank ten Western tree species according to their fire resistance. Is any species a “Perfect Ten”?

Closure: Ask the class how people living in wildlands might use information from this activity to increase safety around their homes.

Clean up work areas and equipment, put things away.

Extension

1. Design and carry out experiments for measuring and analyzing the features that make a tinker tree resistant to damage from surface fire. Are any of the pre-fire measurements helpful in predicting how well the tree will survive surface fire?
2. Find out what professional fire scientists are up to. Visit the Internet site

   firelab.org
3. Go to one of the three “projects” there (fire behavior, fire effects, and fire chemistry). Select one researcher, read about his or her work, and make a poster describing it.

Derby Results

Class Page 4

Tinker Team	Length of Branch with Unburned Foliage (cm)	
	Qualifying Round	Finals Round

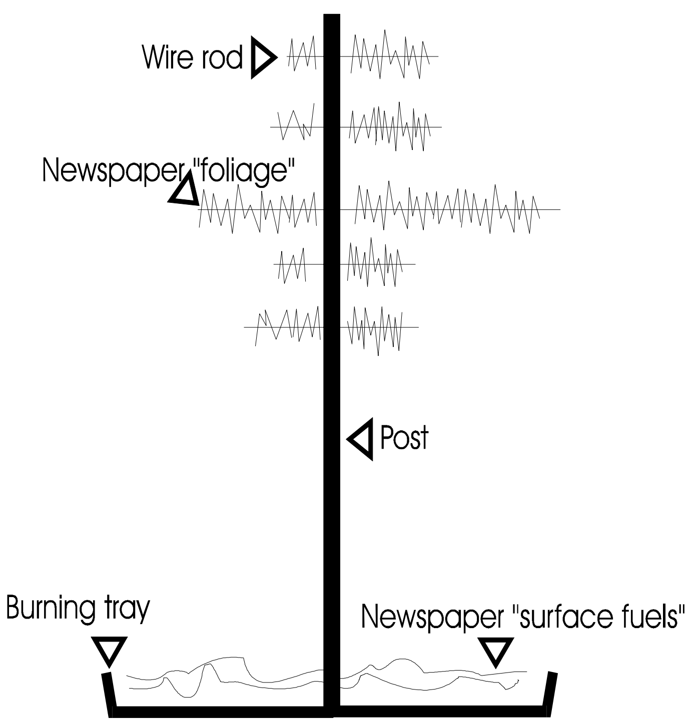
Student Page 10

Derby Rules

A tinker tree is a two-dimensional model of a tree. Its trunk is a lab support stand. Its branches are rods stuck through holes in the trunk. Its leaves are strips of newspaper.

Your Goal:

Design and build a tinker tree that does not burn when a fire passes under it. Your job could be easy—just put together a tree with no leaves. But your tree must have foliage to win the Tinker Tree Derby. You have to figure out how much foliage to use, and how to arrange it on the tree, so the tree will still survive surface fire.



Procedure:

1. Place a support stand in the center of the burning tray.
2. Crumple up two quarter-pages of newspaper. Flatten them out a bit, but make sure that some air can bet between the layers, as shown on Class Page 3.
3. Cut a line from one edge of the newspaper to the middle, then place both layers on the support stand base, with the "tinker tree" at the center.
4. Slide wire "branches" through the holes in the support stand (tree trunk).
5. Cut strips of newspaper 50 cm long and 5 cm wide. Fold them accordion-style and punch a hole through all layers of each strip. This is your tinker tree foliage. (This step may already be done for you.)
6. Slide a foliage strip onto each tinker tree branch. for short branches, you may shorten the newspaper strip.

If you use any water on your tinker tree or experimental setup before it is burned, it will be disqualified.

Student Page 11

Perfect Ten?

This table lists traits of trees that affect their ability to survive a fire. Study the traits of each species. Then, in the column at right, assign 1 to 10 points for the species' ability to survive a fire.

Species	Bark on old trees	Roots	Architecture		Foliage: How Flam-mable?	Survival Score (1-10)
			Tree's Branches	Kind of Forest		
Black cottonwood	thick	shallow	open	open, shrubby	low	
Douglas-fir	very thick	deep	open	moderate to dense	high	
Engelmann spruce	thin	shallow	low, dense	dense	medium	
Grand fir	thick	shallow	low, dense	dense	high	
Lodgepole pine	very thin	deep	high, open	open to dense	medium	
Quaking aspen	very thin	shallow	open	open	low	
Ponderosa pine	very thick	deep	high, open	open	high	
Subalpine fir	very thin	shallow	very low, dense	moderate to dense	high	
Western larch	very thick	deep	high, very open	open	low	
Whitebark pine	thin	deep	high, open	open	medium	

Is your most fire-resistant tree a "perfect ten"?

If not, what traits would make it "perfect"?

Look up your most fire-resistant tree species in the *FireWorks Notebook* or on the Internet at www.fs.fed.us/database/feis.

Does it have any ways to protect its seed from fire? Explain.

If a fire kills the crown of the tree, can it grow back? Explain.

Chapter 4.
All in One House

A biological community is "where it's at" for the science of ecology. A biological community consists of the living things in an ecosystem. Like people living together in one house (or village or town), the organisms in a community depend on one another sometimes, and sometimes compete with or even harm one another. In this topic, students learn about the nature of communities, both human and in forests. They also learn some details about one particular kind of organism, a tree; and they learn to describe and identify some Western trees.

Background

As mentioned in Chapter 1, *FireWorks* focuses on three different kinds of forest that occur in the Rocky Mountains, the Cascade Mountains, and the area between (see chapter 1, fig. 1). Each of these forest types is a community of living things that need each other to survive or compete with and eliminate each other. Three books in the *FireWorks Library* describe these kinds of forest in detail. *Fire in the Forest*, a picture book with beautiful paintings, describes the story of fire and lodgepole pine. *Graced by Pines* is a popular science book about the huge, ancient ponderosa pines that used to dominate forests all over the West in centuries past. *Made for Each Other*, another popular science book, describes the fascinating relationship between whitebark pine ecosystems and Clark's nutcrackers, the birds that feed on and plant its seeds.

Chapter Goals

1. Increase students' understanding
   - of the nature of human and biological communities
   - that there are many kinds of living things in an ecosystem
   - that observations can be used to identify organisms
2. Increase students' ability to
   - make observations
   - classify information
   - apply new information
   - work together to solve problems
   - describe a concept they are familiar with
   - use a familiar concept in a new way

Chapter Activities

Activity 4-1. What's a Community?	(P,E)
Activity 4-2. Tree Portrait, Plant Portrait	(M)
Activity 4-3. For Primary: Mystery Trees	(P)
Activity 4-4. For Elementary and Middle School: Mystery Trees	(E,M)

Activity 4-1. What's a Community?

Grade levels:
X Primary
X Elementary

What's the Point?

Students describe what they know about human communities and use this knowledge to explore the concept of a biological community. A *biological community* consists of all the organisms in a particular area that are bound together by food webs and other relationships. A community differs from an *ecosystem* because an ecosystem contains non-living things as well. Here is a definition of an *ecosystem*: a biological community and its non-living environment.

After the discussion, students decorate the classroom to depict three different forest communities (dominated by ponderosa pine, lodgepole pine, and whitebark pine) and some of their inhabitants.

Teacher's Map:

Objective(s): Students can list members of human and biological communities, and describe energy relationships in these communities

Subjects: Science, Reading, Speaking and Listening, Library Media

Duration: 30 minutes

Links to Standards[27]:

National Science Teachers' Association—Grades K-4:
A1) Ask a question about the environment
A4) Use data to construct an explanation
C1) Identify needs of various organisms
D1) Identify properties of earth materials
D3) Understand that the sun provides light and heat to earth

National Science Teachers' Association—Grades 5-8:
B3) Understand that energy is transferred in many ways
C4) Recognize that ability to obtain and use resources, grow, reproduce… are essential for life

North American Association for Environmental Education—Grades K-4:
0A) Identify basic kinds of habitat and plants and animals living there
0B) Produce images of the area at the beginning of European settlement
1C) Collect information about environment
2.2A) Understand similarities and differences among variety of organisms, habitat concept
2.2C) Understand basic ways organisms are related to environment and other organisms
2.2D) Know that living things need energy to live and grow
2.3E) Recognize that change is a normal part of individual and societal life….

North American Association for Environmental Education—Grades 5-8:
0A) Classify local ecosystems. Create food webs
1E) Classify and order data, organize and display information
2.2A) Understand biotic communities and adaptations
2.2D) Understand how energy and matter flow in environment

[27] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

Vocabulary: animal, community, ecologist, ecosystem, energy, plant, species

Materials

In this trunk...	*...where?*[28]	*You must supply*
Feltboard Backgrounds (3)	Teacher/C	Tacks or tape to hang up feltboard backgrounds
Feltboard Notebooks (3): *Roaring Tree-Top Fires* *Creepy Crawly Fires* *Rollercoaster Fires*	Teacher/C	Art materials & supplies
FireWorks Library	Main/B	

Preparation

Remove the background displays for the feltboards from the *Teacher Box*. Hang them up in your classroom, preferably where they can be on display while you use *FireWorks*. The three forest types that you will study occur at progressively higher elevations. Ponderosa pine is at the lowest elevations, along valley bottoms and on warm lower slopes. Whitebark pine occurs on ridges and near mountain tops. Lodgepole pine grows in the middle but overlaps with both of the other species. Try to depict that in your displays by locating the three feltboards next to each other, with lodgepole slightly higher than ponderosa and whitebark even higher. Another way to do it would be to have a student volunteer sketch a mountain slope and label the drawing to show where the different kinds of forest occur.

Plan student work teams and assignments. Three teams (2 or more students each) will assemble the feltboards. If you wish to display some of the books in the *FireWorks Library* in your classroom and have students borrow them while you are using the curriculum, ask another team to "assemble" the Library. If this leaves some students without tasks, assign them to examine one book from the *FireWorks Library* and prepare a poster for the classroom depicting something they learn in it.

Procedure

1. Give each feltboard team a feltboard notebook (either *Roaring Tree-Top Fires*, *Creepy Crawly Fires*, or *Rollercoaster Fires*) and show them which feltboard background to work on. Ask them to assemble the feltboards to look like the photo near the front of each notebook. Ask them to label each feltboard with the laminated sign in the looseleaf notebook and to find out, by reading or by asking someone who can read, what the name of the forest is and where it occurs (high in the mountains, near valley bottoms, or in between).
2. Ask the Library team, if you are using one, to arrange the *FireWorks Library* books.
3. If some students are making posters, arrange for them to borrow books from the Library.
4. Assign some seat work for teams who finish while others are still working.
5. When the classroom is decorated, ask students to be seated for discussion.

[28] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

GUIDED DISCUSSION—What's a Community?

6. **For Primary Students,** hold this discussion as a "circle time" or "storytelling time." **For Elementary Students,** record information from students in a chart on the board or on a flipchart: Make three columns—"Community," "Human Community," and "Forest Community." During the discussion, fill in this chart with concepts like those in table 9.
7. Ask if anyone can explain what a community of people is. You could ask a student to find a definition in the dictionary.
8. Ask for descriptions and examples of human communities. Write community-related concepts, such as *inhabitants, place, birth, death, having babies, obtain energy, change,* in the left column of the blackboard chart. Write students' examples from human communities in the middle column.
9. Ask what a forest community might be. As the discussion develops, write examples in the right column.
10. Explain that the study of living things and their environment is the work of *ecologists.*

Evaluation: Name one plant and one animal that lives in a forest community. Where does each of them get energy for life?

Closure: Ask each feltboard team to tell the class the name of their forest and where it occurs. **For Elementary Students:** Point out that forests are much more complicated than the feltboards show. Moist places, for instance (in creek beds and on north slopes), have different kinds of trees and wildlife. Examine and discuss the moist sites shown on the feltboards.

Table 9—Similarities between human communities and forest communities. Use for guided discussion in Activity 4-1.

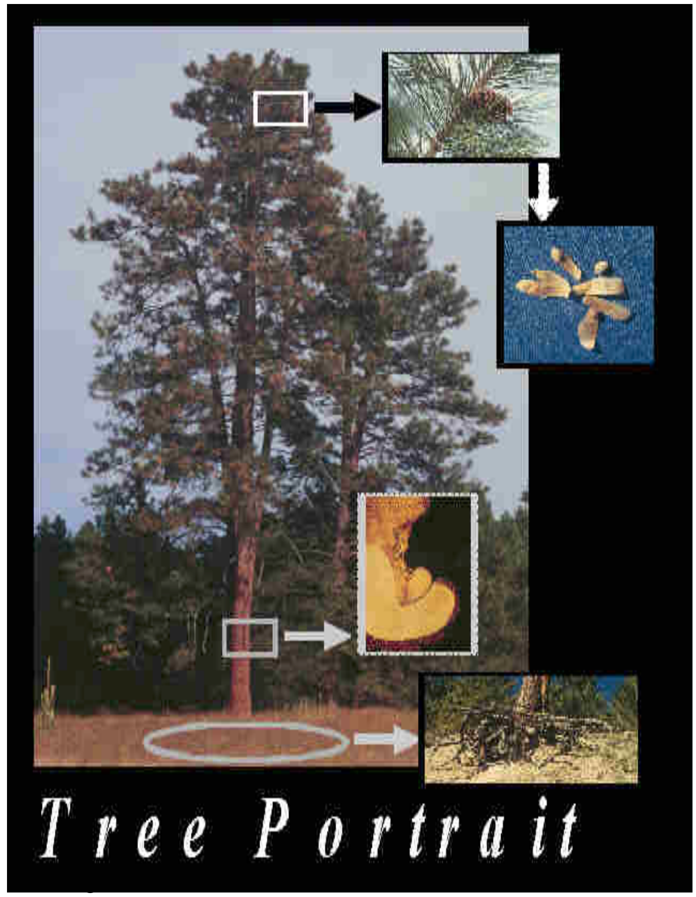
Community	Human Community	Forest Community
Where? a particular place—any size, shape	city, town, school, church, club, family, class	mountainside, valley, meadow, huge wilderness
Who lives there?	people	hundreds of kinds of plants, animals, fungi, and other organisms
	In both human communities and forests, members get into the community through birth and moving in; they leave it by dying or by moving out.	
All need energy. How do they live?	They have to have food. Most adults grow their own food or work for food. Human communities also use fossil fuels, water, wind, and sunlight for energy.	Plants use sunlight energy directly. Animals obtain energy from plants or by eating other animals. Hundreds of species, including many fungi, decompose ("recycle") dead material so its nutrients can be used again.
Change	Human communities change constantly—people are born, grow up, and die. Buildings are built and torn down. Roads and businesses change. Storms, fires, and floods change the community.	Forests too change constantly. Plants grow and die, animals come and go. Storms, floods, and fires cause some dramatic changes. Other changes are so slow that it is hard for humans to notice them.

Extensions

1. All of us use products from forest communities. Try making “Sawdust Clay,” one of the Carpentry Art projects described in *Exploring Wood* (in the *Teacher Box*), p. 17.
2. Make “Arm Tree Prints” or “Paper Trees,” both described in *Exploring Wood* (in the *Teacher Box*), pp. 24-25.
3. Go on a “Tree Safari,” observing trees in the neighborhood of your school. Ideas about preparing for your safari, what to do on the way, and what to do when you return are in *Exploring Wood* (in the *Teacher Box*), p. 30.

Activity 4-2. Tree Portrait, Plant Portrait

Grade levels:
X Middle



What's the Point?

This activity uses a poster (fig. 12), a glossary (Student Page 12), and a role-playing exercise to help students learn about a tree's structure and living parts. Students identify parts of trees, especially those that are vulnerable to injury from fire. The tree characteristics studied in this activity are the subject of the experiments in Chapter 6. Tough Plants, Tough Animals.

For Elementary Students, it may not be necessary to use the poster and reading tasks in this activity. You can go immediately to the construction of the living tree model described under **Conclusion.**

Teacher's Map:

Objective: Given a drawing of a tree, students can identify where its growing points are and what areas contain mostly dead cells

Subjects: Science, Reading, Speaking and Listening, Arts

Duration: 25 minutes

Links to Standards[29]:

National Science Teachers' Association—Grades K-4:

C1) Identify needs of various organisms
C2) Identify structures of various organisms and the needs they serve

National Science Teachers' Association—Grades 5-8:

B4) Identify ways in which energy moves in and out of a system
C1) Describe structure and function in a living system
C2) understand cell functions
C4) Recognize that ability to obtain and use resources, grow, reproduce… are essential for life
D3) Describe interaction of organisms with atmosphere

[29] See Appendix 4 for links to Montana educational standards, grades K-4 and 5-8.

cont'd.

North American Association for Environmental Education—Grades K-4:
2.2B) Understand that plants and animals have different characteristics, and many are inherited
2.2C) Understand basic ways organisms are related to environment and other organisms
2.2D) Know that living things need energy to live and grow
North American Association for Environmental Education—Grades 5-8:
2.1C) Understand energy transfer
2.2A) Understand biotic communities and adaptations
2.2D) Understand how energy and matter flow in the environment

Vocabulary: botanist, bud, cambium, growing point, phloem, root, xylem, and other terms in the Tree Parts Glossary (Student Page 12)

Materials

In this trunk...	***...where?***[30]	***You must supply***
Tree Portrait poster	Main/B	Sticky-tack or tape
Ancient Tree poster	Main/B	Copy of *Tree Parts Glossary*, Student Page 12, for each student
"Fuels... Tree & Soil Parts, and Fire Targets (arrows)" kit	Teacher/C	

Procedure

1. Display the *Tree Portrait* (a composite photo of ponderosa pine) at the front of the classroom. Explain: Conifers, like this one, have needle-like leaves rather than broad, flat leaves. Most conifers (but not all) keep their needles through the winter, so some people call them "evergreens." Some trees have leaves that fall off each autumn, called "deciduous trees" from a Latin word meaning "to fall."
2. Distribute the *Tree & Soil Parts* labels and the *Fire Arrows* labels among students.
3. Give a copy of the *Tree Parts glossary* (Student Page 12) to each student.
4. Ask students to prepare: The students who received *Tree* and *Soil Parts* labels should look up their terms in the glossary, read the description there, and prepare to describe it to the class. The students who received *Fire Arrows* labels should read the glossary and circle the name of each tree part listed there that is alive (that is, has living cells).
5. When all students are prepared, ask each student with a *Tree or Soil Part* to locate that part on the *Tree Portrait,* tape the label onto the *Portrait* in an appropriate place, and explain to the class what that part is. Have students attach the *cambium, bark, and wood* labels to the *Ancient Tree* poster, so the relationship between these three parts of the tree trunk is clear. **One point that student presenters may miss is that "buds," as used by botanists, refers not only to flower buds but also to growing points throughout the plant, anywhere that the plant can sprout new tissues. It is the *growing-point bud*, not the *flower bud*, that we study in *FireWorks*.** The three *bud* labels should point to a branch tip, the tree's top, and the root tips.

[30] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

6. Ask each student with a *Fire Arrow* label to tape it onto a *Tree Part* that is alive, that is, an area that has living cells. These are the locations where fire does the most damage to trees. Fire arrows should point to needles, buds, cambium, seeds, and roots.
7. Explain or discuss the following:
   - The *Fire Arrows* identify the parts of the tree that can be killed by fire.
   - Unless a fire kills many of the living cells of a tree, the tree will survive
   - If a tree is killed by fire but its seed survives, the species will probably be present in the new forest that develops after the fire.
   - Duff and mineral soil are not alive. However, if the duff is dry enough to burn, or if the fire releases a lot of heat, the tree roots growing in duff and soil may be killed, which could kill the tree.
8. Explain that this kind of information is used by *botanists.*

Evaluation: Name one part of a tree that has lots of living cells, so heat from fires can damage it a lot.

Closure: This closure is quite long; it will require 15-20 minutes. But it's a very active way to learn about tree structure and function. The students become a living model of a tree. The directions here are written for a class of about 25, but you can adjust the numbers so everyone participates.

1. Ask the tallest two students to stand back-to-back, with their arms stretched high and reaching slightly outward. Explain: These students' arms are the tree's branches and leaves, which must gather energy from sunlight and turn it into nutrients that all living cells in the tree can use—a process called *photosynthesis*; their bodies are the tree's *hearatwood,* which supports the tree but has no living cells. Ask the students to pantomime photosynthesis by wiggling their fingers. If you have a sturdy stool for these students to stand on, the activity will work better.
2. Ask 4-6 students to stand in a circle around the tree's heartwood, front-to-back, with their right sides all to the inside and their left sides to the outside. Explain that these students are the outer wood of the tree; *sapwood,* a mixture of living and nonliving cells, is on their right sides, close to the center. More living cells are on their left sides, close to the bark; these are *xylem* cells. Xylem and sapwood share the job of lifting water and dissolved minerals from the roots to the branches of the tree. Ask the students to pantomime this work.
3. Ask 4 more students to stand shoulder-to-shoulder in a circle around the sapwood and xylem, facing out. Explain that these students represent the living cells that carry nutrients throughout the tree—from leaves to branches, stem, and roots, in any direction that nutrients need to be delivered. Ask them to pantomime this work. (Explain that these are *phloem* cells.) We call the phloem cells, the water-lifting cells of the xylem, and the cells that form these two layers the tree's *cambium*.
4. Ask 5 more students to stand shoulder-to-shoulder outside the phloem cells, facing in. Explain that they represent the tree's bark, which contains mostly dead cells and protects the cambium from injury. Ask them to look very strong to show their job.
5. Ask the remaining students to lie on the floor—feet at the base of the tree, heads and arms spread out along the ground. Explain that they are the roots, with their tips and tiny hairs growing out, searching for water. They can spread their hair out on the floor and wiggle their fingertips to show their work.

6. Ask all the students to do their work at once. Now ask them to add a sound effect that fits their role. They will see that a living tree is a very busy mixture of living and dead parts, all with important work to do.

Extensions

1. Write and illustrate a booklet about the life of a tree for First Grades students. Use a book in your classroom or the school library to find a poem or song about trees; create a dance or drawing to illustrate it.[31]
2. Tour your school's neighborhood to "Meet the Trees," using Activity 2 in the *Woodsy Owl Activity Guide*, pp. 14-15 (in the *Teacher Box*).

[31] Thanks to "Investigating Your Environment," from the U.S.D.A. Forest Service, for these activities.

Student Page 12

Tree Parts Glossary

bark: the outside covering on a tree's trunk and branches, the tree's "skin"

branch: limb of a tree or shrub that grows out from the trunk.

broad-leafed: the kind of tree that has wide, flat leaves. Most broad-leafed trees in our area drop their leaves in the fall.

bud: There are two kinds of buds. One kind is the flower bud. That's the flower before it opens. The second kind is the starting point for plant growth. That's the kind of bud we talk about in *FireWorks*. Sometimes people call this kind of bud the ***meristem***. These buds grow at the tips of tree and shrub branches, at the tips of roots, and sometimes in other places. Buds have lots of living cells.

cambium: a layer of living cells under a tree's bark. This layer of a tree's trunk, branches, and roots produces the *xylem* and *phloem*, the cell layers that carry water and nutrients between roots and leaves.

cell: the smallest living part of a plant that can make new living parts

cone: the "package" in which a conifer stores its seeds

conifer: the kind of tree that stores its seeds in cones

crown: a tree's top, where most of the buds and leaves are

deciduous: able to shed its leaves in the fall or when it becomes very dry

duff: the top layer of soil in a forest. Duff is made up of dead, rotting plant parts.

leaf: the green part of a plant that uses sunlight, water, and minerals to provide energy to the tree. Leaves can be wide and as flat as paper, or they can be shaped like needles or scales. The leaves of most deciduous plants live only one year.

litter: the layer of dead material, not yet rotted, at the top of the forest floor.

mineral soil: soil that has very little dead plant material in it. In a forest, mineral soil is usually below the duff.

needle: leaf of a conifer. Needles contain very busy living cells. Most needles live three years or longer, then fall off.

root: the part of a plant that lives underground. Roots collect water and minerals from the soil and carry them into the stem of the plant. Roots also support the plant. Roots have living cells at their tips and under their "bark."

seed: a very tiny, living plant—just waiting to grow—and its protective covering, filled with nutrients. Some seeds have fluffy or scaly "wings" to catch the wind as they fall. The seed needs just the right temperature, water, sunlight, and soil conditions before it can grow.

trunk: the part of a tree that connects leaves and branches in the air to roots in the ground. People often call the trunk of a small tree its "stem."

wood: the strong material inside a tree's bark and cambium that supports the tree and helps carry water from roots to leaves. Wood consists mainly of cells produced in past years that have died and become hollow.

Activity 4-3. For Primary: Mystery Trees

Grade level:
X Primary

What's the Point?

Students have already learned about three kinds of forest—those dominated by ponderosa pine, lodgepole pine, and whitebark pine. In this activity, students examine specimens from the three species (fig. 13). Then the teacher or an older student reads a story to them describing the life history of each species. Students try to verify facts reported in the story with the specimens they have studied.

Figure 13—Elementary students examine plant specimens that represent their mystery tree.

Teacher's Map:

Objectives: Students can use a set of specimens from a tree species to illustrate a narrated story describing the life history of that species.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Arts, Workplace Competencies

Duration: one 15-minute group session and three 15-minute story sessions

Links to Standards[32]:

National Science Teachers' Association—Grades K-4:

B1) Understand size, weight, shape, color, temperature….
C2) Identify structures of various organisms and the needs they serve

North American Association for Environmental Education—Grades K-4:

0A) Identify basic kinds of habitat and plants and animals living there
1C) Collect information about environment
1D) Understand need for reliable information. Judge merits of information.
2.2A) Understand similarities and differences among variety of organisms. Understand habitat.
2.2B) Understand that plants and animals have different characteristics and many are inherited.

Vocabulary: botanist, branch, crown, ecologist, forester, needle, reproduction, seed, tree, trunk

[32] See Appendix 4 for links to Montana educational standards, grades K-4.

Materials

In this Trunk…	*… where?*[33]
Tree trunk sections with bark (3 pine species)	Main/A
Tree cones (3 pine species)	*Tree Cones Box*, Main/A
15-cm rulers (6)	*Hardware Box*, Main/A
Mystery Trees Box: photo collecdtions (3 pine species) laminated branches (3)[34] tree name labels (3)	Main/B
FireWorks Notebook	Teacher/C

Preparation

Find the tree specimens for the three pine species, marked with the code letters below:

lodgepole pine	E
ponderosa pine	O
whitebark pine	J

Set up three work stations, one for each species. At each station, place two rulers, the laminated species name label, tree trunk section, photo collection, foliage sample, and cones for one species. Separate the photos so they can be handled separately, but don't lose track of the ring and label that they are packaged with.

Procedure

1. Divide the class into three "Tree Teams" and assign each group to a station.
2. Explain: The kind of information used in this activity is needed by *botanists, foresters,* and *ecologists*.
3. Explain: At the work stations, the students will have a short time to look at the specimens, feel them, and pass them around the group. Then, as the teacher reads the story of their species, that team will have a chance to illustrate the story by showing the specimens to the rest of the class.
4. Select one of the three species to read about, and find its life story in the *FireWorks Notebook.*
5. After 7-8 minutes or when students have finished examining the specimens, ask them to gather in a circle. Tell them which species you are going to read about, and let Tree Team bring their tree specimens and rulers to the circle.
6. Read the life history of the species from the *FireWorks Notebook*. Encourage that species' Tree Team to raise their hands when they can illustrate a fact from the story with one of their specimens. Then let them show the specimen and pass it to the other students. When the story includes a measurement, such as how long the needles are, ask the Tree Team to measure their specimen to see if it matches the reported size.
7. After finishing the story, ask the Tree Team to put their specimens away.
8. At another time in the next day or two, repeat Steps 4-6 for the other two pine species.

[33] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).
[34] If possible, cut fresh branches from the three pine species and attach tree-code labels to them. Use the plastic-coated branch specimens for any species that you can't get live branches for.

Evaluation: Draw a picture of one of these three tree species: ponderosa pine, lodgepole pine, or whitebark pine. Circle three things on this tree that are different from the other species and explain how they are different.

Closure: Read the life story of one of the other plants in the *FireWorks Notebook.* Ask students to discuss similarities and differences between the trees they have studied and this other species.
Reassemble the photos for each tree species. Put materials away.

Extensions

1. Visit a forested area near your school. Use the *Rocky Mountain Tree Finder* in the *FireWorks Library* to identify the mystery tree species and other tree species.
2. Try one of the art projects described in Exploring Wood (in the Teacher Box), pp. 26-29: autumn leaf prints, leaf and bark rubbings, sawdust pictures, evergreen branch painting, and twig frames.
3. Ask students to find out the states in which the "Mystery tree" species occur, using use the U.S. Department of Agriculture's "plants" database, on the Internet at plants.usda.gov

Activity 4-4. For Elementary and Middle School: Mystery Trees

Grade levels:
X Elementary
X Middle

What's the Point?

In this activity, students describe and learn to identify nine tree species that occur in the Rocky Mountains and intermountain area. First, each of nine teams describes a single tree species by studying specimens and photos; teams are not to share information on their species with others. Then each team receives a "mystery tree," one of the species described by other teams, and a copy of all teams' observations. Students use the observations of other teams to identify their "mystery tree." The two parts of the activity can be completed in two separate class sessions. In a third step, for the Middle School level only, students learn about the habitat requirements of their mystery trees and use a feltboard to develop a model of a forest that shows where species co-occur, forming specific forest communities.

The tree specimens in *FireWorks* are permanently labeled with a code letter. The key linking letter codes with species names is below. **HINT for remembering species codes:** Take the third letter of the species' common name ("a" for black cottonwood), then go to the next letter of the alphabet ("b"). That's the code letter—except that the code letter for quaking aspen starts after the fourth letter of its common name, "k."

black cottonwood	B
Douglas-fir	V
Engelmann spruce	H
lodgepole pine	E
ponderosa pine	O
quaking aspen	L
subalpine fir	C
western larch	T
whitebark pine	J

Teacher's Map:

Objective: Given biological specimens, students can discover ways to distinguish species and use a drawing to show others how to distinguish them.

Subjects: Science, Mathematics, Reading, Speaking and Listening, Arts, Workplace Competencies

Duration: **Elementary level,** 40 minutes, best done in two 20-minute segments; **Middle level,** 60 minutes, best done in 3 20-minute segments

Links to Standards[35]:

National Science Teachers' Association—Grades K-4:

A2) Plan and conduct a simple investigation
A3) Use simple equipment and tools to gather information
A4) Use data to construct an explanation
B1) Understand size, weight, shape, color, temperature…
C2) Identify structures of various organisms and the needs they serve

National Science Teachers' Association—Grades 5-8:

A6) Use mathematics in science
C6) Understand nature of populations and classification
G2) Understand that science results must be communicated

North American Association for Environmental Education—Grades K-4:

0A) Identify basic kinds of habitat and plants and animals living there
1C) Collect information about environment
1E) Describe data, organize information to search for patterns
2.2A) Understand similarities and differences among variety of organisms. Understand habitat
2.2B) Understand that plants and animals have different characteristics and many are inherited

North American Association for Environmental Education—Grades 5-8:

1E) Classify and order data, organize and display information
1G) Synthesize observations into coherent explanations

Vocabulary: aspect, bark, botanist, branch, bud, cone, ecologist, elevation, flower, forester, habitat, leaf, moisture requirement, needle, seed

Materials

In this Trunk…	***… where?[36]***	***You must supply***
Tree trunk sections with bark (9)	Main/A	1 copy, Species Assignments (Class Page 5)
Tree Cones Box	Main/A	9 copies, *This Tree's No Mystery* (Student Page 13)
Rulers, 15-cm (9)	*Hardware Box,* Main/A	Large grocery bags (9)
Mystery Trees Box: photo collections (9) laminated branches (9) tree name labels (9) 1-letter labels (9)	Main/B	
FireWorks Notebook pages for the 9 species	Teacher/C	
For Middle School level: Feltboard Background for Ponderosa Pine Forest *Mystery Trees Box* Straight pins	 Teacher/C Main/B *Hardware Box,* Main/A	**For Middle School level:** overhead projector 9 copies of *Tree Habitat* (Student Page 14)

[35] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

[36] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Preparation

Tie a laminated tree code label (the 1-letter squares) onto each grocery bag. Into each bag place the tree trunk section, branch specimen, cone collection, and photo collection for that species. Also put in the laminated tree species name and any additional specimens with that label.

For Middle School level: Find the felt background for the Ponderosa Pine Forest. Tack it up in your classroom, preferably near a table where the Mystery Trees specimens can be displayed at the end of this activity. From the Feltboard Kit for Mystery Trees, attach the pieces representing Sasquatch Peak (brown) and Footprint Creek (blue) to the feltboard (fig. 14). Attach the "elevation bar" along the right-hand edge of the feltboard. Attach the "moisture bar" along the bottom. Attach the two transparent labels that indicate site moisture diagonally between the creek and the horizon. After placing these pieces on the feltboard, secure them with straight pins.

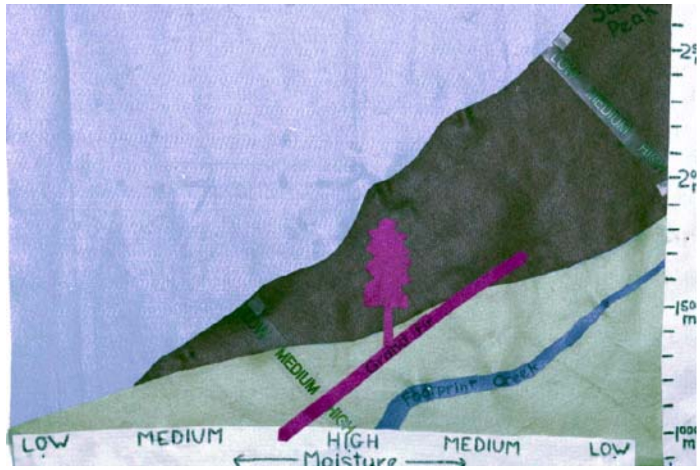


Figure 14—Setup of feltboard for Middle School students working on mystery trees.

Procedure

PHASE 1:

1. Explain to students: Each team will describe a tree species and then use the observations of their classmates to identify a "mystery tree" species. Explain that only 9 species are included in this activity, but there are probably 20 or more native trees in the forests of your area. Explain that this kind of information is gathered and used by *botanists, ecologists*, and *foresters.*
2. Designate 9 areas or tables in the classroom as "observation sites." Assign a team of students to work at each site.
3. Give the students at each observation site a ruler, a data sheet (Student Page 13), and a grocery bag with their collection inside. On your copy of the ***Species Assignment*** sheet (Class Page 5), note the species assigned to each group. You will use this list later to avoid giving any team the species they just described as their "mystery tree."
4. Ask each team to complete the data sheet describing their species. Ask them to write neatly, so other students will be able to read their observations. When they have completed the data sheet, they should turn it over and draw a portrait of their tree. Then they should see if their species is in the *FireWorks Notebook.* If it is, find two interesting things about it to share with the class. Then they can do other seat work but *not* wander around looking at other specimens.
5. When each team finishes its work, visit their observation site. Pick up the species name label. Check the data sheet for completeness and accuracy. Ask the team to revise it, if necessary, so it will be useful for other students in identifying mystery trees.

6. After a team's data sheet is completed satisfactorily, ask them to place their collection back in the grocery bag and return it to you.

   This is a good time for a break.

PHASE 2:

7. Make nine photocopies of each data sheet; collate them so each team will have a complete collection.
8. Distribute the grocery bags of specimens again. Use your notes on the *Species Assignment Sheet* (Class Page 5) to avoid giving any team the species they identified in the first phase.
9. Explain: This bag contains the team's "mystery tree." Each team should identify their mystery tree by referring to the observations of their classmates on the photocopied data sheets. They will have 15 minutes to complete their task. They may want to separate the photocopied data sheets so they can read the pages individually.
10. After 15 minutes, ask each team to report the identity of their mystery tree to the class and explain what clues they used to figure it out. Ask the students who prepared the original data sheet to verify or correct the identification and describe two interesting things about this tree species from the *FireWorks Notebook.*

PHASE 3—FOR MIDDLE SCHOOL LEVEL. (Elementary level, go to "Evaluation.")

This is another good time for a break.

11. Give each team a copy of the *Tree Habitat* page (Student Page 14), the color-coded felt tree outline for their species, and the long felt arrow for their species.
12. Explain: Each kind of tree has habitat where it grows best, and also areas where it cannot grow at all. Elevation, aspect, soil, and moisture influence tree habitat a lot. Some trees can't grow at low elevations because summers are too hot and dry. Some can't grow on ridge tops because the summers are too short or the soil too shallow. Some can grow only near creeks because they need so much water. Some can grow far from water on north-facing slopes but not on south-facing slopes, because the soil dries out too fast.
13. Ask students to use the data sheet to figure out where to position their arrow on the feltboard to show the area in the fictitious Bigfoot National Forest where their species is most common. Use the felt arrow and outline for grand fir to illustrate (fig. 14).
14. Ask students to attach the felt arrow for their species to the feltboard. After the arrows are attached, have them attach the tree outlines too. (An alternative activity is to have the students draw the tree outlines themselves and outline to match the colored arrow.) The trees look best when the tree base is placed on top of the arrow for that species (fig. 15).
15. Explain to students: The feltboard shows how complicated a typical forest is in our area. As they continue with *FireWorks* activities, they will focus on just three kinds of forest: ponderosa pine/Douglas-fir, lodgepole pine/subalpine fir, and whitebark pine/subalpine fir.
16. Ask students to place the three felt pointer-labels for the three forest types on the feltboard (fig. 15). These are the most common tree species in each forest type; use the feltboard to discuss other species likely to occur there. For example, western larch and Douglas-fir can occur in lodgepole pine/subalpine fir forest; lodgepole pine commonly occurs together with whitebark pine; if you move from a ponderosa pine/Douglas-fir forest to a place just slightly more moist, you are likely to find western larch there.

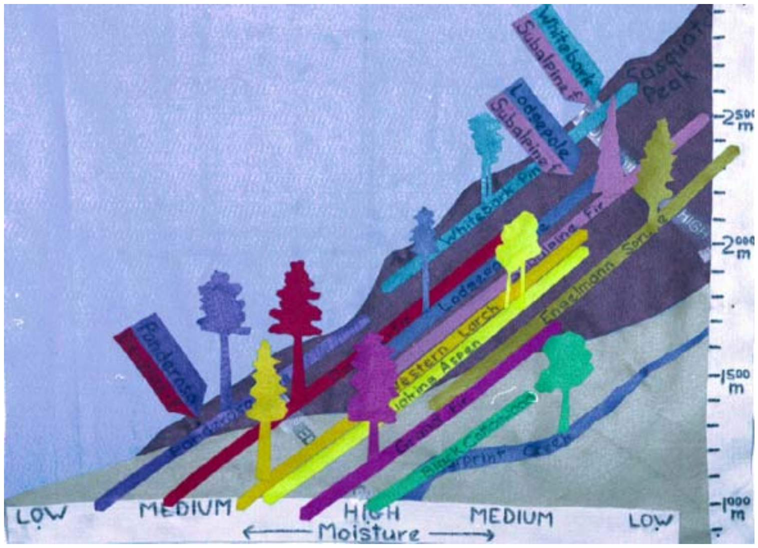


Figure 15—Feltboard display completed by Middle School students at end of "Mystery Trees "activity.

Evaluation:

1. Draw a picture and label it so that a first-grader could tell the difference between two of the tree species in this activity. If you can "borrow" a first-grader, try out your explanation with him or her. Then revise it to make it better.
2. **For Middle School students:** Suppose you own some forest land that has lots of lodgepole pine on it. What species might be likely to grow there if it were a wetter location? if it were hotter in the summer? if it were higher in elevation?

Closure: Return the tree species labels to the student teams. Have them display their specimens, with names, in the classroom.

Extensions

1. Develop a dichotomous key for identifying these tree species. For a bigger challenge, add other plants from the *FireWorks Notebook*; many of these are represented by specimens in the *Buried Treasures* Box.
2. Visit a forest near your school. Use the *Field Guide to Forest Plants of northern Idaho* in the *FireWorks Library,* or a dichotomous key for plants in your geographic area, to plants.
3. Look up or ask local experts to learn the range of these species in their area and construct a table like Student Page 14 for their local area, then illustrate what they learn on a graph.

Class Page 5

Species Assignments for *Mystery Trees*

Species Name	Code	Students or Team Name
black cottonwood	B	______________________
Douglas-fir	V	______________________
Engelmann spruce	H	______________________
lodgepole pine	E	______________________
ponderosa pine	O	______________________
quaking aspen	L	______________________
subalpine fir	C	______________________
western larch	T	______________________
whitebark pine	J	______________________

Student Page 13

This Tree's No Mystery

Tree Species: ____

Team Members____

1. Are the leaves broad and flat (more than 1 cm wide) or long and narrow (less than ½ cm wide)?____________________________
   Remember that a *conifer* needle is a kind of *leaf.*

2. How long and how wide are the leaves? ______ cm long by ______ cm wide

3. Do the leaves grow in bundles, or do they grow right out of the stem? ________________________

4. Measure the biggest bud—not the **flower** bud, but the starting point for next year's growth. How wide is it? ____________________ cm

5. How long is the biggest bud? ________________________ cm

6. Do the buds have pointy or rounded tips? ____________________

7. Does the tree produce seeds in flowers or cones? ______________________

8. Describe the flowers, seeds, or cones — size, color, how they look: ______________ ____________________________

   ____

9. How thick is the bark? ________________________ cm

10. Describe the bark: ____

12. Does the tree's crown look "open"? Can you see light through its branches? ___________________________

13. Do the branches reach all the way to the ground? _________________

14. Describe other things that might help identify your tree:

Student Page 14 Tree Habitat

Here is information about the trees that grow on Sasquatch Peak and along Footprint Creek in the Bigfoot National Forest**,** which is somewhere in the Western states. The valley bottom, along Footprint Creek, is at 900 m elevation. The summit of Sasquatch Peak is at 3000 m.

Tree Species	Elevations where this species is most common (m above sea level)	Need for moisture
Black cottonwood	900-1400	high
Douglas-fir	900-2000	low to medium
Engelmann spruce	1300-2400	medium to high
Grand fir	900-1700	medium to high
Lodgepole pine	1500-2300	low to medium
Quaking aspen	900-1900	medium to high
Ponderosa pine	900-1700	low
Subalpine fir	1400-2500	medium
Western larch	900-2000	medium
Whitebark pine	1800-2600	low

Chapter 5.
Fire History[37]

People can learn about the history of a forest—and their own history—from looking at tree cross-sections. In this activity, students use fire-scarred "tree cookies" to describe the fire history of two kinds of forest—ponderosa pine and lodgepole pine. They link events in their personal history and in world history with events in the forest.

Background

Read p. 21 in Brian Capon's *Plant Survival* (in the *FireWorks Library*) for a description of tree ring formation. Alex Shigo's *Tree Basics* describes this topic with excellent photos.

Chapter Goals

1. To increase student skills in
   - observing
   - recording data
   - describing and interpreting data mathematically
   - working in teams
   - communicating observations
   - finding connections between ideas
2. To increase student understanding
   - that forests have a history, just as humans do
   - that fire is an important part of the history of most forests in our geographic area
   - that different kinds of forests have different fire histories
   - that forest history is often intertwined with human history

Chapter Activities

Activity 5-1. For Elementary: Tree Stories	(E)
Activity 5-2. For Middle and High School: Tree Stories	(M,H)
Activity 5-3. Repeating the Story?	(M,H)

[37] Adapted from *Getting to Know Wildland Fire*. See Appendix 3 for more information.

Activity 5-1. For Elementary: Tree Stories

Grade level:
X Elementary

What's the Point?

Scars on trees and tree growth rings show that fire has been a part of the history of most Western forests for thousands of years, but different kinds of forest have different patterns of fire history. In this activity, students learn about growth rings and how scars form on trees. Then they learn that many trees survive some fires, especially in ponderosa pine forests.

Teacher's Map:

Objective(s): Students can describe how tree growth rings are formed. Given a cross-section of a tree trunk (or a photographed cross-section), students can estimate the tree's age and determine how many fires have scarred it.

Subjects: Science, Mathematics, Reading, Speaking and Listening, Social Studies, Library Media, Workplace Competencies

Duration: 40 minutes

Links to Standards[38]:

National Science Teachers' Association—Grades K-4:
A1) Ask a question about the environment
A2) Plan and conduct simple investigation
A3) Use simple equipment and tools to gather information
A4) Use data to construct an explanation
A5) Communicate investigations and explanations
C2) Identify structures of various organisms and the needs they served
E4) Understand that scientists and engineers often work in teams to solve problems
F5) Understand that changes in environments can be slow or rapid, rate has consequences

National Science Teachers' Association—Grades 5-8:
A1) Identify questions that can be answered scientifically
A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations
A6) Use mathematics in science
C1) Describe structure and function in a living system
C4) Recognize that ability to obtain and use resources, grow, reproduce, and maintain internal stability are essential for life
F3) Recognize sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades K-4:
0C) Describe aspects of the environment that change on a temporal basis
1A) Identify basic kinds of habitat and plants and animals living there
1B) Produce images of the area at the beginning or European settlement
1C) Collect information about environment
1D) Understand need for reliable information. Judge merits of information
2.2A) Understand similarities and differences among variety of organisms. Understand habitat

[38] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

North American Association for Environmental Education—Grades 5-8:
1C) Locate and collect reliable information about environment
1E) Classify and order data, organize and display information
1G) Synthesize observations into coherent explanations

Vocabulary: cambium, dendrochronology, fire scar, growth ring, heartwood, sapwood, surface fire

Materials

In this trunk…	***… where?***[39]	***You must supply***
Ancient Tree poster	Main/B	overhead projector, pens
FireWorks Cookie Book (optional)	Teacher/C	
"Real" tree cookies (trunk cross-sections)	Main/B	1 piece of black plastic cut from trash bag, about 15 by 60 cm
Tree Cookie photos (set of 19)	Main/B	
Class Page 6, *Tree Stories* transparency	Both in *Visual Aids & Handouts*, Teacher/C	
Class Page 7, *Fire Scars* transparency		

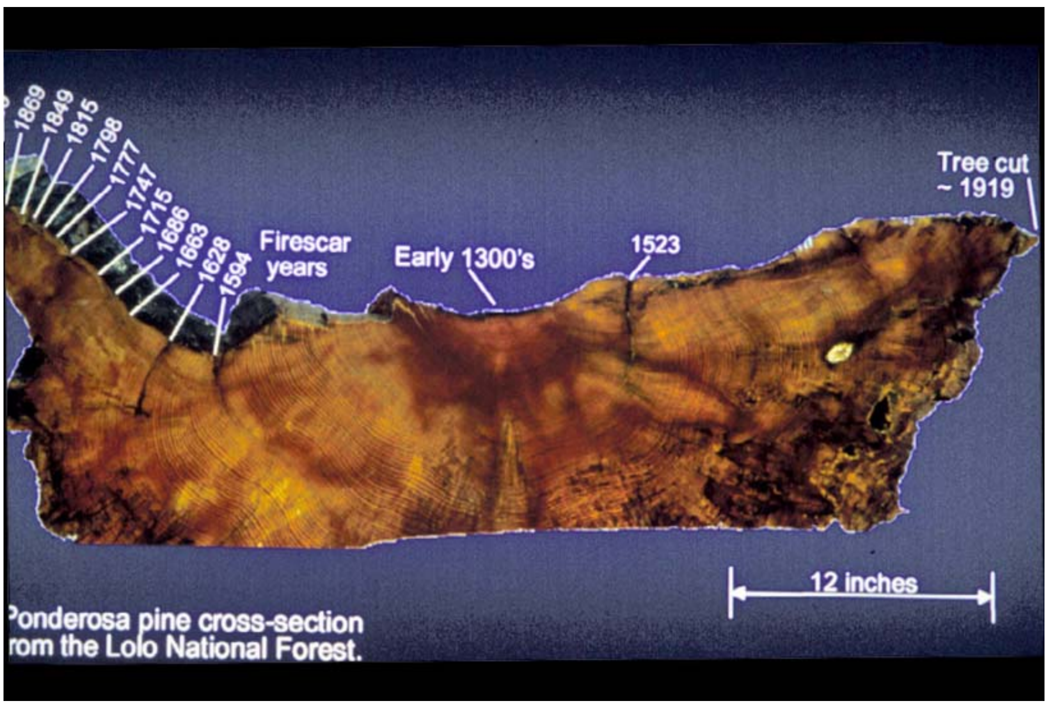


Figure 16—*Ancient Tree* poster. Various trunks may contain different versions.

Preparation

Display the *Ancient Tree* poster (fig. 16) in your classroom. In your trunk, find the tree cross section that has no fire scars ("Demonstration Cookie") so you can use it to introduce your students to tree rings. Also get out the 3 or more fire-scarred tree cookies and the set of 19 laminated cookie photos. Provide one cookie or cookie photo for every 1 or 2 students. *Do not use the "real" whitebark pine cookie or Cookie Photo 19 yet;* you will refer to them at the end of this activity. Cut a piece of black plastic about 15 cm wide and 60 cm long.

[39] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Each tree cookie is labeled with species (ponderosa pine or lodgepole pine) and a number that identifies it in the *FireWorks Cookie Book,* where its fire history is recorded.

Procedure

1. With the students, examine the growth rings on the unscarred Demonstration Cookie.
2. Explain: A tree growth ring is formed nearly every year as the tree grows, so you can estimate a tree's age by counting its growth rings. Pass the Demonstration Cookie around the class for students to examine.
3. Show students the ***Ancient Tree*** poster (fig. 16). This cookie came from a ponderosa pine tree in western Montana. With the students, examine its growth rings and the scars that form little notches along the blackened edge. This tree was much older than the Demonstration Cookie tree when it died—nearly 600 years old. A crown fire would have killed this tree, so you can infer that no crown fire has occurred in its location in the past 500+ years.
4. Now examine the scars on the *Ancient Tree*. Each scar was made by a fire. Ask students if they have any scars or have seen a scar on someone. (Be prepared: This could lead to a *long* discussion.) People become scarred when their skin receives a deep injury. Trees become scarred for a similar reason: when part of a tree's outer wood (the ring of living cells under the bark, called *cambium*) is killed by heat from a surface fire. In the years after fire, new wood forms at the edge of the damaged area. (When a person is injured, new skin forms in many places on the wound, but it usually grows fastest from the edges.)

   On a tree, new growth rings form each year and gradually curl over the edges of the damaged area, beginning to cover it. From the outside, the scar looks like a triangular patch arising from the ground (use Class Page 7 to illustrate). On the polished surface of a tree cross-section ("cookie"), a fire scar shows where a little notch occurs along the burned edge and young wood curls over older wood, making a bubble-shaped formation of wood.
5. Demonstrate how a fire scar forms (fig. 17) and how a fire scar can eventually be "buried" or "hidden" by later tree growth:
   a) One student forms a ring with hands and arms to represent the *cambium*.
   b) One student acts as surface fire, burning around the tree, killing and charring a portion of the cambium. Drape a piece of black plastic over the "killed" section to remind the class that these cells are dead and the wood is probably charred.
   c) One student on each side represents the tree's growth ring in the year after the fire by placing a hand against the area of

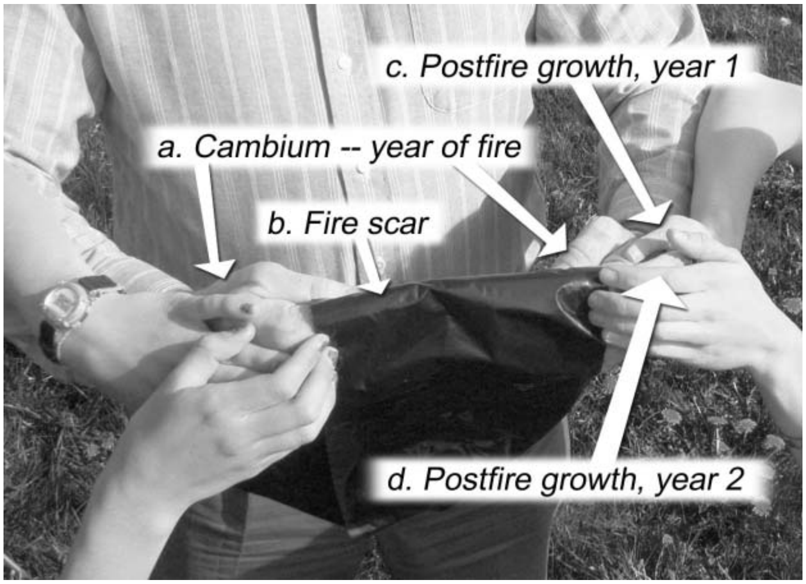


Figure 17—Students build a living model of tree cambium and fire scar with their hands. See Step 5 for explanation.

"living cambium" at each edge of the area killed by fire (black plastic).

d) To represent the tree's growth in the second postfire year, the student on each side of the fire scar places his/her other hand on top of the first. The hand representing the second year's growth ring is not laid flat against the first hand, however. Instead, its fingertips curl around the first-year growth ring at the edges of the fire scar, because cells at the edge of the scar can divide both outwardly and laterally, covering part of the scar. This is the beginning of the "bubble" of growth that usually forms at the edges of a fire scar.

e) Use two more students to represent two more years of growth after fire so the development of this "bubble" formation is clear. If you want, add another fire scar and show a second bubble of woody growth developing after it.

5. Pass a fire-scarred ponderosa pine and lodgepole pine cookie (real ones—not photos) around the class. Ask students to look at the fire scars carefully so they will be able to identify and count them on the cookies they are about to study.

6. Explain: Students will study fire scars on their assigned tree cookie photos. Write on the board what each team should report:
   - Kind of Tree (written on front or back of cookie)
   - Tree Cookie Number (written on front or back)
   - How many fire scars?
   - How many rings? (An estimate is OK; in most cases, students <u>cannot</u> count all rings.)

8. Explain: Scientists count a tree's rings to estimate its age. They use hand lenses and microscopes to count accurately.

   Many of the tree cookies in *FireWorks* do not contain the center ("pith") of the tree. This is especially true for ponderosa pine cookies. These cookies don't show all of the tree's growth rings, so students cannot find out how old the tree was when the cookie was taken. When they report the total number of tree rings on their cookie, mark it with ">" ("greater than") to show that the tree's real age when sampled was greater.

   On some tree cookies and cookie photos, the rings are too small to count. Here is a technique for *estimating* the number of rings on a cookie: (1) Count the number of rings per centimeter in a part of the cookie with narrow (but still countable) rings. (2) Measure the centimeters of growth in which rings are not visible. (3) Multiply (rings/cm)*(cm where rings aren't visible). This produces a *conservative* estimate of the number of rings in that section of the tree cookie, meaning there may be *more* rings in that section but there are probably not *fewer*.

9. Distribute tree cookie photos. Ask student teams to examine their photo and record observations.

> **INFO SPARKS:** Here is some information that may help answer questions as students get started, or you may use it in discussion after the activity is over:
> --Trees are not always killed when a cross section is taken. Many tree cookies are obtained from dead standing trees and stumps. A partial cookie can be collected by cutting through only a small section of the trunk of a living tree (Class Page 7). Pines are damaged little by this procedure.
> --Historians recognize two important sources of fire prior to European American settlement of North America: lightning and Native American burning. Native Americans burned forests and grasslands at many seasons, for many reasons. The relative frequency of these two sources of ignition is hard to figure out.

10. Give students 10-15 minutes to study their cookie photos. If a student team finishes early, they should work on another cookie photo, if available. **OPTIONAL:** Results can be checked against information in the ***FireWorks Cookie Book*** (in the *Teacher Box*)**.** But you

don't need to emphasize a "correct" answer from the Cookie Book. Fire scientists use microscopes and a lot of time to study growth rings; dendrochronology is a difficult science.

> **INFO SPARK:** Students often ask why some of the wood in a tree cookie is dark, while other parts of the cookie are very light. The dark wood marks areas of the wood that are filled with sap, or "pitch." Pitchy wood develops for many reasons. Here are two:
>
> 1) The outer wood (*xylem,* or sapwood) is often lighter in color than the inner wood (heartwood) because the sapwood is filled with water and minerals, not with sap. Cells in the inner sapwood gradually die, becoming heartwood. The tree may fill these with pitch, turning them dark in color. Though the heartwood cells are not alive, they provide support for the tree, like the backbone of a person.
>
> 2) If a tree is wounded, it often deposits pitch around the wound. The pitch prevents decay fungi, which enter through the wound, from spreading. Pitch forms irregular, dark shapes around wounds. Tree wounds are caused by many things, including scrapes from other trees, rubbing by animals, and fire.

11. Ask students to report their data. As they report, record the data on the Class Page 6 transparency.
12. Explain: Nearly every old forest of ponderosa pines has fire-scarred trees, but only about half of lodgepole pine forests have fire-scarred trees. Use this information and the data just collected to discuss these questions: Which kind of tree tends to live longer—ponderosa pine or lodgepole pine? (Ponderosa pine.) Which kind of tree tends to have the most fire scars? (Ponderosa pine.) How would you describe the "story" of fire in each kind of forest?

> **INFO SPARK:** Many ponderosa pine forests are so old that we can't tell when or how they began. Most lodgepole pine forests began after a crown fire that killed nearly every tree.

Evaluation:

1. Explain how a fire scar forms on a tree.
2. Which kind of tree tends to live longer—ponderosa pine or lodgepole pine?
3. Which kind of tree is likely to have more fire scars? Explain why.

Closure: Now show the real whitebark pine cookie and Cookie Photo 19 (also whitebark pine) to the class. Explain that whitebark pine's relationship with fire is different from the ponderosa pine and lodgepole pine stories that they've studied so far. Ask the students to examine the cookies and make observations about the tree's growth rings and fire scars. Pull their observations together with the following information to summarize whitebark pine's relationship with fire: Whitebark pine grows at higher elevations than either of the other pines. Growing seasons are shorter and colder, so whitebark's growth rings tend to be narrower—much harder to photograph and count than those of the other species. The colder summer also means that whitebark pine forests burn less often. But they do burn—in a mixture of crown fire and surface fire. Most old whitebark pines have one or two fire scars.

Extensions

1. Draw a tree cookie to illustrate the story of your life. It should have the same number of tree rings as your age. Label the narrow rings that show difficult years and the wide rings that show years in which you grew a lot in some way. Mark any scars that have changed your life.
2. Read "Is Smokey Wrong?" in the *FireWorks Library.* Summarize what it says for your class in 3 minutes or less; it will take planning and practice to do such a short presentation well.
3. Estimate the year when your tree began its life. Find out one historical fact about that year or decade.

Tree Stories

Class Page 6

Ponderosa pine

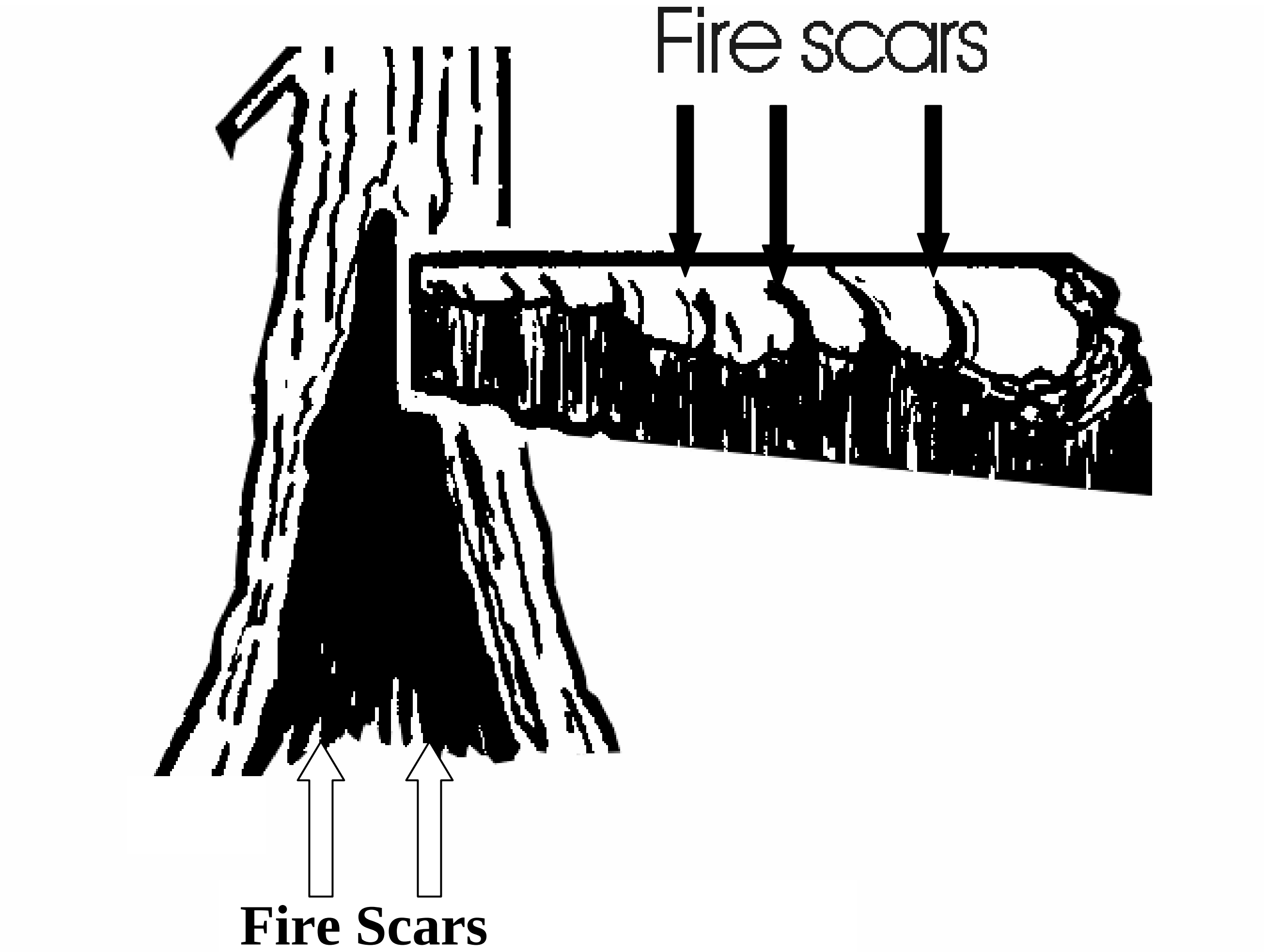
Cookie number	How many scars?	How many rings?
102		
104		
106		
111		
113		
114		
116		
117		
118		

Interior Lodgepole pine

Cookie number	How many scars?	How many rings?
101		
103		
105		
107		
108		
109		
110		
112		
115		

Class Page 7

Fire Scars



Activity 5-2. For Middle and High School:

Tree Stories

Grade levels:
X Middle
X High

What's the Point?

Tree rings and scars on trees tell the history of a forest. Fire has been a part of the history of most forests in North America for thousands of years.

In this activity, students use *dendrochronology* to describe the history of ponderosa pine and lodgepole pine forests over the past several hundred years. The trunk includes one whitebark pine specimen so students can see whitebark pine's growth pattern, but whitebark pine is not used in this activity because it its growth rings tend to be very narrow and hard to count.

First, students study the history of tree cross sections ("cookies") and cookie photos in the *FireWorks* trunk; then, in Activity 5-3, they will use their tree cookie data to compare fire history in two kinds of forest: ponderosa pine and lodgepole pine. Finally, they will learn about fire regimes in whitebark pine.

Dendrochronology, the science of learning about trees and climate from tree growth rings, is challenging. Its imprecision may be frustrating to some students, but this field fascinates most students.

Teacher's Map:

Objectives: Given a cross-section of a tree trunk or a photographed cross-section, students can identify growth rings and fire scars, and calculate the average time between fire scars.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Social Studies, Technology, Arts, Workplace Competencies

Duration: 60 minutes

Links to Standards[40]:

National Science Teachers' Association—Grades 5-8:

A1) Identify questions that can be answered scientifically
A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations
A6) Use mathematics in science
C4) Recognize that ability to obtain and use resources… is essential for life
G1) Recognize that scientists work alone and in teams
G2) Understand that science results must be communicated
G3) Recognize that uncertainty, debate, further investigation, and evaluation are part of science

National Science Teachers' Association—Grades 9-12:

A4) Use technology, mathematics, logic and previous research in investigations

North American Association for Environmental Education—Grades 5-8:

1C) Locate and collect reliable information about environment
1E) Classify and order data, organize and display information
1G) Synthesize observations into coherent explanations
2.2A) Understand biotic communities and adaptations
3.1A) Use information to investigate environmental issues
3.1B) Identify consequences of specific environmental issues

North American Association for Environmental Education—Grades 9-12:

0B) Investigate short- and long-term environmental changes

[40] See Appendix 4 for links to Montana educational standards, grades 5-8, 9-12.

1C) Collect reliable information, using technology as needed to gather and display data 1E) Organize and display information 2.4A) Understand that humans change environment and ability to absorb these impacts is limited 3.1B) Evaluate consequences of specific environmental changes… for humans and ecosystems

Vocabulary: cambium, dendrochronology, fire scar, growth ring, heartwood, sapwood, surface fire, xylem

Materials

In this trunk…	***… where?***[41]	***You must supply***
FireWorks Cookie Book (optional)	Teacher/C	calculators
Ancient Tree poster	Main/B	
hand lenses (4)	Both: *Hardware Box*, Main/A	dissecting microscope (optional)
Pins in film canister		Copy of *Tree Story* data sheet (Student Page 15) for each team
Tree cookies (trunk cross-sections)	Main/B	
Tree Cookie photos (set of 19)	Main/B	
Class Page 8, *Fire History Data* transparency	Both in *Visual Aids & Handouts,* Teacher/C	1 piece of black plastic cut from trash bag, about 15 by 60 cm
Class Page 7, *Fire Scars* transparency		

Preparation

Display the *Ancient Tree* poster in your classroom.

In your trunk, find the tree cross sections ("cookies"). Pull out the cookie that has no fire scars ("Demonstration Cookie") so you can use it to introduce your students to tree rings and dendrochronology. Your trunk also contains fire-scarred cookies-- as few as three and as many as ten "real" cookies and a set of 19 cookie photos. Have your students work with as many "real" cookies as you have, and then use the photo cookies to make sure you have one cookie for every 1 or 2 students. *However, do not use the "real" whitebark pine cookie or Cookie Photo 19;* you will refer to them at the end of Activity 5-3. Cut a piece of black pastic about 15 wide by 60 cm long.

Hand lenses are essential for completing the fire history of real tree cookies; they are no help with cookie photos. Use dissecting microscopes if the platform will support a tree cookie and if the eyepiece can be raised above the tree cookie.

Each tree cookie (real or photo) is labeled with the tree's species (ponderosa or lodgepole pine) and a number identifying it in the *FireWorks Cookie Book*, where its history is recorded.

Procedure

1. Pass the Demonstration Cookie around the class. Examine the growth rings on both the *Ancient Tree* poster and the Demonstration Cookie. Examine the scars that form little notches along the blackened edge of the *Ancient Tree* cookie. They were made by surface fires. This tree was much older than the Demonstration Cookie tree when it died—nearly 600 years old. Therefore, you know no crown fire occurred in the location where it stood for nearly 6 centuries, between the early 1300s and 1919.
2. Explain fire scars to the students: A fire scar is formed when part of a tree's *cambium* is killed by heat from a fire. If the cambium is damaged only part-way around the tree, the tree often survives. In the years after the fire, new wood forms at the edge of the damaged area. Year after year, new rings are formed that gradually curl over the edges of the damaged area and begin to cover it. From the outside, the scar looks like a triangular wound coming up from the ground. (See Class Page 7, p. 97).
3. Build a human model of a fire-scarred tree using Step 5 and fig. 17, in Activity 5-1 (pp 93-94).

[41] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

4. Pass a fire-scarred ponderosa pine and lodgepole pine cookie (real ones, not photos) to students. Ask them to look at the fire scars carefully so they will be able to identify them on the cookies they are about to study. Explain: Students will study fire scars on their assigned tree cookies or cookie photos.

   The students working with real cookies need hand lenses; students working with photos don't. **WARNING—About hand lenses!!!!** If students are working with hand lenses in direct sunlight or near sunny windows, be alert for students trying to light fires with their hand lenses. It's almost irresistible, but it's not what the magnifiers are for in this case.

   Students should work singly or in pairs. Team members should either work separately and compare their results, or share the work and discuss decisions about "when the fire actually occurred" or "is this really a tree ring?" If a student team finishes while others are still working, ask them to collect data from another cookie photo.
5. Explain: In this activity, each student will describe the fire history of at least one tree. In the next activity, they will pool their data and add other data collected at the Fire Sciences Laboratory in Missoula, MT, to describe the historic patterns of fire in ponderosa and lodgepole pine forests.
6. Pass out fire-scarred tree cookies and/or cookie photos, hand lenses, straight pins, and *Tree Stories* data sheets (Student Page 15) to teams of students. Distribute calculators. Explain that students may stick pins into the wood of the real cookies and into the laminated cookie photos to mark fire scars or help keep track of counts. **They may not use ink in any form.**
7. Review/explain:
   - Fire scars are made by *surface fires* that are not severe enough to kill the tree. On the polished top of a tree cookie or photo, a fire scar is marked by an indentation that follows the line of a growth ring, and by later wood that curls over the fire-damaged cambium cells. Seen from the front of a tree or the charred edge of a tree cookie, the same fire scar looks like a vertical fold in the wood (use Class Page 7, on p. 97, to illustrate).

   INFO SPARK: The *Fire Scars* transparency (Class Page 7) illustrates how a tree cookie is cut. Many tree cookies are obtained from dead trees and stumps. When a cookie is taken from a live tree, it usually damages the tree very little because (1) only a small section of the trunk is cut and (2) the tree produces pitch around the wound, protecting the rest of the wood from decay. Pines are especially good at producing pitch around wounds.

   - Historians recognize two important sources of fire prior to European American settlement of North America: lightning and Native American burning. The relative frequency of these two sources of ignition is hard to figure out.
   - Can we learn anything from tree cookies about crown fire? Only that the last crown fire on a site occurred <u>before</u> the tree began to grow. That would be <u>before about 1300</u> for the Ancient Tree.
8. Review the concept of an average and how to calculate it. Students will need this skill for question 6 on Student Page 15 and also for Activity 5-3.
9. Give students 15-30 minutes to study their tree cookies and complete their data sheets. If a student team finishes one cookie, have them collect data from another one.

   INFO SPARKS on *"Tree Stories,"* Student Page 15—keyed to numbered questions:

   8. Decreases in fire activity can be caused by moist time periods, increases by dry periods. Very few trees have fire scars dating after 1920 or 1930. This is because successful programs excluding fire from forests and grasslands began in those years, and also because livestock grazing reduced fine vegetation (fuels) such as grass and shrubs.

   9-12. Poor growth is likely to occur after fire if the fire killed many of the tree's needles or much of the cambium. Rapid growth after fire may be caused by decreased competition from other vegetation for moisture and nutrients or by an increase in nutrients from burned vegetation.

   13. Answers to this question vary from place to place and from one tree species to another. When fire is excluded for a long time from ponderosa pine/Douglas-fir forests, dense undergrowth develops. This understory makes fires very hazardous and likely to kill even large, old trees. A dense understory can also weaken large, old trees by consuming moisture and nutrients. In contrast, lodgepole pine forests are less affected by lack of fire. They have followed the pattern of severe, infrequent burning for

thousands of years. Lack of fire can alter lodgepole pine forests by increasing uniformity in the mosaic of forest patches across the landscape.

OPTIONAL: Check dendrochronology results against information in the ***FireWorks Cookie Book.*** This book contains a list of approximate fire intervals for each cookie.

INFO SPARK: Students often ask why some of the wood in a tree cookie is dark, while other parts of the cookie are very light. The dark wood marks areas of the wood that are filled with sap, or “pitch.” Pitchy wood develops for many reasons. Here are two:

1) The outer wood (*xylem,* or sapwood) is often lighter in color than the inner wood (heartwood) because the sapwood is filled with water and minerals, not with sap. Cells in the inner sapwood gradually die, becoming heartwood. The tree may fill these with pitch, turning them dark in color. Though the heartwood cells are not alive, they provide support for the tree, like the backbone of a person.

2) If a tree is wounded, it often deposits pitch around the wound. The pitch prevents decay fungi, which enter through the wound, from spreading. Pitch forms irregular, dark shapes around wounds. Tree wounds are caused by many things, including scrapes from other trees, rubbing by animals, and fire.

Evaluation: Many people think that fire kills every tree in a forest. Write a paragraph and draw a diagram to explain to a younger brother or sister how a fire can scar a tree without killing it.

Closure: Don’t “close” this activity. Go on to Activity 5-3.

Extensions

1. Estimate the year when your tree cookie’s first fire scar formed. What do you think your city or town looked like in that year? Write a paragraph or draw a picture to describe it.
2. Learn the birth years of family members, particularly parents, grandparents, and great-grandparents. Label the birth years of these family members on the *Ancient Tree* time line. Do you know anyone who was alive when the *Ancient Tree* was alive (1919 and before)?
3. Learn more about how tree rings form and the science of dendrochronology from *Tree Basics* in the *FireWorks Library* and from: web.utk.edu/~grissino and www.ltrr.arizona.edu (click on the tree cross-section, the rectangular photo right at the top of the page).

Student Page 15

Tree Stories: Cookie Number _______

1. Does your tree cookie contain a tiny ring at the center (the "pith"), or is the pith missing on your cookie?

   ____

2. **Estimate** how old your tree is. How? In a part of the cookie that seems to have average-sized rings, count how many rings are in a centimeter. Measure the distance from the tree's pith to its bark. Multiply to get the total number of rings:

   Rings/cm __________ X _________ cm = total rings ________

   This number is an estimate of tree age. The last crown fire in that forest happened **before** the tree started to grow, but we don't know **how many years** earlier.

3. If the pith is not present, go to question 4. If the pith is present, how old was your tree before it was first scarred by surface fire? ____

4. A tree may survive several fires in its lifetime. How many fires have burned your tree? ___

5. How long were the intervals between fires? _______ _______ _______ _____ ______

   _______ _______ _______ _____ ______ _______ _______ _______ _____ ______

6. What was the average interval between fires? ___________ years

7. How long has it been since your tree's last fire scar? ________ years

8. Is this interval very different from the average in 6 above? If it is, try to explain why (on the back of this page).

9. Wide tree rings show good years for tree growth, when moisture, sunlight, and nutrients were plentiful. Rings that are very close together show years of drought, disease, injury, shading, or crowding by other trees. At about what age did your tree grow best? _______

10. At about what age did your tree grow most slowly? ______________

11. Were the years right after fire usually good or poor for growth? _____________________

12. How would you explain your tree's response to fire (your answer to question 11)?

    ____

13. Do you think your tree could be damaged by **lack** of fire? Explain on back of page.

Activity 5-3. Repeating the Story?

Grade levels:
X Middle
X High

What's the Point?

This activity synthesizes information from Activity 5-2, *Tree Stories*. The pattern of fire history for a particular kind of forest is called its *fire regime*. The fire regime describes how often fire usually occurs and how severe it usually is. Many forests dominated by ponderosa pine were, in past centuries, characterized by frequent surface fire (usually averaging every 5 to 30 years); crown fires were uncommon. Forests dominated by lodgepole pine and whitebark pine had less frequent surface fires—one or two per century. Crown fires were infrequent in whitebark pine forests but occurred every century, more or less, in lodgepole pine.

In this activity, the class works together to compare historic fire regimes in ponderosa pine and lodgepole pine forests. Whitebark pine is used only at the end of the activity; students do not study it directly because its fire history is complex and very difficult to decipher.

Teacher's Map:

Objective: Given information on numbers of fire scars and years between fire scars on individual trees, students can calculate the average interval between surface fires and describe the fire regime for that forest type.

Subjects: Science, Mathematics, Writing, Speaking and Listening, Technology, Workplace Competencies

Duration: 40 minutes

Links to Standards[42]:

National Science Teachers' Association—Grades 5-8:
A4) Think critically to establish relationships between evidence and explanations
A6) Use mathematics in science
G2) Understand that science results must be communicated
G3) Recognize that uncertainty, debate, further investigation, and evaluation are part of science

National Science Teachers' Association—Grades 9-12:
A2) Design and conduct experiment, use mathematics and models to explain results
A4) Use technology, mathematics, logic and previous research in investigations

North American Association for Environmental Education—Grades 5-8:
0A) Classify local ecosystems. Create food webs
1A) Develop, focus and explain questions about environment
1D) Judge weaknesses and strengths of the information they are using
1G) Synthesize observations into coherent explanations
3.1B) Identify consequences of specific environmental issues

North American Association for Environmental Education—Grades 9-12:
0A) Identify several plants and animals common to local ecosystems. Describe concepts….
0B) Investigate short- and long-term environmental changes
2.2C) Understand the living environment as comprised of interrelated, dynamic systems

[42] See Appendix 4 for links to Montana educational standards, grades 5-8, 9-12.

3.1B) Evaluate consequences of specific environmental changes, conditions and issues

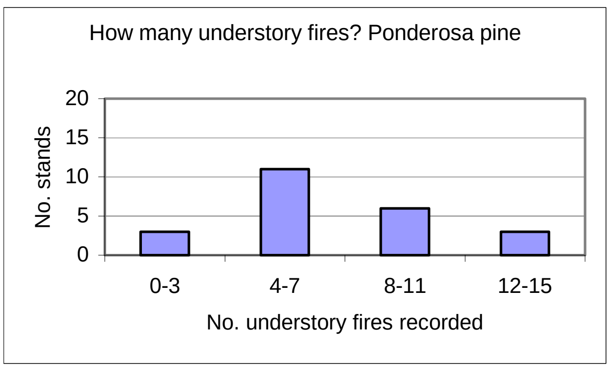
Vocabulary: crown fire, fire regime, surface fire

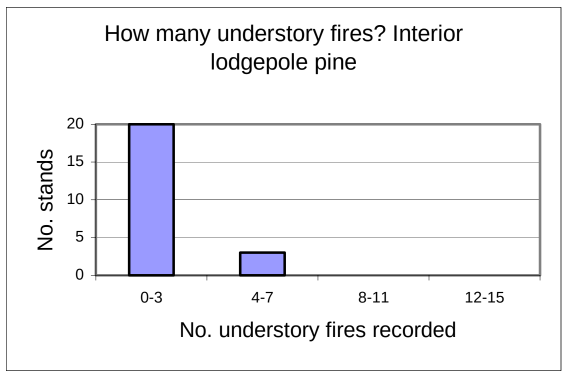
Materials

In this trunk…	*… where?*[43]	*You must supply*
Fire History Data transparency (Class Page 8)	*Visual Aids & Handouts,* Teacher/C	calculators overhead projector & pens

Procedure

1. Make sure students have their *Tree Stories* data sheets (Student Page 15) from Activity 5-2.
2. Display the transparency for Class Page 8, but keep the lower half covered. Ask students to report their data. Record data on the transparency.
3. Explain: The class has now collected half of the data needed to describe fire history. But many tree cookies cannot be studied from photographs. Many have no fire scars, so they would be boring to use in this activity. The lower half of the table provides data from these sources.
4. Uncover "the rest of the story." Ask students if they see or suspect any patterns in the data. Ask how they might analyze the data to identify patterns. Here are suggestions:
5. First, as an individual assignment or as a group activity, draw a histogram of the number of fire scars for each species. The results should resemble these:





6. Next, compute the average age when sampled, number of scars, and fire interval for each species. Since many tree cookies are incomplete, many age estimates are minima, so you can only compute a *minimum* average for tree ages when sampled. Mark them as minima using a ">" sign. Your results should be similar to these; they will not be identical, since each *FireWorks* trunk contains different real tree cookies.

	Average Age when sampled (yr)	**Average No. scars**	**Average Fire interval (yr)***
Ponderosa pine	>284	6.6	28.9
Lodgepole pine	>172	1.3	38.3

*This average describes *only* forests with fire scars—90% of ponderosa pine and 50% of lodgepole pine.

[43] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

7. Discuss: In what ways did historic fire patterns in ponderosa pine forests differ from those in lodgepole pine? (Numerous studies show that many ponderosa pine forests had surface fires every 5 to 30 years for hundreds of years; crown fires were uncommon in this kind of forest, so the trees lived for many centuries. Lodgepole pine forests burned every century or so in severe fire; about half of lodgepole pine forests also burned in surface fires, usually 1-2 per century.) Interesting questions:
   - How different are the averages for ponderosa and lodgepole pine forests? Do they just represent variation from one location to another, or do they represent real differences between kinds of forests? (Research scientists would answer this question using statistics. These data are not from a random sample and therefore statistical testing is not entirely appropriate. However, students could use a 2-sample t test or a Mann-Whitney U test to see if the two samples seem to be significantly different.)
   - Why might the fire-free intervals be different from one forest to another? (Lightning incidence and Native American uses differed greatly in different kinds of forest. Native American use probably depended a lot on the season of the year.)
   - Could the answer to question 13 on the *Tree Stories* data sheet ("can trees be damaged by ***lack*** of fire?") differ from one kind of forest to another? This information may help:
     - **ABOUT PONDEROSA PINE FORESTS:** Dr Steve Arno, recently retired from the Fire Sciences Laboratory in Missoula, MT (interviewed on the videotape "Managing Wildland Fire—a Matter of Choice" in Activity 8-1) thinks that many forests with ponderosa pine should be thinned to remove some of the thickets of small trees. He recommends underburning these forests after thinning to reduce the number of small trees and the amount of fuel on the ground. (Burning in this way is a job for trained professionals only.) These actions, Dr. Arno believes, will make more water and nutrients available to large, old trees and reduce the likelihood of crown fire.
     - **ABOUT LODGEPOLE PINE FORESTS:** Fire history studies show that these forests often grow for a century or more without fire and then burn in a large, severe fire. Sometimes they underburn once or twice in between. Many scientists think that lodgepole pine-subalpine fir forests are gradually becoming older and more uniform without fire. This means less habitat variety and increasing risk of large fire.

Evaluation: Based on what you know about fire regimes in lodgepole and ponderosa pine forests, which kind of forest would you choose to build your home in? Explain your reasoning.

Closure: Now show the real whitebark pine cookie and Cookie Photo 19 (also whitebark pine) to the class. Explain that whitebark pine's relationship with fire is different from that of ponderosa or lodgepole pine. Ask the students to make observations about whitebark's growth rings and fire scars. Pull their observations together with the following information to summarize whitebark pine's relationship with fire: Whitebark pine grows at higher elevations than either of the other pines. Growing seasons are shorter and colder, so whitebark's growth rings tend to be narrower—much harder to photograph and count than those of the other species. The colder summers also mean that whitebark pine forests burn less often. But they do burn—in a mixture of crown fire and surface fire. Most old whitebark pines have one or two fire scars.

Explain: Dr. Bob Keane, at the Fire Sciences Laboratory in Missoula, MT, is worried about high-elevation whitebark pine forests because thousands of these pines have been killed by a non-native disease, white pine blister rust. (The *FireWorks Notebook* contains an essay about white pine blister rust and its devastation of whitebark pine forests**.**) A few whitebark pines survive the rust, so their seeds should have the best possible chance to grow up in the sunny openings created by recent fire. The Clark's nutcracker—the bird that is solely responsible for whitebark pine reproduction—prefers burned sites to forest for hiding its year-round food supply, the whitebark pine seed.

Extensions

1. Use the *Ancient Tree* poster (see Activity 5-1, fig. 16) to make a time line linking the *Ancient Tree*'s story to human history: On the board, have one or two students list the current year, the year when the *Ancient Tree* died (1919), and dates of fires from the *Ancient Tree* poster, leaving space between dates for other things to be written in. This will form your time line. Ask students to recall or look up events in human history, find out when they occurred, and enter them in the right location on the time line. Here is a list of some dates from American and European history that may help students link a tree's history to human history.

YEAR	EVENT
1910	Glacier National Park created
Nov. 8, 1889	Montana becomes 41st state
July 3, 1890	Idaho becomes 43rd state
1849	Gold discovered in California
1805	Lewis and Clark expedition
1776	Declaration of Independence signed
1734	Daniel Boone born
1620	Pilgrims land at Plymouth Rock
1595-1617	Pocahontas's lifetime
1564	Shakespeare born
1519	Magellan begins voyage around the world
1508	Michelangelo starts painting Sistine Chapel
1492	Columbus lands in Americas
1446	Gutenberg uses printing press
1348	Black Death (bubonic plague) kills 1/3 of Europe's population

2. Visit the Fire Effects Information System on the Internet at

   www.fs.fed.us/database/feis

   Select a species featured in the *FireWorks* trunk or another species that occurs in your local area, find its Web page, and look up its "Fire Ecology" to obtain information about fire regimes and fire effects on that species.
3. Look up the kinds of wildland fires that occurred in past centuries throughout the United States on the Inernet site

   www.fs.fed.us/fire/fuelman

   Examine the national fire regimes map.
4. Learn more about fire history and succession in a plant community in your area from one of the *Fire Ecology of…* reports in the *FireWorks Library.* A report on eastern Montana, western Montana, northern Idaho, or another geographic area in the Rocky Mountains is in your *FireWorks* trunk.

Class Page 8

Fire History Data[1]

Ponderosa pine

Cookie number	3. Approx. age	4. No. scars?	6. Ave. Interval
Real			
102			
104			
106			
111			
113			
114			
116			
117			
118			
The rest of the story:			
7	300	8	26.9
16	280	4	43.3
17	460	6	60.2
36	261	7	26.5
53	291	9	31.2
55	447	10	26.8
58	190	4	34
77	339	4	24
63	300	7	30.7
86	458	12	24.9
88	323	3	21
202	459	4	56.7
351	334	0	can't be calculated
352	297	0	

Interior Lodgepole pine

Cookie number	3. Approx. age	4. No. scars?	6. Ave. Interval
Real			
101			
103			
105			
107			
108			
109			
110			
112			
115			
The rest of the story:			
91	150	1	can't be calculated
215	145	1	
350	178	1	
303	112	0	
304	202	0	
305	186	0	
306	137	0	
307	117	0	
308	386	0	
309	90	0	
310	350	0	
311	101	0	
312	70	0	
313	150	0	

[1] According to fire historians Steve Arno and Steve Barrett, about 10% of mature ponderosa pine forests and 50% of mature lodgepole pine forests have no fire-scarred trees. Cookie numbers greater than 300 are used here to represent these forests, so that students can analyze the full range of the history of surface fire for each forest type.

Chapter 6.
Tough Plants, Tough Animals

Many plants and animals have ways to survive fires, especially the kind of fire that has occurred for thousands of years in the past. Many plants have ways to reproduce after fire even if they are killed. The traits that enable organisms to survive or reproduce in a particular environment are called *adaptations*. The ability some species to to survive better than others knits the species together with their environment into a working *ecosystem.* The fact that some individuals in a species can survive and reproduce better than others drives *natural selection*.

In this chapter's activities, students learn about plant adaptations to fire. They also discuss animal strategies for avoiding and surviving fire. Fire changes animal habitat, sometimes dramatically. For some kinds of animals, the changes are positive; for others, they are not.

Background

- *Made for Each Other* focuses on whitebark pine and the Clark's nutcracker. This symbiotic relationship is an excellent example of a group of species adapted to benefit from each other and benefit from fire, the topic of this chapter.
- Pages 29 through 34 in Patrick Cone's *Wildfire* (in the *FireWorks Library*) provides more information about fire effects on trees and forests. This book has excellent color illustrations.
- Jack deGolia's book *Fire—a Force of Nature* (in the *FireWorks Library*) describes fire effects. See pages 28-30.
- The *Unfinished Song* videotape in the *Teacher Box* describes adaptations to fire and fire effects in the lodgepole pine-dominated ecosystems of the Greater Yellowstone Area.

Chapter Goals

1. To increase student skills in
   - observing
   - describing observations
   - working in teams
2. To increase student understanding
   - that wildland fire changes, but does not usually "destroy," a forest community
   - that it is possible for organisms to avoid or survive fire
   - that it is possible for some organisms to reproduce after fire even if they are killed

Chapter Activities

Activity 6-1. Dead or Alive!	(E)
Activity 6-2. For Primary: Buried Treasure	(P)
Activity 6-3. For Elementary and Middle School: Buried Treasure	(E,M)
Activity 6-4. Tree Skin	(M,H)
Activity 6-5. Recipe for a Lodgepole Pine forest	(E,M)
Activity 6-6. Designer Trees	(E)
Activity 6-7. Great Escape	(E)

Activity 6-1. Dead or Alive!

Grade level:
X Elementary

What's the Point?

To understand how plants survive fires, it is important to understand that all complex organisms have both living and nonliving parts. Nonliving parts often support and protect the living parts, but they can be damaged or removed without killing the organisms. In this activity, students think about what they know about their own bodies in order to understand how plants live, grow, and die—and sometimes survive wildland fires. The specific concepts covered in this **guided discussion** are:

- Living organisms have living and nonliving parts. The living parts are called cells
- Fire can damage or kill some parts of a plant without killing the whole organism

Teacher's Map:

Objective: Students can identify cells as the basic living part of an organism and can list living and non-living parts of plants.

Subjects: Science, Speaking and Listening

Duration: 30 minutes

Links to Standards[44]:

National Science Teachers' Association—Grades K-4:
A2) Plan and conduct a simple investigation
C1) Identify needs of various organisms
C2) Identify structures of various organisms and the needs they serve

National Science Teachers' Association—Grades 5-8:
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations
C1) Describe structure and function in a living system
C2) Understand cell functions
C4) Recognize that ability to obtain and use resources, grow, reproduce, and maintain internal stability are essential for life

North American Association for Environmental Education—Grades K-4:
1C) Collect information about environment
2.2B) Understand that plants and animals have different characteristics and many are inherited
2.2C) Understand basic ways organisms are related to environment and other organisms

North American Association for Environmental Education—Grades 5-8:
1G) Synthesize observations into coherent explanations
2.2A) Understand biotic communities and adaptations

Vocabulary: bud, cambium, embryo, exoskeleton, leaf, needle, phloem, seed, xylem

[44] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

Materials

In this trunk…	*… where?*[45]	*You must supply*
Tree Portrait poster	Main/B	Sticky-back or transparent tape
"Fuels… Tree & Soil Parts, and Fire Targets" kit—pull out the labels for bud (3), cambium, leaf, needle, and seed	Teacher/C	Salted-in-the-shell peanuts, one per student

Preparation

Display the *Tree Portrait* in the classroom. Write on the Board, "Are you completely alive?"

Procedure

1. Explain: Living things are made up mainly of tiny individual parts called "cells." Let's explore the question about being completely alive by thinking about these cells.
2. Ask: Is your hair alive? One way to tell whether a part of you is living or not is to ask, "Does it bleed or hurt?" Does it bleed or hurt when you cut your hair? Does it hurt when you pull a hair out? (Hair is composed mostly of a material, a protein, that is produced by living cells. The protein itself isn't alive, so it doesn't hurt when it gets cut. The living part of a hair, which *does* hurt when it gets pulled, is the end—the "root"—that is buried in your scalp. The root contains many growing cells that constantly make more hair protein, so your hair grows slowly but constantly. We can refer to the root of the hair as a "growing point.")
3. Can you think of other parts of you that may be non-living? Here are some:
   - Fingernails and toenails. (Nails are also composed of a protein produced by growing points at the base of the nail. If you damage the base of your nail, some of the growing cells are destroyed, so they can't produce the nail material. The old nail then grows out and comes off, and a new one begins growing from the base.)
   - The outer surface of skin. (Our skin is constantly sloughing off. This is obvious in dandruff, on calluses of hands and feet, and around injuries. Skin is made up of several layers. The inner layers consist of living cells; they are full of nerves, so they are very sensitive to pressure and injury. These skin cells continually divide and push outward, where they eventually die and form the outermost layer of skin. Anytime something rubs against your skin, some of the dead cells at its surface rub off. What activities might cause you to shed skin cells? Washing and drying hands, clothes rubbing over skin, handling objects.)
4. Think about animals other than humans. What are some of their nonliving parts? (Mammals' fur, claws, horns, antlers; birds' beaks, claws, feathers; fish scales; insects' *exoskeletons* (outer shells); clams' and snails' shells.)
5. Ask, "Is a plant completely alive?" Explain: You can't ask a plant if it "hurts" when something is cut or pulled, burned or scraped. Plants don't have blood or a heart to pump it around, so you can't check to see if the plant is bleeding. You can only watch what happens after the plant is injured. Does the injury kill the plant or affect its growth?
6. Ask students to look at the *Tree Portrait* and think about plants that they are familiar with. What parts have living, growing cells and what parts are nonliving? As the following points

[45] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

emerge in the discussion, pull the appropriate label from the *Tree and Plant Parts Labels* and tape it to the *Tree Portrait*.

- A plant has living *growing-point buds* at its top, at the tip of each branch, and the tip of its roots. (Flower buds are just one kind of bud—the kind that will eventually make seeds. But the plant has many kinds of growing-point buds.)
- A plant also has living *cambium cells* under the bark of stems, twigs, branches, and roots. The inner wood of a tree is composed mostly of dead cells.
- A plant has living cells in its *leaves.* (*Needles* are just one kind of leaf.)
- In its *seed*, a plant has not only living cells but an entire new plant!

7. Distribute the peanuts, one per student.
8. Ask students to take the peanuts out of their shells, then *gently* pull the two fleshy halves apart. At the base of one of the halves, they should find a tiny, whitish plant. This is the new peanut plant (the *embryo*), ready to start growing. Since the peanuts are roasted and salted, however, the embryo won't grow... so they might as well eat it!

Evaluation: List two living parts of a plant and two non-living parts.

Closure: Have students become a living model of a tree. This activity is a bit long for a “closure,” so you may want to use it the day after the activity as a review. The directions here are written for a class of about 25, but you can adjust the numbers so everyone has a chance to participate.

1. Ask the tallest two students to stand back-to-back, with their arms stretched high and reaching slightly outward. Explain that these are the tree's branches and leaves, which must gather energy from sunlight and turn it into nutrients that all living cells in the tree can use. Ask them to pantomime their work by wiggling their fingers. If you have a sturdy stool for these students to stand on, the activity will work better.
2. Ask 4-6 students to stand in a circle around the "branches," front-to-back, with their right sides all to the inside and their left sides to the outside. Explain that these students are the wood of the tree; a few living cells are on their right sides, close to the center. More living cells are on their left sides, close to the bark. (You can explain that they are *xylem* cells.) Xylem cells lift water and dissolved minerals from the roots to the branches of the tree. Ask the students to pantomime this work, keeping their right sides completely still.
3. Ask 4 more students to stand shoulder-to-shoulder in a circle around the wood, facing out. Explain that these students represent the living cells that carry nutrients throughout the tree—from leaves to branches, stem, and roots, in any direction that nutrients need to be delivered. Ask them to pantomime this work. (You can explain that these are *phloem* cells.) The phloem and xylem cells are made by a thin but essential layer that lies between them (the backs of the phloem students), the *cambium*.
4. Ask 5 more students to stand shoulder-to-shoulder outside the phloem cells, facing in. Explain that they represent the tree's bark, which contains mostly dead cells and protects the cambium from injury. Ask them to look very strong to show their job.
5. Ask the remaining students to lie on the floor—feet at the base of the tree, heads and arms spread out along the ground. Explain that they are the roots, with their tips and tiny hairs growing out, searching for water. They can spread their hair out on the floor and wiggle their fingertips to show their work.

6. Ask all the students to do their work at once. Now ask them to add a sound effect that fits their role. They will see that a living tree is a very busy mixture of living and dead parts, all with important work to do.

Extensions

1. Ask students to research what other human tissues are living and nonliving—for example, teeth, bones, heart, lungs, and stomach.
2. Draw a series of pictures that depicts ways in which old, decaying trees provide resources for the forest. Here are some ideas:
   - While still alive, a decaying tree can provide a nest site for woodpeckers, then for bluebirds. owls, or flying squirrels. Under its bark, beetles may lay their eggs, which hatch and feed on the tree's cambium.
   - If a rotten tree dies but remains standing, it is still used for nests. With its upper branches bare, it provides a hunting perch for hawks and owls. Ants build multi-storied cities in its dead interior. As the bark peels away, brown creepers or bats may nest under it.
   - After the tree falls, pine squirrels may nest inside its hollow trunk. (A hollow log can *only* come from a once-living hollow tree; it cannot be "hollowed out" by fungi or animals after it falls.)
   - Mice and voles travel along the ground in the shelter of fallen logs, partly hidden from predators. Not easily fooled, pine martens raise their young nearby so they can feed on the small mammals.
   - Worms and many-legged creatures eat decaying wood; their feces enrich the soil. Fallen logs block leaves and soil that roll downhill, so a tiny, rich garden forms on the uphill side.
   - Even after a lot is mostly broken down, when it only looks like a long trail of wood flakes along the ground, thousands of pieces of its wood lie within the soil. they keep the soil from being packed down by rain and animals traveling above. they are a continuing source of nutrients for living things in the soil and above it.

Activity 6-2. For Primary: Buried Treasure

Grade level:
X Primary

What's the Point?

Most children are aware of the variety of plants occurring in their local areas and the above-ground appearance of those plants. The plants' underground parts, however, are unknown to many children. In this activity, the students get a chance to imagine what the underground parts of various plants are like, then see the real structures for themselves.

Teacher's Map:

Objective: Given a chance to examine a plant's aboveground parts, students can imagine, and sketch belowground parts that might enable the plant to survive fire.

Subjects: Science, Speaking and Listening, Arts, Workplace Competencies

Duration: 30 minutes

Links to Standards[46]:

National Science Teachers' Association—Grades K-4:

A2) Plan and conduct a simple investigation
C1) Identify needs of various organisms
C2) Identify structures of various organisms and the needs they serve
D2) Describe properties of soil

North American Association for Environmental Education—Grades K-4:

0A) Identify basic kinds of habitat and plants and animals living there
1C) Collect information about environment
2.2A) Understand similarities and differences among variety of organisms. Understand habitat
2.2B) Understand that plants and animals have different characteristics and many are inherited
2.2C) Understand basic ways organisms are related to environment and other organisms

Vocabulary: above-ground part, below-ground part, plant, root, soil, stem

Materials

In this trunk…	***… where?[47]***	***You must supply***
8 plant specimens from *Buried Treasures*: arrowleaf balsamroot, pinegrass beargrass, serviceberry fireweed, smooth woodrush glacier lily, wild onion	*Buried Treasures Box,* Main/B	8 large grocery bags scissors tape marker pencils
Pages from the *FireWorks Notebook* about each of these species	Teacher/C	drawing paper for each student

[46] See Appendix 4 for links to Montana educational standards, grades K-4.
[47] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Preparation

Get eight of the plant specimens out of the *Buried Treasures Box*. Each specimen is labeled by a number. You need all of them except #8, which doesn't show the plant roots so it wouldn't be useful in this activity. Class Page 9 lists the number codes and species names of the Buried Treasures. Prepare each plant specimens as follows:

1. Lay a grocery bag on its side.
2. Cut a line from the open edge of the bag to the middle of a flat side.
3. Cut a hole in the bag that is *just the right size* to go around the plant specimen's stem.
4. Place the specimen in the hole with its underground parts hidden inside the bag.
5. Tape around it to secure the hole shut.
6. Write the plant's name on the outside of the bag. Plant names are listed on Class Page 9 (page 119). Shorten the name if you wish; "glacier lily" could just be labeled "lily."
7. Place the 8 bags at 8 stations around the classroom. Next to each specimen, place the page from the *FireWorks Notebook* that describes that species and shows a picture.

Procedure

1. Give each child a large piece of drawing paper. Show students how to fold it into 8 sections.
2. Explain: This activity lets students learn about underground plant parts.
   - Do they know the names of any underground plant parts? (They are likely to mention roots. Bulbs are a good possibility. There are many others, including *corm* and *rhizome*, defined in the *FireWorks Glossary*—in the *Library*.)
   - What are those parts for? (For holding the plant in place, obtaining water and nutrients, storing nutrients for reproduction and more growth—like leaves in the spring, and protecting the plant when conditions above-ground are too dangerous—like during winter and during fires.)
3. Ask students to take the next 15 minutes and circulate to a certain number of stations. You decide how many stations are feasible—all 8? two? as many as they can get to? At each station, they should copy down the plant's name. Then they should look carefully at the plant's above-ground parts. both the specimen and the photo from the *FireWorks Notebook*, and sketch them. Finally, they should try to imagine what the plant is like below ground and sketch their idea of what the plant looks like underground. They can use a lot of imagination for this step. If they have never learned about underground plant parts before, they should think about what those parts *do* and design structures to carry out those functions.
4. One at a time, open the bags and show students the plant specimens. Ask them to compare the plants' real belowground structures to their drawings.

Evaluation: Draw two plants—both the aboveground and belowground parts. One should be able to survive fire because of its belowground parts; label it "Survivor." The other should be unable to survive fire; label it "Non-Survivor."

Closure: Share some of the drawings from **Evaluation**. Ask how a Non-Survivor might continue to live in a place where fire occur. (Clever seed storage and rapid seed dispersal are two possibilities—see **Extension 1** below.)

Explain that students may be using belowground plant parts every day: onions! Slice some onions in half and distribute to the students on paper plates. Ask them to examine the roots and the small shoot at the top of the onion. Suggest that they peel some of the leaves (yes, they really are a special kind of leaf) to examine the many layers of the onion.

Finally, explain that collections of plants, like the one used in this activity, should be made in a responsible way. Plants should be collected for a useful purpose such as learning or research. A collection should benefit as many people as possible. A plant collector should have permission from the land owner before taking any plants. If permission is granted, he or she should be careful to take only specimens of common plants. Use the "1-in-20" rule: If a plant has 20 leaves, collect no more than 1. If it has 20 flowers, collect no more than 1. If 20 specimens are present on a site, collect no more than 1.

Extensions

1. Read in the *FireWorks Notebook* about the ways in which **fireweed, snowbrush *Ceanothus*, and lodgepole pine** reproduce from seed after fire.
2. If flower bulbs are available, purchase a few, show them to the class, and then plant and care for them, watching them sprout new plants from belowground parts over the next few weeks.
3. Learn how to make new soil or make a "hollow log home" in *Exploring Wood* (in the *Teacher Box*), pp. 50 and 51.
4. Make one of the Forest Art projects ("mossy branches" or "mushroom prints") described on p. 51 of *Exploring Wood* (in the *Teacher Box*).

Activity 6-3. For Elementary and Middle School: Buried Treasure

Grade levels:
X Elementary
X Middle

Figure 18—High school student examines rhizomes of beargrass plant.

What's the Point?

One important way that plants survive fire is by "hiding" underground. Many plants have underground stems that are protected from fire by the soil. Examples are *rhizomes* and *bulbs.* A fire may kill all of a plant's aboveground parts (leaves, growing-point buds, and cambium), but if its underground parts survive it may be able to sprout a new stem and leaves.

In this activity, students use a description of a plant species from the *FireWorks Notebook* to identify species and examine underground plant parts (fig. 18). Then they dissect a bulb, and they may examine bulbs that were planted earlier to look for developing stems and leaves. They learn that, even if a plant is completely killed by fire, its seeds may survive and begin to grow afterward, so it does not disappear from the burned area.

Teacher's Map:

Objective: Given a description of a species and its ways to survive fire, students can identify the species from a small collection.

Subjects: Science, Reading, Speaking and Listening, Library Media, Arts, Workplace Competencies

Duration: 30 minutes

Links to Standards[48]:

National Science Teachers' Association—Grades K-4:

C2) Identify structures of various organisms and the needs they serve
F5) Understand that changes in environments can be slow or rapid; rate has consequences

National Science Teachers' Association—Grades 5-8:

C6) Understand nature of populations and classification

North American Association for Environmental Education—Grades K-4:

0A) Identify basic kinds of habitat and plants and animals living there
1C) Collect information about environment
2.2A) Understand similarities and differences among variety of organisms. Understand habitat
2.2B) Understand that plants and animals have different characteristics, many of them inherited
2.2C) Understand basic ways organisms are related to environment and other organisms

North American Association for Environmental Education—Grades 5-8:

1E) Classify and order data, organize and display information
2.2A) Understand biotic communities and adaptations

Vocabulary: adaptation, bud, bulb, corm, reproduction, rhizome, root, seed, sprout, survival, trait

Materials

In this trunk…	***… where?[49]***	***You must supply***
Plant specimens	*Buried Treasures Box,* Main/B	Copy of Class Page 9, *Plant Species Codes*, for Teacher Team
FireWorks Notebook—pages describing arrowleaf balsamroot beargrass fireweed glacier lily pinegrass serviceberry smooth woodrush snowbrush *Ceanothus* wild onion	Teacher/C	OPTIONAL: Prize for most species correct or first team to get all species correct

Preparation

Ask a team of 3 to 5 students to do the teaching in this activity. Divide the rest of class into teams of 2 to 3.

Give the teaching team the *Buried Treasures* box, the *FireWorks Notebook,* and the list of plant codes and species on Class Page 9. Ask them to study these materials and then prepare a presentation (no longer than 4 minutes) about each species and how it reacts to fire, survives, and reproduces. They should pay special attention to the sections about *reproduction* and *fire* in the *FireWorks Notebook*. They should write their plant's name on the board at the start of their presentation; they should practice making the presentation so they can do it within 4 minutes. Explain that you will stop them in the middle if they go over the time limit.

[48] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.
[49] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Procedure

1. Explain that class members will play several "roles" in this activity. First, one team of students will be *teachers*; they will present information, answer questions, and help students solve problems. The rest of the class will be *botanists*; they will use information presented by the teachers to identify plants and examine the traits that enable them to survive fires.
2. Explain: The Teacher Team will teach the Botanist Teams about nine plants. These are different plants from the Mystery Trees studied in Chapter 4). None of the Mystery Trees could survive fire if their tops were killed; all of these plants can. The Botanists will use what they learn to identify nine plants. The Botanists should take notes or make drawings during the presentations. If the Teacher Team says something or uses a term that they don't understand, the Botanists should ask for clarification.
3. Ask each Botanist Team to prepare a piece of paper numbered 1-9, with names at the top.
4. Ask the Teacher Team to make their presentations and show the plant specimens to the class. Be careful to limit the length of their presentations to 4 minutes.
5. After the presentations, ask the Teacher Team to pass out the specimens, one to each Botanist Team, and then take the specimens from group to group as students finish examining them.
6. Ask the Botanist Teams to identify each specimen and write the name of the correct species on their team's paper. When they have identified all 9 plants, they should hand in their paper.
7. You can make this a contest: The Botanist Team with the most correct answers, or the first team with all correct answers, wins a prize.

Evaluation: Design a plant that can survive fire because of its underground parts. Draw the plant, give it a name, and identify its parts using correct botanical terms (stem, bud, root, rhizome, etc.). Look up correct terms in the *FireWorks Glossary*, a dictionary, or a science book.

Closure: Ask some students to show and describe their "Designer Plants." Number and display the posters in your classroom. Have students select the two or three that are most likely to survive fire.

Explain that collections of plants, like the one used in this activity, should be made in a responsible way. Plants should be collected for a useful purpose such as learning or research. A collection should benefit as many people as possible. A plant collector should have permission from the land owner before taking any plants. If permission is granted, he or she should be careful to take only specimens of common plants. Use the "1-in-20" rule: If a plant has 20 leaves, collect no more than 1. If it has 20 flowers, collect no more than 1. If 20 specimens are present on a site, collect no more than 1.

Extensions

1. Find out what states the plants represented in this activity occur in, using the U.S. Department of Agriculture's "plants" database, on the Internet at http://plants.usda.gov
2. Use the same Internet site to find out if the plant genera represented in this activity (*Allium, Amelanchier*, *Balsamhoriza, Calamagrostis, Ceanothus, Epilobium, Erythronium*, *Luzula,* and *Xerophyllum*) contain other species and, if so, to learn about their locations.

Plant Species Codes for "Buried Treasures"

Each plant in the *Buried Treasures* Box has a number marked on it or attached to it. Here are the species for those code numbers:

1..	Arrowleaf balsamroot
2.	beargrass
3.	fireweed
4.	glacier lily
5.	pinegrass
6.	serviceberry
7.	smooth woodrush
8.	snowbrush *Ceanothus*
9.	wild onion

Activity 6-4. Tree Skin

Grade levels:
X Middle
X High

What's the Point?

Bark thickness influences a tree's ability to insulate its cambium from heat. It is not the only influence, of course; presence of pitch and bark density also influence a tree's resistance to heat damage, and other parts of a tree (buds, roots, seeds) are also vulnerable to fire. In this activity, students use a "model" tree trunk (coffee can wrapped in newspaper) and "model" tree bark (quilt batting of various thicknesses) to measure the rate and extent of temperature increase due to heating.

This activity can be done in several ways. The *FireWorks* trunk provides ***only one*** set of supplies. You can use either Student Page 16 to look at the effect of insulation in small increments, or Student Page 17 to simplify the procedure and look at just two thicknesses of insulation. We suggest you demonstrate this activity by obtaining one set of measurements (for one thickness of insulation), then set it up as an activity center (perhaps using Activity 7-5, "Puzzling It Out," as another center). You can run the activity center for contract learning by providing blank data sheets (Student Page 16), then agreeing with students that they can collect 5 lines of data for an A, 4 lines for a B, etc.

Teacher's Map:

Objective: Given several measurements of insulation or tree bark thickness, students can predict that thicker insulation (or bark) will cause temperature changes to be slower but last longer.

Subjects: Science, Mathematics, Speaking and Listening, Technology, Workplace Competencies

Duration: 30 minutes to complete entire data table (Student Page 16), 10-15 minutes to complete short data table (Student Page 17)

Links to Standards[50]:

National Science Teachers' Association—Grades 5-8:

A1) Identify questions that can be answered scientifically
A2) Design and conduct a scientific investigation
A4) Think critically to establish relationships between evidence and explanations
A6) Use mathematics in science
B1) understand properties of matter
B2) Describe physical and chemical changes
B3) understand that energy is transferred in many ways
C1) Describe structure and function in a living system
G1) Understand that scientists work alone and in teams

National Science Teachers' Association—Grades 9-12:

A2) Design and conduct experiment, use mathematics and models to explain results

[50] See Appendix 4 for links to Montana educational standards, grades 5-8, 9-12.

cont'd.

A4) Use technology, mathematics, logic and previous research in investigations
North American Association for Environmental Education—Grades 5-8:
1C) Locate and collect reliable information about environment
1E) Classify and order data, organize and display information
1G) Synthesize observations into coherent explanations
2.1C) Understand energy transfer
2.2A) Understand biotic communities and adaptations
2.2D) Understand how energy and matter flow in environment
North American Association for Environmental Education—Grades 9-12:
0B) Investigate short- and long-term environmental changes
1C) Collect reliable information, using technology as needed to gather and display data
1E) Organize and display information
1G) Use evidence and logic to develop hypotheses
2.2D) Use interaction of matter and energy to explain environmental characteristics

Vocabulary: cambium, heat, insulation, temperature, thermocouple. thermometer

Materials

In this trunk...	***...where?***[51]	***You must supply***
Hair dryer	Main/A	Masking tape
Digital thermometer	All in *Hardware Box,* Main/A	Graph paper (1 page/student or team)
Coffee can (1.5 pound)		Clock with second hand
Rulers, 15-cm		5 layers of newspaper large enough to cover the coffee can
Tree trunk sections (9)	Main/A	Copy of Student Page 16 or 17 for each student or team
"Tree Skin" insulation (fabric pieces and quilt batting)	Main/A	Overhead projector and pens

Preparation

1. Check the battery of the digital thermometer. Have a 9-V battery and a screwdriver on hand in case it quits during the experiment.
2. Ask one or two students to refer to the data collected in *Mystery Trees* (Activity 4-4) and write on the board each species' name and its bark thickness, in cm.
3. Use masking tape to attach 5 layers of newspaper to the coffee can.

> **INFO SPARK:** If you have a digital thermistor/data logger and spreadsheet software, you may want to use that equipment for this experiment instead of having students graph data and calculate averages manually.

Procedure

1. Set the papered coffee can on a demonstration bench so the class can see it. Place the cloth samples on one side.
2. Plug the thermocouple wire into the digital thermometer. Place it on the other side of the coffee can.

[51] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

3. Plug in the hair dryer.
4. Assign students to the following tasks:
   - Heater: Hold the hair dryer 5 cm from the *surface* of the coffee-can tree (he or she should measure the distance with a 5-cm ruler). Keep this distance constant, no matter how much insulation is placed between the tree's *surface* and the thermocouple itself. You are measuring the ability of the "tree" to insulate its cambium, not its ability to insulate the outer bark.
   - Reader: Hold the digital thermometer so students can see it. Call out "official" temperature every 15 seconds
   - Timer: Call out "time" every 15 seconds during the 4-minute experiment, as follows: "Go"... then "15"... "30"... "45"... "1 minute"... "15"... "30"...
   - Recorder: Record temperature on transparency at start of experiment and every 15 seconds throughout the 4 minutes
5. Use masking tape to attach the thermocouple to the newspaper covering the can. The coffee can represents the tree’s inner wood. The newspaper represents the tree’s cambium layer. The brown cloth, with various levels of insulation, represents tree bark (fig. 19).
6. Do the following steps 2 or 6 times, depending on whether you want to use Student Page 16 or 17. (Student Page 17 takes less time than 16 and makes the point that increased insulation decreases the rate of temperature increase. However, Student Page 17 will not enable you to observe that temperature *decay* is also retarded by increased insulation.) Do the experiment the first time with only the brown cloth covering the thermocouple, then once with each set of quilted materials (brown side out).

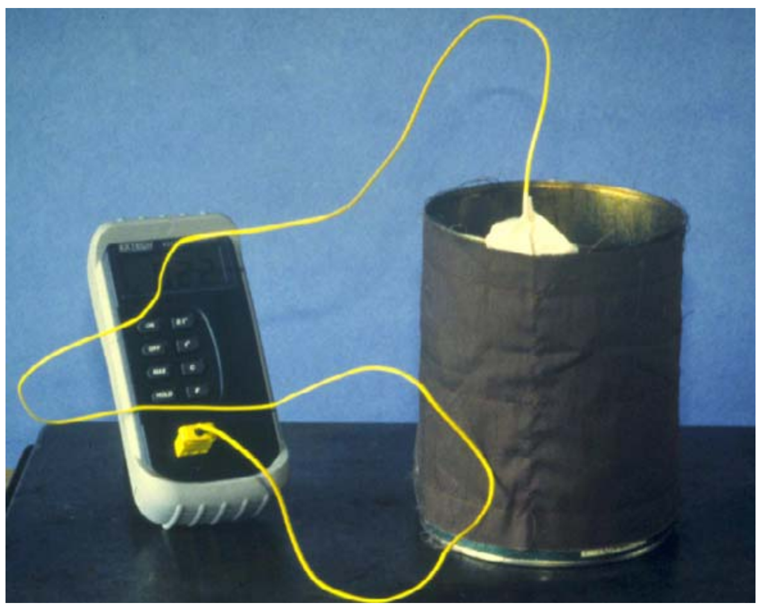


Figure 19—Experimental setup for “Tree Skin” activity. Coffee can is model of tree trunk, with thermocouple attached under cloth insulation (bark) to observe temperature change at “cambium.”

   a) Reader, turn the digital thermometer "on," and call out the temperature.
   b) Recorder, write this temperature down at "time=0."
   c) Timer, say "Go"... Then, every 15 seconds throughout the experiment, call out the time.
   d) Heater, when Timer says “Go,” turn the hair dryer on the “high” position. Hold it 5 cm from the brown cloth **until the Timer says “30.”** **<u>Then turn it off!</u>**
   e) Recorder, every 15 seconds record the temperature that the Reader calls out.
7. Ask students to graph the data, with “Time” in 15-second intervals on the X axis and “Temperature” on the Y axis, as illustrated in fig. 20.
8. Ask the class to discuss explain the time-temperature traces on their graphs. (Main points to notice: The thinner the insulation, the faster the thermocouple temperature rises and the

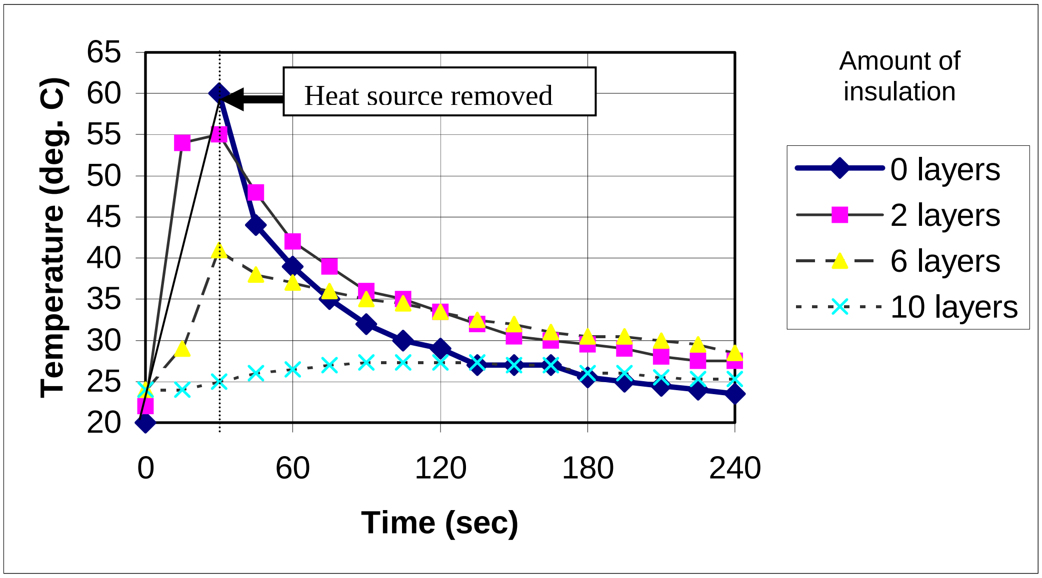


Figure 20—Graph of sample data from "Tree Skin" with 4 levels of insulation.

higher it goes. The thicker the insulation, the slower the temperature rises <u>and falls</u>; in fact, the temperature may continue to rise even after the heat source—hair dryer—is removed.)

Evaluation: Does thick bark protect a tree from all three kinds of fire—surface, crown, and ground fire? Write a paragraph to explain your answer. It should contain at least one sentence about each kind of fire. (Thicker bark usually means greater protection against surface fire. Surface fires usually burn past a tree quickly, and thick bark keeps the temperature at the cambium from rising very fast. If the fire is burning through the crowns of the trees, it will kill the leaves and thick bark will be no defense against that. Ground fires burn very slowly. If a source of heat is long-lasting, like a ground fire, it may heat the bark enough to kill the cambium cells. A ground fire may also heat the soil so much that a lot of roots are killed, so thick bark isn't a very good defense against ground fire.)

Closure: Use these questions to guide further discussion.

Based on bark thickness alone, rank the trees studied in *Mystery Trees* according to their resistance to damage from fire.	Results depend on the specimens in your trunk. Ponderosa pine, western larch, and Douglas-fir are well known for their thick bark, especially when old; subalpine fir and quaking aspen usually have thin bark.
What other properties of bark might make some trees more vulnerable or more resistant to damage from fire? How could you test these hypotheses?	Pitch on the bark makes it flammable and less fire-resistant. Scars from old wounds may have little or no bark covering them, so the area around them has little protection. Different tree species have bark of different colors and densities, which affect heat transfer.

Extensions

1. Suppose you read an article in the newspaper reporting that a team of scientists has developed a new kind of tree. It will grow much thicker bark than any other species in your area and they think it will be able to survive fires that other species in the area can't. Local people are suggesting that this new species be planted in the public wildlands of your state. Do you think that is a good idea or a bad idea? Write a letter to the editor about the proposal. Explain your reasoning.
2. If your class does the "Tree Skin" activity in teams, treat each set of student data as a replication of the experiment. Use a spreadsheet to calculate the average value for each observation, then graph the results. Discuss this data summary with the class. Here are some possible lead questions:
   a) In what ways is the graph of averages more useful or more informative than the individual graphs?
   b) What information is lost in the graph of averages?
   c) Are there ways to show "lost" information on the graph of averages?
   d) Do any of the averages seem affected by "outlier" data points, data that seem unreasonable and might be observational errors?
   e) What should a scientist do with outlier data?

Student Page 16

Cambium Temperature of Coffee-Can Tree

Time (sec)	Layers of Insulation					
	0	2	4	6	8	10
0						
15						
30						
45						
60 (1 min)						
75						
90						
105						
120 (2 min)						
135						
150						
165						
180 (3 min)						
195						
210						
225						
240 (4 min)						

Student Page 17

Cambium Temperature of Coffee-Can Tree

Time (sec)	Layers of Insulation	
	0	2
0		
15		
30		
45		
60 (1 min)		
75		
90		
105		
120 (2 min)		
135		
150		
165		
180 (3 min)		
195		
210		
225		
240 (4 min)		

Activity 6-5. Recipe for a Lodgepole Pine Forest

Grade levels:
X Elementary
X Middle

What's the Point?

Lodgepole pine forests cover very large areas in the West. Most of these forests began after fire sometime during the past 150 years. Many of the fires were very severe, at least in patches. These forests will probably burn again in the next century, as they have for hundreds of years. A few years after fire, most burns in lodgepole pine are home to millions of lodgepole pine seedlings. Why? This species stores much of its seed in resin-sealed cones that stay on the tree for many years. They open when heat melts the resin and frees the seeds. In this activity, students extract the seeds from lodgepole pine cones and study and count them. As an extension, students may plant the seeds and see how many germinate.

This activity has four parts. The last two are optional:

- Treat the cones with hot water so they will open
- A day or two later, remove seeds from cones and count them
- Prepare seed and plant it
- Study germinating trees

Teacher's Map:

Objectives: Given a collection of lodgepole pine cones, students can open them and extract see, identify filled vs. empty seed, build a histogram from the data, and interpret it.

Subjects: Science, Mathematics, Writing, Speaking and Listening, Technology, Workplace Competencies

Duration: 30 minutes

Links to Standards[52]:

National Science Teachers' Association—Grades K-4:

A1) Ask a question about the environment
A2) Plan and conduct simple investigation
A3) Use simple equipment and tools to gather information
A4) Use data to construct an explanation
A5) Communicate investigations and explanations
B3) Demonstrate production of heat, conduction and convection
C1) Identify needs of various organisms
C2) Identify structures of various organisms and the needs they serve

National Science Teachers' Association—Grades 5-8:

A1) Identify questions that can be answered scientifically
A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations

[52] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

cont'd.

A5) Communicate procedures and explanations
A6) Use mathematics in science
C1) Describe structure and function in a living system
C4) Recognize that ability to obtain resources, grow, reproduce… are essential for life
C8) Recognize that population size depends on resources
F6) Recognize difference between science questions and other questions

North American Association for Environmental Education—Grades K-4:

0A) Identify basic kinds of habitat and plants and animals living there
1A) Develop questions to learn about environment
1B) Design simple investigations
1C) Collect information about environment
1D) Understand need for reliable inforation. Judge merits of information
1E) Describe data, organize information to search for patterns
2.2A) Understand that plants and animals have different characteristics and many are inherited
2.2C) Understand basic ways organisms are related to environment and other organisms

North American Association for Environmental Education—Grades 5-8:

0A) Classify local ecosystems. Create food webs
1A) Develop, focus and explain questions about environment
1B) Design investigations to answer questions
1C) Locate and collect reliable information about environment
1D) Judge weaknesses and strengths of information being used
1E) Classify and order data, organize and display information
2.2A) Understand biotic communities and adaptations
2.2B) Understand importance of genetic heritage and traits

Vocabulary: cone, embryo, experiment, filled seed, histogram, hypothesis, maximum, mean, median, natural selection, observation, serotiny, trait, viable

Materials

In this trunk...	***...where?***[53]	***You must supply***
Lodgepole pine cones	*Fuels Box*, Main/B	one sticky note for each student, 7.5 x y.5 cm
Cones examined in *Mystery Trees* (Activity 4-3 or 4-4)	*Tree Cones Box*, Main/A	aluminum pie tins (2-4), 8- or 9-inch diameter
Lodgepole Pine Seed, Sasquatch National Forest transparency (Student Page 18)	*Visual Aids & Handouts*, Teacher/C	spoons (2-4)
		paper plates (1 per student)
		flipchart paper
Optional: *Lodgepole Pine Data* transparency, Class Page 10; and *Lodgepole Pine Seed Production* transparency, Class Page 11	*Visual Aids & Handouts*, Teacher/C	boiling water
		overhead projector, pens
		Optional: Copy of Student Page 19 for each student

[53] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

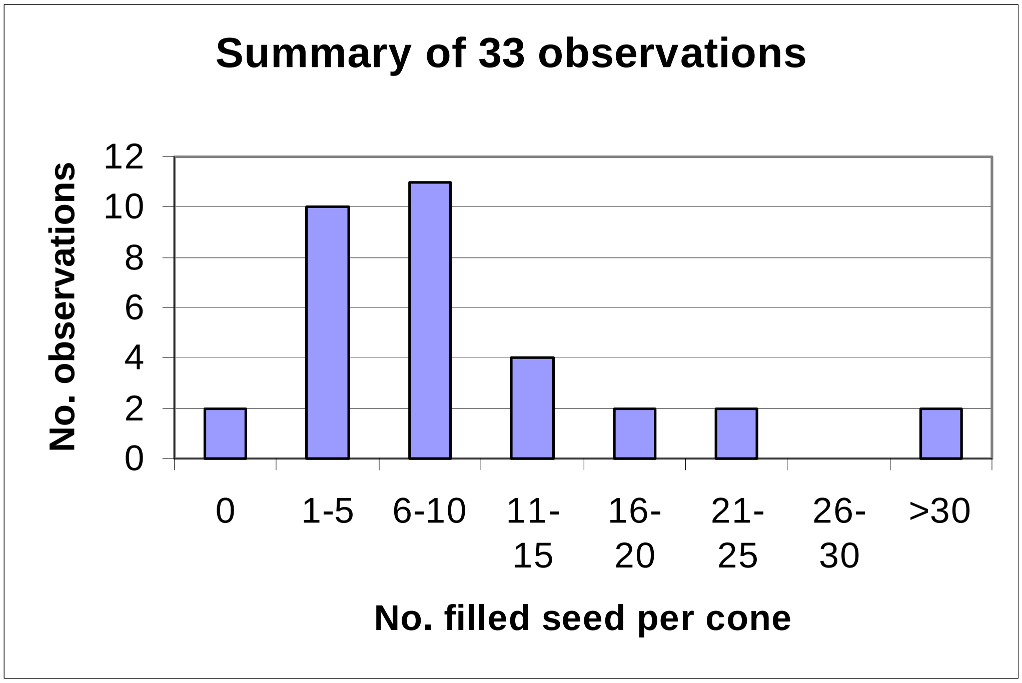


Figure 21—Sample histogram from this activity. Data were collected by a class of eighth graders.

Preparation

Set up your classroom with 2 to 4 activity stations. At each station, place a pie tin, a spoon, and several paper towels.

Use a flipchart page (about 40 X 40 inches) to make an outline for a histogram like the one in fig. 21. Make the bars 7.5 cm wide, or the same width as your sticky notes. Label the y axis so that a count of “1” is 7.5 cm above the x axis, a count of “2” is 15 cm above, a count of “3’ is 22.5 cm above, etc. Thus each “cell” in the graph is the size of a sticky note. **Alternative:** If you want students to analyze the data and design the histogram independently, use the *Lodgepole Pine Data* transparency (Class Page 10) for gathering data. If you don’t want to bother with the flipchart graph, you can draw the histogram on Class Page 11, *Lodgepole Pine Seed Production.*

Prepare boiling water.

Procedure

1. On the board, make two columns: *Hypotheses* and *Experiments*.
2. Distribute lodgepole pine cones—at least one per student. Give each student a sticky note.
3. Ask students to notice that the cones are tightly closed, unlike cones from most other trees. This property is called cone *serotiny*. Pass around the cones used in *Mystery Trees* (Activity 4-3 or 4-4) for comparison. Explain that *some* lodgepole pine cones do open at maturity, unlike those in this activity. Cone serotiny varies a great deal from one location to another.
4. Ask for ideas about how the closed lodgepole pine cones might be opened in nature (*hypotheses*), and how they could test these ideas (*experiments*). Write the hypotheses and experiments on the board. Hope that "heat" or "fire" is on the list.
5. Test the hypotheses related to heat by using the following recipe:

- Pour boiling water into a pie tin.
- Place lodgepole pine cone in the water for 20 seconds, then remove with a spoon. While it is in the water, pay attention to what you see and hear (fig. 22) (The resin closing the cones is melted by the hot water, and expanding air begins to come out of the cone, making tiny bubbles and popping noises.)
- Place cones on a paper towel and leave in a warm, dry place overnight.
- Shake and tap each cone over a paper plate to catch the seeds. If they don't come out easily, roll the cone back and forth on the paper plate.
- Examine the seeds carefully. Those that are "filled" contain a tree *embryo*. Filled seeds have a rounded brown lump, about 2 mm across, attached to the papery wing. Throw away unfilled seeds.
- Write your name on the sticky note. Count the filled seeds and write the number on your sticky note. Make it big, readable from across the room. **Even if there are no filled seeds, write it down**!

6. Place each sticky note in the correct histogram column (above the number range that includes that count). For instance, a sticky note that says "8," meaning 8 filled seeds were found, should be placed in the column "1-10." Place the sticky notes on the histogram from the x-axis up, like building blocks. This way, the data themselves build the bars of the histogram. Since each student wrote a sticky note, the count along the y axis is clearly not a number of seeds but a number of *observations.*

Figure 22—First graders retrieving their lodgepole pine cones from pan of water.

7. Analyze and discuss the data and the histogram.
   - How common are trees with no seeds?
   - What is the largest number (*maximum*)?
   - Calculate the *average* and *median*, and discuss the meanings of these numbers.
   - Why does the number of filled seed vary from cone to cone? (Genetics, location, soil, weather, and chance all affect cone and seed production.)

Evaluation:

Elementary Level: Provide each student with a copy of Student Page 18, *Lodgepole Pine Seed in the Sasquatch National Forest.* Explain that students need not do the whole assignment on the page. Instead, they should answer three questions:

1. How many cones had no filled seed at all? (2)
2. How many cones had more than more than 20 seeds? (2+2=4)

3. How many cones had between 1 to 10 seeds? (10+11=21)

Middle School Level: Assign Student Page 18, *Lodgepole Pine Seed in the Sasquatch National Forest*. A student completes the worksheet successfully if he or she answers clearly ("I'm worried about getting a new forest there" or "I'm not worried about it") and uses information from the histogram to explain his or her reasoning. Here are two successful answers:

- "I'm not worried because nearly a third of the cones I collected had more than 5 seeds in them."
- "I'm worried because some of the cones I collected had no seed at all."

Closure: Ask the class to recall from studying tree cookies (Activity 5-1 or 5-2) what kinds of fires occur in lodgepole pine forests. Ask: Based on this information, would serotinous cones be a useful *trait* in other kinds of forest, like the ponderosa pine forests of the past? (Serotinous cones serve as a seed reservoir in forests burned by crown fire—a reservoir that becomes available right after the fire. In forests that experienced few crown fires, like historic ponderosa pine forests, serotinous cones would trap seeds in the tree crown, making them unavailable to germinate on the ground. Since crown fires were unusual in historic ponderosa pine forests, *natural selection* would not favor ponderosa pines with the *trait* of serotiny.)

Extensions

1. In Step 4 above, students are likely to come up with some hypotheses that can easily be tested in the classroom. "Animals pound or bite them open"... and "Water opens them..." are two possibilities. As the students to design experiments to test these hypotheses; help them make sure their experiments are *controlled,* varying only one factor at a time. Help them set up and carry out the procedures. Ask them to present their results to the class.
2. Use the *Lodgepole Pine Facts* and observations from your experiments to answer the questions on *Lodgepole Pine Challenge* (Student Page 19). If you do this activity, here are some hints about solving the math problems:

   Question 4. (500+1000)/2 cones/tree * median number of seeds/cone

   Question 5. (1500+4000)/2 trees/hectare * (classroom area, m^2)/(10000 m^2/ha)

   Question 6. (answer from #5) * (answer from #4) * 20 years
3. Plant the seeds from this experiment.
   a) Rub each filled seed gently to break off its papery wing.
   b) Wrap all seeds in a moist paper towel and place in an unsealed plastic bag.
   c) Store in refrigerator for 4 weeks. Keep moist but <u>not wet</u>.
   d) Place potting soil 5-10 cm deep on the bottom of a clay pot.
   e) Place seeds on this soil and cover with 2 mm more of soil.
   f) Place in a warm, sunny place. Mist with a spray bottle every day or two to keep soil moist <u>but not wet</u>. Wait 4 to 8 weeks for seedlings to emerge.
   g) Measure germination success.

Class Page 10

Lodgepole Pine Data

Name ______________________________

1. List the number of seeds in each cone. If someone found no filled seed in a cone, record a "0." If most of the trees in a forest are producing no live seed, that's important to know.

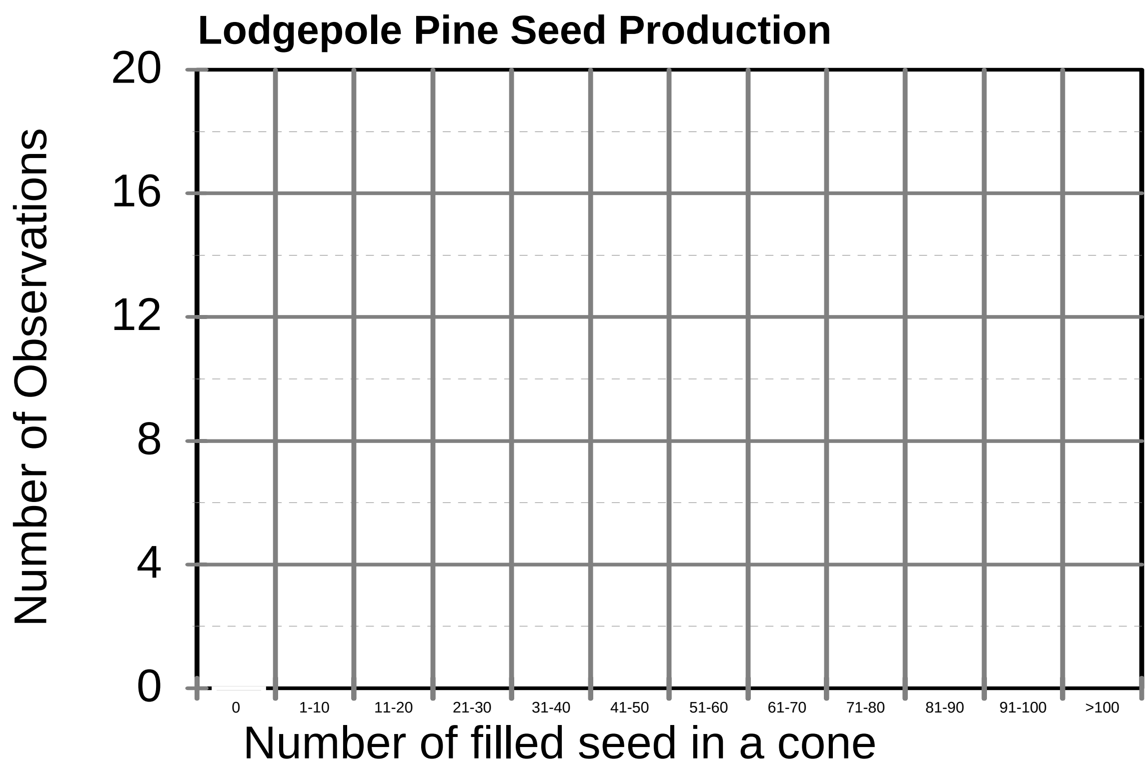
2. Count the number observations from above that showed zero seed, the number with 1-10 seeds, etc.

No. of seed/cone	Number of students finding that many seeds/cone
0	
1-10	
11-20	
21-30	
31-40	
41-50	
more than 50	

3. Show your results on a bar graph. Write "Number of observations" along the Y axis. Write "Number of Seeds per Cone" along the X axis. Write these categories along the X axis: 0, 1-10, 11-20, 21-30, 31-40, 41-50, >50. Draw bars that show the results of your tally. This kind of graph is called a "histogram."

Class Page 11

Lodgepole Pine Seed Production: *Histogram* of Seeds per Cone

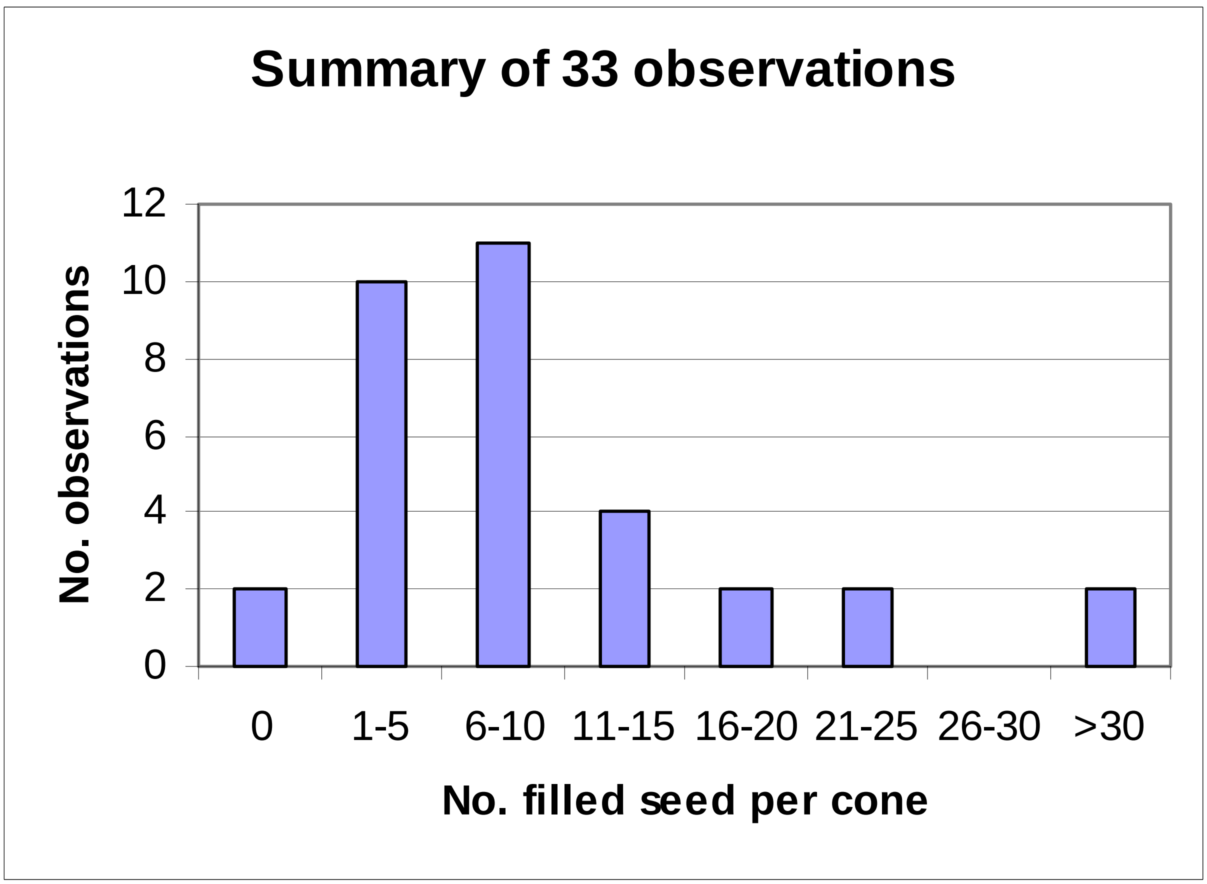


Student Page 18

Lodgepole Pine Seed in the Sasquatch National Forest

Name ____________________

You are a forester working in the Sasquatch National Forest. A large area of lodgepole pine burned in your forest last year, and you wonder how many seeds are available to produce new trees. You visit an unburned area right next to the burn, collect 33 cones, use heat to open them, shake the seeds out, and count the seeds. You display your results in the histogram below. Do you think your burned forest will grow plentiful new trees, or are you worried about the next forest to grow there? Write your answer below in one or two complete sentences. Explain how you used your data to reach that conclusion.



Student Page 19

Lodgepole Pine Challenge

Name ____________________

PINE FACTS

- An average lodgepole pine produces 500 to 1,000 cones every year.
- More than half of the cones in a lodgepole pine forest may be resin-sealed.
- Much of the seed in resin-sealed cones stays *viable* (able to grow) for 20 years or more. Some lodgepole pine seed has germinated after 150 years!
- 1,500 to 4,000 lodgepole pine trees may live in an area 100 by 100 meters (This area is a "hectare," an area a little bigger than a football field.)
- Lodgepole pine trees live about 100 to 150 years. Grown trees are often killed by mountain pine beetles or by fire.

ECOLOGY CHALLENGE

Use **your class's data, the facts** above, and **your thinking skills** to answer these questions. If you don't know an answer, think of an experiment that would help you find the answer.

1. How well does hot water, like you used in the experiment, mimic fire?
2. How well does a refrigerator mimic winter?
3. Why do lodgepole pine seeds have wings?
4. How many seeds might be produced by a whole lodgepole pine tree in one year?
5. How many grown lodgepole pines are likely to live in an area the size of your classroom?
6. If a crown fire occurs in a patch of forest as big as your classroom, how many tree seedlings would you probably find the next year?
7. What happens to keep some seedlings from growing into large trees?
8. Why are resin-sealed cones and long-lasting seeds useful traits for lodgepole pine?
9. Ask another question about lodgepole pine. Can you answer it? If not, can you think of an experiment that will help find the answer?

Activity 6-6. Designer Trees

Grade level:
X Elementary

What's the Point?

Students design a tree that is well suited to a particular environment. Their choices are guided by their understanding of plant adaptations to fire and by the constraints of limited resources. Resource limitations are represented in this activity by a budget of "sun dollars" to be spent and traded for traits that enable their "designer tree" to survive or reproduce well after fire.

Teacher's Map:

Objective: Given a limited amount of resources and a particular environment, students will identify traits that enable tree species to survive or reproduce well after fire.

Subjects: Science, Mathematics, Writing, Speaking and Listening, Arts, Workplace Competencies

Duration: 40 minutes

Links to Standards[54]:

National Science Teachers' Association—Grades K-4:

C1) Identify needs of various organisms
C2) Identify structures of various organisms and the needs they serve
F3) Understand that resource supplies are limited

National Science Teachers' Association—Grades 5-8:

A6) Use mathematics in science
C1) Describe structure and function in a living system
C4) Recognize that ability to obtain and use resources, grow, reproduce … are essential for life

North American Association for Environmental Education—Grades K-4:

0A) Identify basic kinds of habitat and plants and animals living there
2.2A) Understand similarities and differences among variety of organisms. Understand habitat
2.2B) Understand that plants and animals have different characteristics and many are inherited
2.2C) Understand basic ways organisms are related to environment and other organisms

North American Association for Environmental Education—Grades 5-8:

2.1C) Understand energy transfer
2.2A) Understand biotic communities and adaptations
2.2B) Understand importance of genetic heritage and traits
2.3C) Understand political and economic systems and relationship to environment

Vocabulary: reproduction, resource, trait

[54] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

Materials

In this trunk…	*… where?*[55]	*You must supply*
Designer Trees Kit	Teacher/C	Large paper for drawing
Designer Tree Rules transparency (Class Page 12)	*Visual Aids and Handouts*, Teacher/C	Masking tape

Procedure

1. Select a **Resource Banker**. This person displays the Resource Bank sign from his or her desk and sets up "sun dollars" for distribution.
2. Select a **Tree Trait Store Manager**. This person displays the Tree Trait Store sign at his or her desk, displays the Price List where it will be easy for students to see, and sets up Tree Trait cards for sale. He or she should obtain about $5,000 from the Banker for change, mostly in $100s. The Banker and Store Manager can be the same person.
3. Designate 6 to 12 teams of students as Tree Designers. For 6 teams, use only one set of Place Cards and Tree Trait cards. For 7 to 12 teams, use two sets.
4. Shuffle the Place Cards and place them upside-down on a desk.
5. Display *Designer Tree Rules* (Class Page 12); use it to go over the game rules with the class.
6. Have each Tree Designer team draw a Place Card. The card describes the location for which this team will design a tree. The location may be at a low or high elevation, it may have infrequent or frequent fires, and it may have poor or rich soil (table 10). Some locations have more resources available for plants than others. The Place Card states how many sun dollars the team can get at the Resource Bank for this location.
7. Have each Tree Designer team visit the Bank and collect the sun dollars allowed on their Place Card.
8. Have each team plan the Tree Traits that will enable a tree living at their special location to survive fire, reproduce well after fire, or both. As students plan their budget or after it is complete, they can visit the Tree Store to buy Trait Cards. Table 11 provides a price list. A team can return any Trait Card to the bank for a refund. If you want to complicate the math a bit, have the Banker charge a service fee—a price of $25 or 10% of the original purchase price—for any Trait Card returned. Teams can trade and buy Trait Cards from each other and bargain over prices.
9. When a team has finished buying and bargaining for Traits, have them draw a diagram of their Designer Tree at its special place. On the diagram, they must include all information on the Place Card and label every Tree Trait.

Evaluation: Each team should present and explain its Designer Tree to the class. Students can ask questions and assess the ability of the tree to survive and reproduce after fire.

Closure: Ask the students if any of the Designer Trees resemble real trees that they learned about in *Mystery Trees* (Activity 4-4). Discuss the similarities and differences.

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[55] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Table 10—Place cards in the *Designer Trees* game. The *Designer Trees Kit* in the Teacher Box contains two copies of each.

Site	Fire Pattern	Worth, Sun Dollars
Low elevation, long growing season Ordinary soil	Fires occur every 5 to 30 years. They often have low flames.	$900
Low elevation, long growing season Soil full of gravel, poor for growing trees	Fires occur every 5 to 30 years. They often have low flames.	$800
Low elevation, long growing season Soil rich in ash from ancient volcano, good for growing things	Fires occur every 5 to 30 years. They often have low flames.	$1,000
High elevation, short growing season Ordinary soil	Fires occur every 50 to 100 years. They often have very high flames.	$700
High elevation, short growing season Soil full of gravel, poor for growing trees	Fires occur every 50 to 100 years. They often have very high flames.	$600
High elevation, short growing season Soil rich in ash from ancient volcano, good for growing things	Fires occur every 50 to 100 years. They often have very high flames.	$800

Table 11—Tree trait cards in the *Designer Trees* game. The *Designer Trees Kit* in the Teacher Box contains 2 sets of each kind of card.

Trait	Cost in Sun Dollars	Number Cards per Set
Basic tree: roots, trunk, leaves	$300	6
Bark (purchase by the centimeter of thickness)	$20/cm	20
Extra thick buds	$100	3
Serotinous cones	$200	2
Extra fast-growing trunk and branches	$150	2
Produces seed and cones at a very young age	$150	2
Loses low branches easily but still grows well	$250	2

Extension

Design another fire-surviving plant using a lesson from Discovery Channel on the Internet site

pictures.discovery.com/dppages/wildfire/teacher/lesson1.html

Designer Tree Rules

Each Tree Designer Team:

1. Draw a Place Card. The card describes the place that you will design a tree for. The place may be at a low or high elevation, and it may have poor or rich soil. The Place Card states how many "sun dollars" you can get for your location at the Resource Bank. Some locations have more resources available for plants than others.

2. Visit the Bank. Obtain the money that your Place Card entitles you to.

3. Plan how to use your sun dollars to buy Tree Traits. Your Designer Tree should be able to survive the kinds of fires likely in your special place, or it should be able to reproduce well after fires, or both.

4. After you finish your budget, visit the Tree Store to buy Trait Cards.

5. You can return any Trait Card to the bank for a refund. The banker may charge a fee for returned cards.

6. You can trade or buy Trait Cards from other teams. If you bargain, both teams have to agree on the price.

7. When you have finished buying and bargaining for Traits, draw a picture of your Designer Tree in your special Place. Include all the information from your Place Card and label every Trait that you bought or traded for.

8. Present and explain your Designer Tree to the class.

Activity 6-7. Great Escape

Grade level:
X Elementary

What's the Point?

Students have been studying ways in which the plants of a forest community are affected by fire, and ways in which they can survive fire. This dialogue between students lets them think about the animals of the forest community and how they deal with the fires that shape their habitat.

Teacher's Map:

Objective: Given demonstrations of animal adaptations to fire, students can describe ways in which animals survive and reproduce in fire-dependent forests (by fleeing, avoiding heat in protected locations, or leaving eggs/larvae in protected locations).

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Social Studies, Technology, Library Media, Arts, Media Literacy, Health, Workplace Competencies

Duration: 20 minutes

Links to Standards[56]:

National Science Teachers' Association—Grades K-4:
A5) Communicate investigations and explanations
C1) Identify needs of various organisms
C2) Identify structures of various organisms and the needs they serve
C3) Identify relationship between senses and environmental cues
F2) Understand source of resources
F4) Understand changes in environments can be slow or rapid; rate of change has consequences

National Science Teachers' Association—Grades 5-8:
A4) Think critically to establish relationships between evidence and explanations
C4) Recognize that ability to obtain and use resources, grow, reproduce, and maintain internal stability are essential for life
C5) Recognize that behavior evolves in response to internal and external environment
F3) Recognize sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades K-4:
0A) Identify basic kinds of habitat and plants and animals living there
0C) Describe aspects that change on temporal basis
1C) Collect information about environment
2.2A) Understand similarities and differences among organisms. Understand habitat
2.2C) Understand basic ways organisms are related to environment and other organisms
2.2D) Know that living things need energy to live and grow

North American Association for Environmental Education—Grades 5-8:
1A) Develop, focus and explain questions about environment
1G) Synthesize observations into coherent explanations
2.2A) Understand biotic communities and adaptations
2.2B) Understand importance of genetic heritage and traits

Vocabulary: burrow, cavity, cavity nester, ecologist, surface fire, wildlife biologist, zoologist

[56] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

Materials

In this trunk...	*...where?*[57]	*You must supply*
FireWorks Notebook	Teacher/C	chalk & chalkboard

Preparation

Ask for nine student volunteers to help with teaching. Give This "Teacher Team" the *FireWorks Notebook* and ask each member to select an animal from the notebook and learn how that animal (American marten, Clark's nutcracker, elk, flammulated owl, grizzly bear, mountain pine beetle, red squirrel, pileated woodpecker, red-backed vole) survives or avoids fire. Explain that they must *pantomime* the way each animal deals with fire—not using any words. Students may work together in their pantomime demonstrations; one student may want to "be" fire, while others represent animals, plants, sheltered places, etc.

Procedure

1. Ask the class what people should do if a fire occurs in their school or home. (First and most important, get out of the building! Then go to a pre-determined location, and call for help.)
2. Ask the class how plants survive and reproduce after fires. Do they think animals have any such abilities?

   HINTS: Some plants have underground bulbs. Animals can use the underground part of the forest, too. (Many small mammals have underground runways and burrows. They escape fire by "holing up" while it passes over. Some do not survive, however, either because of heat or smoke.) Some trees have high crowns that stay above the flames from surface fires. Animals can use this part of the forest, too. (Birds that nest high in trees, especially those that use holes in the tree trunk—"*cavity nesters*"—can avoid surface fires.)
4. Ask members of the Teacher Team, one at a time, to write the names of their animals on the board and then pantomime for the class how that animal deals with fire. Then call on individual students to describe the survival/reproductive strategy or to ask questions, which the Teacher Team must answer *without words*. When the Teacher Team agrees that the class "gets it," have them write the survival/reproductive strategy on the board. ask the students to give their presentations.

Evaluation: Pretend that you were a mouse living in a ponderosa pine forest when a surface fire burned it. Write a paragraph or two that tells how you detected danger, what you did to survive, and how the forest was different after the fire was over. Describe things that you observed with all your senses. Describe your feelings as all of these things were happening.

Closure: Ask students to exchange "fire mouse" stories from the Evaluation, read and edit them, and return them to the writer for revision. Ask a few students to share their stories with the class.

[57] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Extensions

1. Choose any of the activities in the “For Animals” section of *Exploring Wood* in the *Teacher Box* (pp. 55-73). Discuss how each animal could avoid being hurt by fire, and how each one’s habitat is changed by fire.
2. View the “Fire and Wildlife” video in the (*Teacher Box*) to learn about how professional wildlife managers use fire to improve habitat for animals.
3. Use an encyclopedia, CD-ROM, or the Internet to find more information on the animals studied in this activity. Advanced readers may be able to obtain information from the Fire Effects Information System:

   www.fs.fed.us/database/feis

Chapter 7.
Communities in Action

Many of the activities in *FireWorks* focus on the individual plants, fungi, and animals that make up a forest community. In this chapter, students weave their understanding of individual organisms and habitat into an understanding of the biological community—how organisms interact, how they obtain energy, and how they change over time—with fire and without it. This chapter describes activities that explore food and resources webs, relationships between organisms, and succession. Students conduct library research (using the *FireWorks Notebook* provided in the trunk) to learn about individual organisms and use feltboards and role-playing to demonstrate how individuals interact in an ecosystem.

Background

Use the following resources in the *FireWorks Library* and the *Teacher Box*:

- *National Geographic* article "The Essential Element of Fire" by Michael Parfit, pages 116 through 139 in the September 1996 issue, Vol. 190 (3)
- Jack deGolia's book *Fire - a Force of Nature*, pages 30-31
- *Fire and Vegetative Trends in the Northern Rockies* compares historic photos with modern photos, depicting succession in many Western ecosystems.
- Read Chapters 5, 6, and 10 of Ronald Lanner's *Made for Each Other*. These chapters describe the cones and seeds of whitebark pine (and related pines), the Clark's nutcracker's habit of burying whitebark pine seeds, and how animals use whitebark pine.
- Succession and reliance on fire are not unique to the three kinds of forest described in *FireWorks*. Read pp. 43-45 in the *Fire in Florida's Ecosystems* Educator's Guide.
- Read pp. 73-75 in Brian Capon's *Plant Succession* to learn about succession without fire.
- Read *Graced by Pines* to learn about the natural history of ponderosa pine forests.

Chapter Goals

1. To increase student skills in
   - researching technical information
   - communicating technical information
   - working together to prepare and give a presentation
2. To increase student understanding
   - that a forest has many kinds of organisms, which influence one another
   - that a forest changes constantly through time
   - that native organisms have ways to survive fire or reproduce after fire, or both

Chapter Activities

Activity 7-1. In the Web (E)
Activity 7-2. Always Changing (M,H)
Activity 7-3. Story Time (P,E)
Activity 7-4. Puzzling It Out (M)

Activity 7-1. In the Web

Grade level:
X Elementary

What's the Point?

Forest communities survive and thrive because energy flows into and through them, beginning with sunlight and eventually reaching every inhabitant, and also because every organism finds shelter somewhere in the environment. Sometimes shelter is found inside another organism!

In this activity, students individually research 20 to 30 kinds of living things that occur in the three kinds of forests studied in *FireWorks*. They have already "met" many of these organisms in previous activities, but some will be new to them—particularly two fungi, an insect, and a parasitic plant. (*Fungi* are organisms that grow in one place and absorb nutrients through hair-like structures, but unlike plants they cannot turn sunlight directly into energy. They are great decomposers. Sometimes they "recycle" materials before we have finished using them! *Parasites* are organisms that get their energy by draining other organisms of theirs. A parasite damages and eventually kills its "host" organism.)

In this activity, students "adopt" an organism, learn about its life history and fire ecology from the *FireWorks Notebook*, and use what they learn from individual study to build a living model of a *resource web*.

Teacher's Map:

Objective: Given information about a plant, animal, or fungus, students can explain and dramatize its role in a food web to other members of the class.

Subjects: Science, Mathematics, Reading, Speaking and Listening, Social Studies, Library Media, Arts, Workplace Competencies

Duration: 1-2 hours of student preparation, 20 minutes for activity

Links to Standards[58]:

National Science Teachers' Association—Grades K-4:
C1) Identify needs of various organisms
C2) Identify structures of various organisms and the needs they serve
D3) Understand that the sun provides light and heat to earth
F2) Understand source of resources

National Science Teachers' Association—Grades 5-8:
B3) Understand that energy is transferred in many ways
B4) Identify ways in which energy moves in and out of a system
C1) Describe structure and function in a living system
C4) Recognize that ability to obtain and use resources, grow, reproduce… are essential for life
C7) Recognize nature of energy and food webs

North American Association for Environmental Education—Grades K-4:
0A) Identify basic kinds of habitat and plants and animals living there
0C) Describe aspects that change on temporal basis

[58] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

cont'd.

1C) Collect information about environment 2.2A) Understand similarities and differences among variety of organisms. Understand habitat 2.2B) Understand that plants and animals have different characteristics and many are inherited 2.2C) Understand basic ways organisms are related to environment and other organisms 2.2D) Know that living things need energy to live and grow ***North American Association for Environmental Education—Grades 5-8:*** 0A) Classify local ecosystems. Create food webs 1C) Collect and locate reliable information about environment 2.1C) Understand energy transfer 2.2A) Understand biotic communities and adaptations 2.2C) Understand interactions among organisms and populations 2.2D) Understand how energy and matter flow in environment

Vocabulary: animal, food web, fungus, parasite, plant, succession

Materials

In this trunk…	***… where?***[59]	***You must supply***
FireWorks Notebook (pages are removable)	Teacher/C	Art supplies for masks or puppets, or costumes
cotton string	*Hardware Box*, Main/A	Scissors
		Lightweight tray of cookies or other treats
		Copy of Class Page 13 (*Assignment List*)
		Copy of Student Page 20 (*Getting to Know You*) for each student

Preparation

This time, students do the preparation for the activity! Assign each student to research one of the organisms listed on the *Assignment List*, Class Page 13. Each of these is described in a two-page essay in the *FireWorks Notebook* (in the *Teacher Box*). Pages of the *Notebook* are removable, so students can take the page for their organisms out to study it and make their masks/costumes (fig. 23). Record assignments on your copy of class Page 13. Students can supplement the *Notebook* information with other references in the *FireWorks Library* and in your school library. Students with advanced reading skills can consult the Fire Effects Information System on the Internet at www.fs.fed.us/database/feis.

In their research, students should think of themselves as becoming the local experts on their assigned organisms. Student Page 20 (*Getting to Know You*) is a worksheet to help them look for particular information and take notes on it.

Ask the students to depict what they have learned about their forest inhabitant in a costume, puppet, or mask. A student may need to show his or her organism at more than time during its life—perhaps as an egg and as an adult; perhaps right after a fire, then ten or a hundred years later. To do this, students may want to make two items or try a changeable or reversible costume.

Explain what materials are available and what the time frame for the assignment is.

[59] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Figure 23—Sixth grader prepares her pileated woodpecker puppet for “In the Web.”

If possible, find a volunteer helper to play the role of “sunlight” in your food web. Place your tray of cookies near that person or on a desk or chair next to the area you’ll stand in to build your web.

Procedure

When all preparation is done.....

1. Explain: Plants capture the sun's energy and store it in the chemicals that make up their tissues. Later, plants break these energy-storing chemicals apart and use that energy to grow, change, and reproduce. We have learned from experiments that fire releases some of the energy in plant tissues as heat and light. Other living things can release that energy too, using it for their own growth, change, and reproduction.

> **INFO SPARK**: Introduce or review concepts from your curriculum about the carbon cycle—photosynthesis and respiration. Introduce or review concepts from your curriculum about food webs and trophic levels.

2. Ask student actors and actresses to stand in a circle wearing their masks/costumes.
3. Have each student describe the organism he or she represents. The organisms that have already been presented (in ***Mystery Trees*** or ***Buried Treasures*** or ***Great Escape***) can give quite brief presentations; those whom students have not met before should describe themselves in detail.
4. Give the string to the Sun (or tie it to the chair or desk representing the sun).
5. Pass the ball of string to an organism that uses sunlight (a plant), leaving one end attached to the sun.
6. Have the "plant" hold the string and pass the ball to something that it is related to, either in a food web (its food or its consumer) or in a shelter relationship. The ponderosa pine tree, for instance, could pass the yarn to a pileated woodpecker or flammulated owl (which might nests in it) or a mountain pine beetle (which can eat its cambium). Students can help each

other in this activity, explaining their food and shelter relationships. Each student that the string goes to should hold it snug and pass the ball **under the web,** on to the next student. (Always passing the ball under the web keeps it from tangling.)

7. Continue the activity until the person holding the string has no one to pass it to. Explain that other organisms not included in the “cast of characters” here, like insects and worms, will use that organism’s energy. Then cut the string (while the students still hold their web tight), and return the ball to the sun—to be passed to a different plant.
8. Continue the activity until every organism in the ecosystem is connected to one or two others. But don't let students drop the string just yet!
9. Ask students to hold the string tight. Place your tray of "real" energy (cookies or other treats) on the string web, in a place where the string is tangled enough to support it. Explain that this shows that the students themselves are part of a web of energy and cooperation like the one they are depicting.
10. Ask students to slowly, carefully ("on the count of three") bring their string web to the floor so that they set the treats down. Then let them share the treats.

Evaluation: Write down the name of your organism. Write one sentence explaining where your organism gets energy. If it requires other organisms for energy, name one or two of them. Write another sentence explaining what your organism gives to other parts of the food web and what organisms benefit from yours.

Closure: Remind the students that energy is constantly being transferred from one living thing to another, and that people are part of the web too, capturing some of the energy for their own needs. Discuss ways in which humans use energy and materials from forests, too—burning wood for heat, constructing homes and furniture from wood materials, using animals and plants for food and medicines.

Extensions

1. Explore the National Geographic Society’s Internet game about forests at www.nationalgeographic.com/forest
2. Play the *Wildfire Prevention Team Interactive ZIP game* in the *Teacher Box*. This game discusses fire ecology in relationship to many species not mentioned in *FireWorks* materials.
3. Soils are a crucial part of the earth’s energy webs. Explore the riches of soil using Activity 9 in the *Woodsy Owl Activity Guide*, “A Great Recipe for Garbage.”
4. Make tree and owl puppets. Directions are in *Exploring Wood* (in the *Teacher Box*), pp. 32 and 62.

Class Page 13

Assignment List

Forest Inhabitant	Community*	Student Name
American marten	moist, old—especially fir	
Armillaria root rot	PP—favors Douglas-fir trees	
Arrowleaf balsamroot	PP	
Beargrass	LP, WB	
Black-backed woodpecker	LP	
Blue huckleberry	LP	
Clark’s nutcracker	WB	
Douglas-fir	mainly PP	
Douglas-fir mistletoe	mainly PP—favors Douglas-fir	
Elk	all	
Fireweed	mainly LP	
Flammulated owl	PP	
Glacier lily	LP, WB	
Grizzly bear	WB, LP	
Grouse whortleberry	WB	
Lodgepole pine	LP	
Mountain pine beetle	mainly LP	
Pileated woodpecker	PP	
Pinegrass	mainly PP	
Ponderosa pine	PP	
Red squirrel	all, but be sure to show in WB	
Red-backed vole	old, moist—especially fir	
Saskatoon serviceberry	PP, LP	
Smooth woodrush	WB	
Snowbrush *Ceanothus*	PP, LP	
Subalpine fir	LP, WB	
White pine blister rust	WB	
Whitebark pine	WB	
Wild onion	PP, LP	

***** PP=ponderosa pine/Douglas-fir; LP=lodgepole pine/subalpine fir; WB=whitebark pine/subalpine fir.

Student Page 20

Getting to Know You

Name ______________________

Organism ___________________

As you study your forest inhabitant answer these questions. You will need the answers for "In the Web" and "Drama in the Forest."

1. What is your organism—plant, animal, or fungus? ________________________

2. How does it get energy? ____

3. If it gets energy from other organisms, list them.

   ____

4. What other organisms gets energy from yours?

   ____

5. What kinds of trees usually live in your organism's neighborhood?

   ____

6. Does it live best in places burned by surface fire, crown fire, or no fire? Or doesn't it matter?

   ____

7. Does it matter to your organism how long ago a fire occurred? Explain.

   ____

   ____

Activity 7-2. Always Changing

Grade levels:
X Middle
X High

What's the Point?

Forests change over time. Different kinds of plants and animals have different needs. Some grow well only in sunny openings; some grow well almost anywhere as long as they can get water. The forest architecture and the species composition of a forest change over time, a process called *succession*. But many things interrupt succession. A forest is a tremendous storehouse of carbon, which forest residents use for their own needs. Trees add to this huge carbon reserve every day as they capture the sun's energy and store it in their tissues. But trees can't keep carbon to themselves. Fungi consume wood (both living and dead) and roots. Insects feed on needles, tree cambium, and dead wood. Small mammals and birds eat seeds. Just as the forest is constantly changing, it is constantly accumulating carbon and its carbon is constantly being reused and recycled. Fire is the most dramatic recycler.

This *FireWorks* activity asks students to work on three teams (one for each forest type). The teams use information in the *FireWorks Library* to present a play showing 100 years of change in each forest type. A few of the characters in the plays occur in all three forest types, so the students can learn about organisms, like elk, that use many habitats and those that have special habitat needs tied to moist areas, such as American marten and red-backed vole. Students have studied many of the organisms in this activity in previous *FireWorks* lessons.

If you do not have enough students or time to produce a play for all three forest types, have the students choose one of the three and then use the feltboard activity ("Story Time," Activity 7-3) or "Puzzling It Out" (Activity 7-4) to survey the other two types.

ALTERNATIVE ACTIVITY: You can cover the information in this activity in a more structured, less time-consuming way and provide a service to younger students in your school as well: Assign groups of students to prepare the three feltboard stories for the three forest communities (See Activity 7-3, "Story Time") and present them to a younger classroom. Materials are in the Teacher Box.

Teacher's Map:

Objectives: Given reference materials on biology, ecology, and succession, students can prepare and produce a drama showing succession in one of three forest types

Subjects: Science, Reading, Writing, Speaking and Listening, Social Studies, Technology, Library Media, Arts, Workplace Competencies

Duration: 1-2 hours or more for student preparation, 50 minutes for presentations

Links to Standards[60]*:*

National Science Teachers' Association—Grades 5-8:

C4) Recognize that ability to obtain and use resources, grow, reproduce… are essential for life
C7) Recognize nature of energy and food webs

[60] See Appendix 4 for links to Montana educational standards, grades 5-8, 9-12.

cont'd.

C8) Recognize that population size depends on resources
F3) Recognize sources and challenges of natural and human-induced hazards

National Science Teachers' Association—Grades 9-12:

C1) Understand basis for theory of evolution and natural selection
C4) Recognize that energy flow underlies resource webs
C6) Recognize behavior as a form of adaptation to environment
F3) Recognize extent, sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades 5-8:

0A) Classify local ecosystems. Create food webs
0B) Describe habitat needs of species that are locally declining
1C) Locate and collect reliable information about environment
2.2A) Understand biotic communities and adaptations
2.2C) Understand interactions among organisms and populations

North American Association for Environmental Education—Grades 9-12:

0A) Identify several plants and animals common to local ecosystems. Describe concepts (succession, competition, parasitism)
0B) Investigate short- and long-term environmental changes
2.2A) Understand basic population dynamics and importance of biodiversity
2.2B) Understand basic ideas behind biological evolution
2.2C) Understand the living environment is comprised of interrelated, dynamic systems
2.2D) Use interaction of matter and energy to explain environmental characteristics

Vocabulary: succession

Materials

In this trunk...	***...where?***[61]	***You must supply***
Pathways in Time booklets (3)	*FireWorks Library*, Main/B	Art supplies for masks or costumes
FireWorks Notebook	All in Teacher/C	Copies of *Drama in the Forest*, Student Pages 21-23 for student teams
Feltboard Backgrounds (3)		
Feltboard Notebooks (3)		Copy of Class Page 13, *Assignment List*

Preparation

Students will prepare and produce a play in which they depict forest inhabitants using masks or costumes. In the play, a TV reporter (or narrator) interviews plants and animals about changes that have occurred in the past century. You can change the assignment to producing a puppet show, if you prefer that format.

Use the *Drama in the Forest* Student Pages (one for each forest type) for planning.

Procedure

1. Explain: Students will work in teams to present a drama that describes three kinds of forest (ponderosa pine, lodgepole pine, whitebark pine). Each team will present a play showing

[61] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

how this kind of forest looks and works now and what it was like right after a fire 100 years ago. The play should be about 15 minutes long.

2. Ask each student to adopt an organism on the *Assignment List* (Class Page 13) and record his or her choice on the list.
3. Ask the three students depicting the three pine species to be "directors" of the three productions. Give each director a copy of *Drama in the Forest*, the handout for his or her forest community (pp. Student Page 21, 22 or 23), and ask him or her to use the assignment list to fill out this cast of characters.
4. Give each team the *Pathways in Time* booklet for his or her forest community. (You may also provide students with the feltboard kit for that community. The narrative for the feltboard describes the relationship of that community to fire. Students can construct the feltboard, following the directions in the kit, or simply read the narrative for information. If you have them construct the feltboard, make sure they take it apart when finished and put the pieces back in place.)
5. Give each character the page from the *FireWorks Notebook* for his or her organism. The essays in the *Notebook* are removable, so students can borrow them while they prepare. Many characters will appear in only one drama, but others (elk, American marten, red-backed vole, and subalpine fir) will occur in more than one. Explain that these "shared" organisms must work with each team that provides habitat for them.
6. Provide art materials for making masks or costumes.
7. Have students plan their plays, research their plants and animals, write and rehearse.
8. Have students produce their plays for one another and, if possible, for other classes.

Evaluation:

Middle School level: Choose two of the three forest types. Write a paragraph that compares them in terms of **one** of these ideas:

- what kinds of fires were common in each forest type hundreds of years ago
- how fires hundreds of years ago affected specific plants and animals in each type

High School level: Think about how well an organism from one forest type would cope with life in one of the other types. Select an “organism-new habitat” pair from the list below and write a short essay answering these questions:

- What traits does the organism have that would work well in the new forest?
- What traits would make it difficult for the organism to survive or reproduce in the new habitat?
- Do you think the organism could become a permanent resident in the new environment? If not, how long do you think it would last?

Organism	New habitat
Ponderosa pine	Whitebark pine/subalpine fir
Lodgepole pine	ponderosa pine/Douglas-fir
Black-backed woodpecker	ponderosa pine/Douglas-fir
White pine blister rust	Lodgepole pine/subalpine fir

Closure: Explain that students have investigated the story of fire in three kinds of forest, but there are hundreds of kinds of wildlands (forests, grasslands, shrublands, even swamps and estuaries) in North America where fire occurs. Fire’s story is different in each of these ecosystems, and the plants and animals in each have developed traits that enable them to survive fire or reproduce well after fire.

Extensions

1. Report to the class on fire ecology in a different ecosystem than the ones explored in *FireWorks* by studying *Fire in Florida's Ecosystems* or the *Fire Ecology Resource Management Education Unit* (in the Teacher Box).
2. Learn how rocket science at the Kennedy NASA Space Center uses the science of wildland fire. Visit the Kennedy Space Center's Internet site:
   atlas.ksc.nasa.gov/fire/fire.html
3. Learn about current research in whitebark pine ecosystems from the Internet site of the Whitebark Pine Ecosystem Foundation, a group dedicated to protecting this unique ecosystem:
   www.whitebarkfound.org
4. Use computer graphics to produce a slide show or presentation depicting how a forest changes over time and how it is changed by surface and crown fire.
5. View the two videotapes in the *Teacher Box* about the 1988 fires in the Yellowstone area, "Unfinished Song" and "Yellowstone Aflame." Compare and contrast them: What is the main idea of each? Do you think they were produced for the same purposes? What images, sound effects, music, and words are used in each to influence viewers' opinions? Do you like one better than the other? If so, why?

Student Page 21

Drama in the Forest—Ponderosa Pine/Douglas-fir

Character	Name
Interviewer	
Ponderosa pine	
Douglas-fir	
Pinegrass	
Serviceberry	
Snowbrush *Ceanothus*	
Arrowleaf balsamroot	
Armillaria root rot	
Douglas-fir mistletoe	
Pileated Woodpecker	
Elk*	
Flammulated Owl	
Red-backed vole*	
Pine marten*	

Assignment: Produce a play that shows the audience about your forest type, the fires that usually occur there, and how the forest changes over time. Here's a strategy you can try: Use a TV interviewer to ask each organism about its life. The organism can reminisce or use a flashback to show how the forest looked 100 years ago, soon after a fire. Then change the forest (costumes, masks, or props) to 10 or 30 or 100 years later, and interview the organisms again. Eventually, get to the present time and show what the forest is like.

Steps:

1. Fill out the table above. The asterisks mean that you will have to share that organism with other forest types.
2. Learn about succession. Look at the *Pathways in Time* booklet for your forest type. You can read the narrative for the feltboard story for your forest type, too, to find out what the land looked like after fires in the past and how it changed over time.
3. Use the pages for your characters from the *FireWorks Notebook* to find out what each character looks like, where it likes to live, and how it "makes its living" in the forest. Find out if it likes to live in a forest just after fire or many years after fire, or all the time.
4. Prepare and practice your play.
5. Make your masks or costumes.
6. Produce your play for your class or another audience. After you're done, ask the audience for questions.

* "Share" this organism with the other ecosystems.

Student Page 22

Drama in the Forest—Lodgepole Pine/Subalpine Fir

Character	Name
Interviewer or Narrator	
Lodgepole pine	
Subalpine fir*	
Beargrass	
Blue huckleberry	
Glacier lily	
Wild Onion	
Mountain pine beetle*	
Fireweed	
Black-backed woodpecker	
Elk*	
Pine marten*	
Red-backed vole*	

Assignment: Produce a play that shows the audience about your forest type, the fires that usually occur there, and how the forest changes over time. Here's a strategy you can try: Use a TV interviewer to ask each organism about its life. The organism can reminisce or use a flashback to show how the forest looked 100 years ago, soon after a fire. Then change the forest (costumes, masks, or props) to 10 or 30 or 100 years later, and interview the organisms again. Eventually, get to the present time and show what the forest is like.

Steps:

1. Fill out the table above. The asterisks mean that you will have to share that organism with other forest types.
2. Learn about succession. Look at the *Pathways in Time* booklet for your forest type. You can read the narrative for the feltboard story for your forest type, too, to find out what the land looked like after fires in the past and how it changed over time.
3. Use the pages for your characters from the *FireWorks Notebook* to find out what each character looks like, where it likes to live, and how it "makes its living" in the forest. Find out if it likes to live in a forest just after fire or many years after fire, or all the time.
4. Prepare and practice your play.
5. Make your masks or costumes.
6. Produce your play for your class or another audience. After you're done, ask the audience for questions.

* "Share" this organism with at least one other ecosystem.

Student Page 23

Drama in the Forest—Whitebark Pine/Subalpine Fir

Character	Name
Interviewer	
Whitebark pine	
Subalpine fir*	
Smooth woodrush	
Grouse whortleberry	
Red squirrel	
White pine blister rust	
Mountain pine beetle*	
Clark's nutcracker	
Elk*	
Grizzly bear	
Red-backed vole*	
Pine marten*	

Assignment: Produce a play that shows the audience about your forest type, the fires that usually occur there, and how the forest changes over time. Here's a strategy you can try: Use a TV interviewer to ask each organism about its life. The organism can reminisce or use a flashback to show how the forest looked 100 years ago, soon after a fire. Then change the forest (costumes, masks, or props) to 10 or 30 or 100 years later, and interview the organisms again. Eventually, get to the present time and show what the forest is like.

Steps:

1. Fill out the table above. The asterisks mean that you will have to share that organism with other forest types.
2. Learn about succession. Look at the *Pathways in Time* booklet for your forest type. You can read the narrative for the feltboard story for your forest type, too, to find out what the land looked like after fires in the past and how it changed over time.
3. Use the pages for your characters from the *FireWorks Notebook* to find out what each character looks like, where it likes to live, and how it "makes its living" in the forest. Find out if it likes to live in a forest just after fire or many years after fire, or all the time.
4. Prepare and practice your play.
5. Make your masks or costumes.
6. Produce your play for your class or another audience. After you're done, ask the audience for questions.

* "Share" this organism with at least one other ecosystem.

Activity 7-3. Story Time

Grade levels:
X Primary
X Elementary

Figure 24—Fire approaches a cluster of whitebark pine trees in the feltboard story *Rollercoaster Fires.*

What's the Point? __

Forests change over time. Fire is a dramatic force of change, but even without fire, change occurs. Some plants need sunny openings to grow well, and some animals thrive on the plants that live there. These organisms often live in places recently burned. Other plants reproduce almost anywhere, even in deep shade. They may thrive in places not burned for a long time, and the animals that depend on them are present only in old forests. Some plants and animals can live almost anywhere, regardless of when a fire occurred or how the forest changes.

This activity investigates the process of ecosystem change over time, called *succession*. Students use feltboard materials to tell the story of fire and succession in ponderosa, lodgepole, and whitebark pine forests (fig. 24). You may want to spread this activity out over three days, presenting one feltboard each day. **Primary** students help assemble the feltboard as the teacher or other adult reads the story. **Elementary** students may be able to read the narrative themselves with help from an adult; then they can practice working with the feltboard materials and present the story to their class or other students. **If *FireWorks* is being used in the upper grades of your school,** older students may be available to present the feltboard to your class or help your students prepare it.

At some time during the week you're doing this activity, use Smokeygram #2 in your class (fig. 25).

Teacher's Map:

Objective: Given materials and a narrative for storytelling, students can describe fire ecology and succession in a forest ecosystem.

Subjects: Science, Reading, Speaking and Listening, Workplace Competencies

Duration: 15 minutes to prepare, 15 minutes to present, 15 minutes to put away

Links to Standards[62]:

National Science Teachers' Association—Grades K-4:

C1) Identify needs of various organisms

[62] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

-------------------------------Smokeygram #2

Dear Class,

I'm glad you are learning about my homeland. I'm glad you are learning about how fires work, and how plants and animals live in wildlands that burn. As you get smarter about fire, I hope you learn to be even more careful about preventing wildland fires!

Sincerely yours,

Figure 25--"Smokeygram" to be used in Activity 7-3.

cont'd.

C2) Identify structures of various organisms and the needs they serve
F4) Understand that changes in environments can be natural or influenced by people
F5) Understand that changes in environments can be slow or rapid; rate has consequences

National Science Teachers' Association—Grades 5-8:

C4) Recognize abilities to obtain and use resources, grow, reproduce are essential for life
C7) Recognize nature of energy and food webs
C8) Recognize that population size depends on resources
F3) Recognize sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades K-4:

0A) Identify basic kinds of habitat and plants and animals living there
0B) Produce images of the area at the beginning of European settlement
0C) Describe aspects that change on temporal basis
2.1A) Identify changes in physical environment
2.2A) Understand similarities and differences among variety of organisms, habitat
2.2C) Understand basic ways organisms are related to environment and other organisms

North American Association for Environmental Education—Grades 5-8:

0A) Classify local ecosystems. Create food webs
0B) Describe habitat needs of species that are locally declining
2.2A) Understand biotic communities and adaptations
2.2C) Understand interactions among organisms and populations
2.2D) Understand how energy and matter flow in environment

Vocabulary: riparian, succession

Materials

In this trunk...	***... where?***[63]
Feltboard backgrounds (3)	Teacher/C
Feltboard Notebooks: *Creepy, Crawly Fires* *Roaring Treetop Fires* *Rollercoaster Fires*	Teacher/C
Straight pins in film canister	*Hardware Box*, Main/A

Preparation

Set up your storytelling area. Take the narrative pages out of the feltboard book for the reader (yourself?). Hang up the blue felt background *for the forest type you're presenting*.

Procedure

1. Gather the students. Tell them that a story is coming, and some of them may need to help tell it with felt pieces, and all of them may have to help with sound effects.
2. Read the story, directing student helpers to assemble the feltboard according to the directions in parentheses within the narrative. Have the student helpers pat the felt

[63] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

pieces onto the board firmly, or they won't stick. (If they won't stick anyway, attach with pins.) **This whole presentation can be rehearsed by a group of students ahead of time, so it will become a dramatic presentation.**

3. At the start of the second and third stories, tell the students that some organisms are found in all three forest types. (They are elk, American marten, and red-backed vole.) Ask the students to watch for these animals' appearance. When you get to these organisms in the narrative, pause and explain that some animals travel widely and use many different kinds of habitat (like elk), and others have very special needs so they use particular kinds of places wherever they occur (American marten and red-backed vole using moist, *riparian* areas).
4. After the story is completed, use pins to attach the felt pieces to the background for display.

Evaluation: Use any or all of the "Closure" questions below.

Closure: After reading all three feltboard stories with the students, have the class compare the three forest/succession stories. Leading questions:

1. Which forests have really old trees? (ponderosa and whitebark pine)
2. Which forests have very short summers? (whitebark pine)
3. Which forests are likely to have the most spectacular fires? (lodgepole pine)
4. How do Clark's nutcrackers fit into the whitebark pine story?
5. How do mountain pine beetles fit into the lodgepole pine story?
6. How do pileated woodpeckers fit into the ponderosa pine story?
7. How do elk use the three different kinds of forest?
8. All three forest types have wet places. What special animals depend on those places? (American marten, red-backed vole)

You may want to display the feltboards in the classroom. After you are finished, assign students to disassemble the feltboards, one at a time, and put materials away in the notebooks.

Extensions

1. Read *Fire in the Forest* (in the *FireWorks Library*) aloud to students. This book uses beautiful graphics to describe the story of fire in lodgepole pine forests. Work in teams to plan and paint such a book for either ponderosa pine or whitebark pine forests.
2. Set up an activity station where students can try "Puzzling It Out" (Activity 7-4). If students cannot read the clues on the puzzle pieces, see if older students in your school (who may be using *FireWorks* and doing this activity anyway) can help. For Primary-level students, sort the puzzles in one of the envelope kits into three groups—one for ponderosa, lodgepole, and whitebark pine—and have students assemble these puzzles separately.
3. View the two videotapes in the *Teacher Box* about the 1988 fires in the Yellowstone area, "Unfinished Song" and "Yellowstone Aflame." Compare and contrast them: What is the main idea of each? Do you think they were produced for the same purposes? What images, sound effects, music, and words are used in each to influence viewers' opinions? Do you like one better than the other? If so, why?

4. To improve your skill in critical reading, use the "Reporting the Blazes," an activity in the *Fire Ecology Resource Management Education Unit* (U.S. Department of the Interior curriculum) in the *Teacher Box*.
5. Make up verses for the songs "Do you know who lives in my tree?" and "Trees for Lunch" (in *Exploring Wood*, pp. 38 and 81) and sing them for the class.
6. Fire suppression is one of several careers that arise from North America's complicated relationship with wildland fire. Read *Fire—a Force of Nature* (pp. 44-47) and *Yellowstone on Fire* (pp. 57-85), both in the *FireWorks Library*, to learn more about the work and frustrations of fire suppression.

Activity 7-4. Puzzling It Out

Grade level:
X Middle

What's the Point?

Discovering how the inhabitants of a forest interact is a little like assembling a complicated jigsaw puzzle. In this activity, students use what they have learned about fire, plants, animals, and succession to assemble jigsaw puzzles about ponderosa, lodgepole, and whitebark pine forests. They have to use information about many species and distinguish three different kinds of forest to complete the puzzles.

This is a quiet activity that can be done alone or in small groups. *FireWorks* contains four puzzles; they can be assigned as seat work to be fit in with other classroom activities, or set up at activity stations that one or a few students visit at a time.

Teacher's Map:

Objective: Given photographs and text as clues, students can identify components of different ecosystems that relate to one another.

Subjects: Science, Reading, Social Studies

Duration: 20 minutes

Links to Standards[64]:

National Science Teachers' Association—Grades 5-8:

C4) Recognize ability to obtain and use resources, grow, reproduce… are essential for life
C6) Understand nature of populations and classification
C7) Recognize nature of energy and food webs
F3) Recognize sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades 5-8:

0A) Classify local ecosystems. Create food webs
0B) Describe habitat needs of species that are locally declining
2.2A) Understand biotic communities and adaptations
2.2C) Understand interactions among organisms and populations
2.2D) Understand how energy and matter flow in environment

Vocabulary: cavity nester, crown fire, fire scar, fungus, succession, surface fire

Materials

In this trunk…	***… where?[65]***
Puzzling It Out Kit (4 manila envelopes, each with a complete puzzle set of 33 pieces)	Teacher/C

[64] See Appendix 4 for links to Montana educational standards, grades 5-8.
[65] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Procedure

1. Explain: Each team uses one envelope of puzzle pieces to assemble three puzzles simultaneously: one about ponderosa pine forests, one about lodgepole pine, and one about whitebark pine. Each envelope contains the pieces for **three** 11-piece jigsaw puzzles. **The puzzles are all cut on the same pattern.**
   - All have a picture of a pine tree in the center - ponderosa, whitebark, or lodgepole pine.
   - Across the top, all puzzles show typical fires and change in that kind of forest over time.
   - Across the bottom, all puzzles have photos and information about other plants and animals that live in that kind of forest and how they interact with one another.

   Since the puzzles are all cut from the same pattern, many pieces are interchangeable. To assemble them correctly, students will need to use what they already know, look closely at the pieces for clues, and use new information written on the puzzle pieces.
2. **OPTIONAL:** Review these key concepts that students will need to know:
   - Ponderosa pines grow best at low elevations, on dry sites. In the past, most fires here were surface fires and did not kill the large trees. Trees could grow very old and very big.
   - Whitebark pines grow best at high elevations, on dry sites. In the past, some fires were surface fires and some were crown fires. Some burned in surface fuels most of the time, then—when the wind got strong and flames reached a cluster of trees with lots of ladder fuels—reached into the crowns.
   - Lodgepole pines grow well at middle elevations. They do not get very old or very large. Fires are not frequent, but they often crown and kill most of the trees.
3. When students have completed puzzles, check them against the puzzle-master illustrations included in the *Puzzling It Out* Kit and shown (reduced in size, with text omitted) in fig. 26.

A.

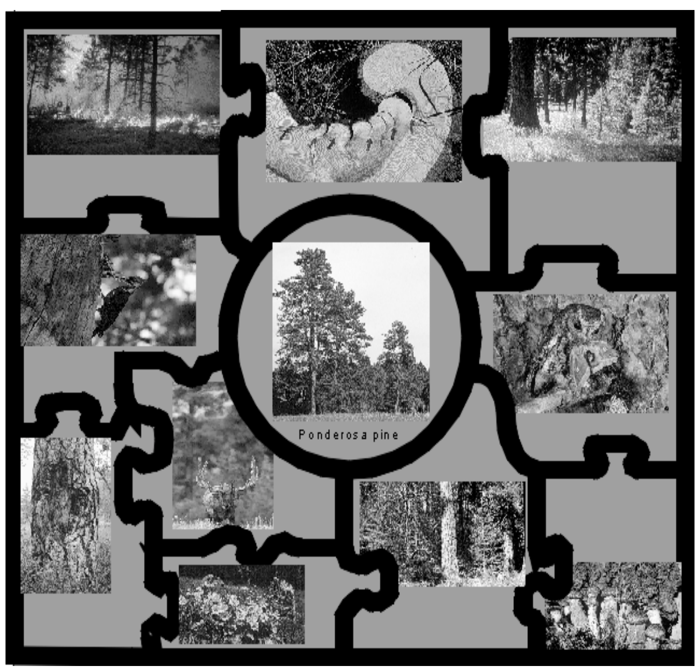
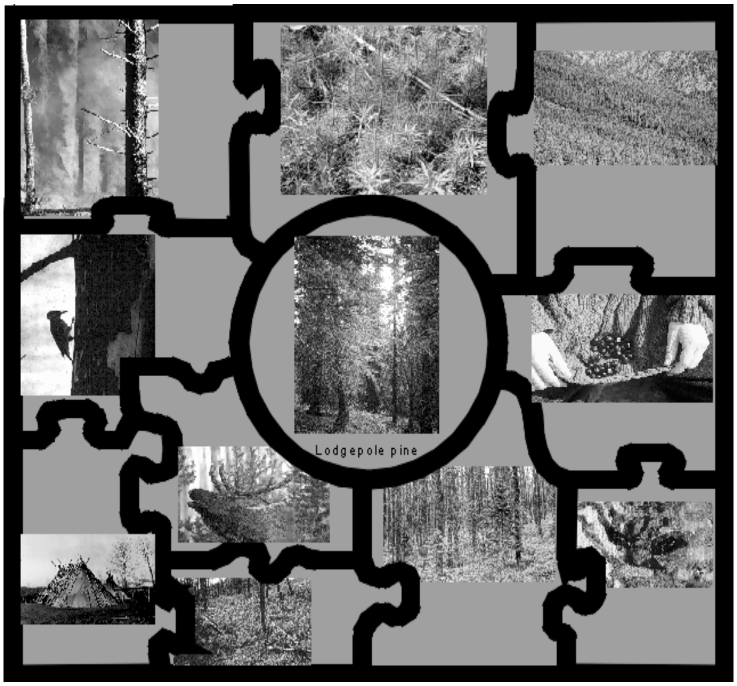


Figure 26—Correctly completed jigsaw puzzles for Activity 7-4. Size is reduced so text has been left out. **A—**Puzzle depicting ponderosa pine/Douglas-fir forest. **B—**Puzzle depicting lodgepole pine/subalpine fir forest. **C—**Puzzle depicting whitebark pine/subalpine fir forest.

B.



C.

Evaluation: Name one kind of bird, insect, or fungus that lives in each kind of forest: ponderosa pine, lodgepole pine, and whitebark pine.

Closure: Repack the puzzles in the correct envelopes, 33 pieces per envelope.

Extensions

1. Design a jigsaw puzzle that describes another kind of ecosystem in your area.
2. Make a flip book[66] illustrating succession in one of the forest types included in this curriculum, or in another ecosystem.
3. Read and report to the class about information in *Made for Each Other* (about whitebark pine ecosystems) or *Graced by Pines* (about ponderosa pine forests), both in the *FireWorks Library*.

[66] Thanks for *Fire in Florida's Ecosystems* Educator's Guide (p. 43) for this activity.

Chapter 8.
People in Fire's Homeland

Fire is quite at home in the forests of the West, and also that the plants and animals of these forests are quite at home with fire. The people who lived in these forests prior to 1800 were also at home with fire, but things have changed. People have built permanent homes in the midst of forests and along their edges. Thousands of people live in valleys that fill with smoke during wildland fires. People need to be informed about fire for their own safety and to help make wise choices about managing wildlands.

In this chapter, students assess the safety of homes built in forested areas. This activity is used in the programs for Elementary, Middle, and High School levels. The other activities in the chapter, designed for Middle and High School students, rely on evaluative reasoning and judgments of complex issues. Students learn about professionals who work with fire and apply what they have learned in planning fire management, studying smoke, and examining their own value systems.

Background

- Read *Evergreen* magazine's article "Montana's Forests: Paradise Lost or Paradise Found" (in the *FireWorks Library*).
- Read pages 35-45 in Patrick Cone's *Wildfire* (in the *FireWorks Library*).
- Read pp. 1 and 13 in the Teacher Background Information booklet in *Fire Ecology, Resource Management Educational Initiative* (in the *Teacher Box*).
- Read an article in *The Use of Fire in Forest Restoration* in the *FireWorks Library*.

Chapter Goals

1. To increase student skills in
   - using new information to solve problems
   - making judgments and decisions based on scientific knowledge and human values
   - critical thinking
   - identifying and describing values
2. To increase student understanding
   - regarding careers in fire management and research
   - that fire affects nearly everyone living near fire-dependent forests
   - that living in areas adapted to wildland fire requires some tradeoffs
   - that people living near forests can do many things to increase fire safety

Chapter Activities

Activity 8-1. A Matter of Choice	(M,H)
Activity 8-2. Houses in the Woods	(E,M,H)
Activity 8-3. Living with Fire	(M,H)
Activity 8-4. Smoke: In or Out?	(M,H)
Activity 8-5. You Decide!	(M,H)
Activity 8-6. Value Choices	(H)

Activity 8-1. A Matter of Choice

Grade levels:
X Middle
X High

What's the Point?

This activity introduces the students to professionals who work with wildland fire and the problems that all people face if they live in areas where fires occur. Students examine national policies regarding fire and view a 12-minute videotape prepared by the U.S.D.A. Forest Service as an introduction to fire management. Then they discuss their views on the same issues.

Teacher's Map:

Objective: After examining a policy booklet and viewing a videotape, students can apply their knowledge of fire science to discuss the issues presented.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Social Studies, Technology, Library Media, Arts, Media Literacy, Health, Workplace Competencies

Duration: 40 minutes

Links to Standards[67]:

National Science Teachers' Association—Grades 5-8:

F1) Identify potential for accidents, make choices that minimize risk of injury
F3) Recognize sources and challenges of natural and human-induced hazards
F4) Make personal and social decisions based on perceptions of benefits and risks
F6) Recognize difference between science questions and other questions
G2) Understand that science results must be communicated
G3) Recognize uncertainty, debate, further investigation, evaluation as part of science

National Science Teachers' Association—Grades 9-12:

C5) Recognize ways in which human-caused changes differ from other changes in ecosystems
E2) Understand interaction of science and technology in producing new knowledge
F3) Recognize extent, sources and challenges of natural and human-induced hazards
F4) Recognize role of active debate among scientists and the public about decisions
G1) Understand science as career and hobby

North American Association for Environmental Education—Grades 5-8:

1D) Judge weaknesses and strengths of the information they are using
2.3C) Understand political and economic systems and relationship to environment
2.3E) Understand change in human systems and conflict over change
2.4A) Understand that human-caused changes affect the environment
2.4D) Understand human ability to control environment as function of knowledge, tech.
3.1B) Identify consequences of specific environmental issues
3.2A) Develop personal views on environmental issues

North American Association for Environmental Education—Grades 9-12:

1D) Apply logic to assess completeness and reliability of information
2.3A) Understand influence of individual and group actions on environment

[67] See Appendix 4 for links to Montana educational standards, grades 5-8, 9-12.

cont'd.

2.4A) Understand that humans change environment and that there are limits to ability of environment to absorb these impacts 3.1A) Investigate environmental issues 3.1B) Evaluate consequences of specific environmental changes, conditions and issues 3.1D) Engage in peer review and open inquiry 3.2A) Communicate, evaluate, and justify views on environmental issue

Vocabulary: dispersion, visibility

Materials

In this trunk...	***...where?***[68]	***You must supply***
Managing Wildland Fire—a Matter of Choice videotape (12 min)	Teacher/C	TV with VCR
Managing Wildland Fire booklets (20)	*FireWorks Library*, Main/B	

Procedure

1. Explain that the class will be doing some "real-world" activities relating to wildland fire, and they will begin by seeing some materials that fire managers have developed—a videotape and an informational booklet.
2. Explain that the assignment, while watching the video and reading the booklet, will be to describe the organization of the video—its outline, and to think about the scientific information and viewpoints being presented.
3. View the 12-minute videotape *Managing Wildland Fire—a Matter of Choice.*
4. Ask the class to describe the organization of the video. It is:
   - I. Ask questions
     - A. Can forests thrive with fire?
     - B. Can people and property be protected
     - C. How much smoke is too much?
   - II. Suggest answers or solutions, at least in part
     - A. Forests can thrive with fire
     - B. People and property can be protected
     - C. Living with Smoke

   Note that each question is paired with an answer.
5. Pick a question-and-answer pair. Ask the class to discuss the video's treatment of that question and answer. **This part of the activity can be done in small groups or as a writing assignment, instead of with the whole class.**
   - Does the information presented seem to be based on valid science? If you can't tell, how might you find out? (Ask an expert that you trust, look up more information in books and scientific articles, do experiments that test some of the

[68] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

ideas presented in the videotape. Internet might provide interesting information; how might they judge its validity?)

- What viewpoint is presented, and what techniques are used to present it?
- Do you agree or disagree with the viewpoint, can you explain why, and can you suggest information or ideas to add to a discussion of the issue?

Evaluation: If you could add one more thought to the videotape, what would it be? Write a script for your 2-minute addition to the video. Explain what part of the video you would use it in, and describe the video footage you would like to include with it.

Closure: Ask students if they think the issues in the videotape are important for your geographic area, and have them explain why or why not. If the issues do not seem important locally, have they ever been to places where the issues might be more urgent?

Extensions

1. Read through the *Managing Wildland Fire* booklets from the *FireWorks Library*. These are the official policies that the videotape was based on. Assess how well the video captured the messages, what was left out, and what was added in. How effective is the video in communicating those messages?
2. Produce a 2-minute videotape from the script prepared in the ***Evaluation*** section.
3. Learn more about wildland fire research by visiting the Fire Sciences Laboratory's Internet site

   www.firelab.org

   Look up one scientist and describe his or her background, interests, and publications.
4. Find out how U.S. and Canadian researchers are learning more about crown fires using very intense experimental burns in Canada's Northwest Territories at the Internet site

   nofc.cfs.nrcan.gc.ca/fire/fmn/nwt

   Some of the crown fire footage in the videotape just viewed was taken in these experiments.

Activity 8-2. Houses in the Woods

Grade levels:
X Elementary
X Middle
X High

What's the Point?

Students apply their knowledge about fuels, fire behavior, and the fire triangle to assess safety around wildland homes. They use a checklist from the National Fire Protection Association to assess homes in photographs (fig. 27). This activity can be done in 3 ways: as a class activity (using the *Wildland Homes* slides), as a team effort to assess photos in the *People in Fire's Homeland* Kit, or as individual work.

Figure 27—One of the home photos that students assess in this activity. Note the presence of ladder fuel. Photo courtesy of Montana Department of Natural Resources and Conservation.

Teacher's Map:

Objective: For homes in forested settings, students can assess hazards and recommend steps to reduce risks from wildland fire.

Subjects: Science, Reading, Writing, Speaking and Listening, Health, Workplace Competencies

Duration: 40 minutes

Links to Standards[69]:

National Science Teachers' Association—Grades K-4:

B3) Demonstrate production of heat, conduction and convection
E1) Identify a technological problem and potential solution
E2) Work individually and with others to solve technological problem, assess solution
F1) Understand and make choices for safety and preventing injury
F4) Understand that changes in environments can be natural or influenced by people

National Science Teachers' Association—Grades 5-8:

E3) Demonstrate risks and tradeoffs in technological design
F1) Identify potential for accidents, make choices that minimize risk of injury
F3) Recognize sources and challenges of natural and human-induced hazards
F4) Make personal and social decisions based on perceptions of benefits and risks
F6) Recognize difference between science questions and other questions

National Science Teachers' Association—Grades 9-12:

E2) Understand interaction of science and technology in producing new knowledge

[69] See Appendix 4 for links to Montana educational standards.

F1) Identify hazards, make choices that minimize risk of injury
F3) Recognize extent, sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades K-4:

2.1C) Be aware of basic behavior of some forms of energy
2.4A) Understand that people depend on, change, and are affected by environment
2.4D) Become familiar with some local environmental issues
3.1A) Identify and investigate issues in local community
3.2A) Examine and express views on environmental issues

North American Association for Environmental Education—Grades 5-8:

2.4A) Understand that human-caused changes affect environment
2.4D) Understand ability to control environment as function of knowledge, technology
3.1A) Use information to investigate environmental issues
3.1B) Identify consequences of specific environmental issues
3.1C) Develop action strategies for addressing particular issues
3.2A) Develop person al views on environmental issues
3.2B) Evaluate need for action

North American Association for Environmental Education—Grades 9-12:

1D) Apply logic to assess completeness and reliability of information
2.3A) Understand influence of individual and group actions on environment
2.4E) Understand environmental issues at variety of scales
3.1B) Evaluate consequences of specific environmental changes for humans, ecosystems
3.1C) Identify action strategies likely to be effective in particular situations
3.2A) Communicate, evaluate, and justify views on environmental issue
3.2B) Decide whether action is needed in a situation

Vocabulary: ladder fuels, safety zone

Materials

In this trunk...	*...where?*[70]	*You must supply*
"People in Fire's Homeland" Kit **or** "Wildland Homes" slides in slide carousel	Teacher/C or Main/C	Copy of *Safety in Fire's Homeland* (Student Page 24) for each student or team OPTIONAL: slide projector and screen
For Middle & High School: "Wildfire—Preventing Home Ignitions" videotape (19 min)		For Middle & High School: VCR

Preparation

Ask 1 or 2 students to measure the dimensions of your classroom (m) and write them on the board. Use the measuring tape in the *FireWorks* Hardware Box or a longer tape.

Procedure

1. Explain: Students will use what they know about fire in evaluating the safety of homes that have been built in wildland areas.
2. With the students, read *Safety in Fire's Homeland* (Student Page 24). Ask the students to identify and discuss what they have learned about fire that supports the points in

[70] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

Table 12—Relationship of safety checklist (Student Page 24) to concepts covered by *FireWorks*.

No.	Safety Checklist Point	*FireWorks* concepts
1	Is the roof metal or shingle? NOTE that home photo 2 shows shakes, 4 shows shingles, and 9 shows metal roofing.	Fires need fuel. Wood shakes, especially untreated ones, are great fuel.
2	Is firewood and other wood stored >10 m away from the house, not touching walls or deck?	Although big logs would be hard to ignite, they would burn long and hot.
3	Are tall grass & weeds cleared away from within 10 m of the house?	Weeds dry out in late summer. Dead, dry, "fluffy" material burns easily.
4	Are tree limbs cleared from the roof and around the chimney?	A single match can start a fire. So can a spark from a chimney.
5	Are dead leaves and needles cleaned from the roof and rain gutters?	Fire needs fuel. Dead leaves and needles burn well.
6	Are trees and shrubs 3 m apart or more?	For fire to spread, heat must reach new fuels.
7	Are "ladder fuels" and low branches pruned from beneath big trees (about 2 m up)?	Heat rises. Saplings and low branches increase chance of crown fire.
8	Is the lawn watered and green, even in late summer?	Green fuels burn less readily than dead, dry fuels.
9	If the house is at the top of a slope, is the "safety zone" 30 m or more?	Heat rises....
10	Is the house on a flat place, or set back from the top of a slope?	Heat rises....
11	Is the road wide enough for a car going out to pass a fire engine going in?	

Table 13—Assessment of fire hazards around wildland homes in *People in Fire's Homeland* Kit. Numbers in the table refer to numbered safety criteria in table 12. Question marks indicate that the criterion was difficult or impossible to assess from the photo.

Home No.	"Yes!"—Looks safe because...	"No"—Needs improvement because...	Can't tell or doesn't apply
1	2, 3, 5, 6(?), 8, 10	1, 4(?), 7	9, 11
2	2(?), 5, 8(?), 10	1, 3, 4, 6, 7	9, 11
3	8, 10	1(?), 2, 3(?), 4, 5, 6, 7	9, 11
4	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	none	none
5	10(?)	3, 4, 6, 7, 8	1, 2, 5, 9, 11
6	3, 4(?), 7, 10	1, 2, 5, 6, 8	9, 11
7	1, 2(?), 4, 5, 6, 7, 10	3, 8	9, 11
8	1(?), 2, 10	3, 4, 5, 6, 7, 8	9, 11
9	1, 3, 5, 10	2, 6, 7, 8	4, 9, 11
10	2(?), 4, 8	3(?), 7, 9, 10	1, 5, 6, 11
11	1, 2, 3, 4, 5, 6, 7, 8, 11(?)	none	9, 10

the checklist. Table 12 lists many such concepts, and table 13 shows how students and teachers using *FireWorks* generally assess the homes in the photos.

3. Explain that the class will need to estimate distances in the activity. Show them the dimensions of the classroom, written on the board (width, length, height) in m.
4. Explain how the class will do the activity. We suggest that **elementary** students use the slides to assess at least some of the homes. **Middle** and **High School** students can work individually <u>or</u> in small groups, using the photo prints in the *People in Fire's Homeland* Kit, then present their assessment to the class.
5. Explain that students may *not* be able to answer every question for every picture, because each photo shows only *some* of the features on the checklist. It's all right to check "can't tell" on the safety checklist!
6. Begin the slide show or ask students to begin their individual/team work; you may use table 13 to guide the discussion.
7. **If the activity has been done by individuals or student teams,** ask for reports after 5-10 minutes.

Evaluation: Select one of the house photos from this activity. Write a letter to the home owner. Explain your observations. If you think the home's safety needs improvement, tell the home owner how to improve it.

Closure:

Elementary level: Introduce Smokeygram #3 from the *Smokeygrams* Kit (fig. 28).

Middle and High School levels: View the videotape "Wildfire—Preventing Home Ignitions" (19 min.). Describe two sources of heat from wildland fire that could ignite homes. (1—radiation from flames; 2—convection/conduction from firebrands.) Which source is more likely to cause ignition? (2—heat from firebrands.)

Extensions

1. *Protecting your Home from Wildfire*, in the *Fireworks Library*, contains detailed instructions about home safety in the wildland/urban interface. Find two points in the booklet that were not covered in this activity, and describe them for the class.
2. You are moving from Chicago to Idaho, and you want to buy a house in a forested area. A real estate agent sends you a photo of a house built on a hillside deep in a ponderosa pine forest. Trees overhang the roof, and you notice that firewood is stacked under the back deck. You call the agent and say that you'd be worried about forest fires if you bought this house. The agent answers that it must be safe, since no fire has burned in the area for 40 years or more. You think about this for a few days before you decide whether to buy the house or not. Then you **write a letter to the real estate company explaining your decision.**
3. Learn more about homes and fire safety at the Internet site

   www.firewise.org

   Use the "interactive" and "videos" sections.
4. <u>Especially for Elementary-age children:</u> Look up information about home safety on Smokey Bear's Internet site:

   www.smokeybear.com

--------------------------------Smokeygram #3

Dear Class,

Everyone can help with fire safety. Scientists and land managers use many methods to increase safety in forests. Sometimes they use fire itself as a tool. That is their job. Your job is fire prevention. My message still holds true: Please do all you can to prevent wildland fires!

Sincerely yours,

Figure 28—Smokeygram #3, to be used in Activity 8-2.

Student Page 24

Safety in Fire's Homeland

Name ____________________

Photo Number: _______

Put a check in the "yes," "no," or "can't tell" column.

		Yes!	No!	Can't tell
About the House:				
1	Is the roof covered with metal or asphalt shingles (<u>not</u> wood shakes)?			
2	Are firewood and other wood stored at least 10 m away from the house, not touching walls or deck?			
3	Are tall grass and weeds cleared away from the sides of the house within 10 m?			
4	Are tree limbs cleared away from within 3 m of roof and chimney?			
5	Are dead leaves and needles cleared from roof and rain gutters?			
Around the House (safety zone, within 10 m):				
6	Are trees and shrubs 3 m apart or more?			
7	Are ladder fuels and low branches cleared from underneath big trees—2 m up?			
8	Is the lawn kept green, even in late summer?			
9	If the house is at the top of a slope, is the safety zone 30 m or more?			
About the Location:				
10	Is the house on a flat place, set back from the top of a slope?			
11	Is the road wide enough for a car going out to pass a fire engine coming in?			
Count the checks in each column:				

Activity 8-3. Living with Fire

Grade levels:
X Middle
X High

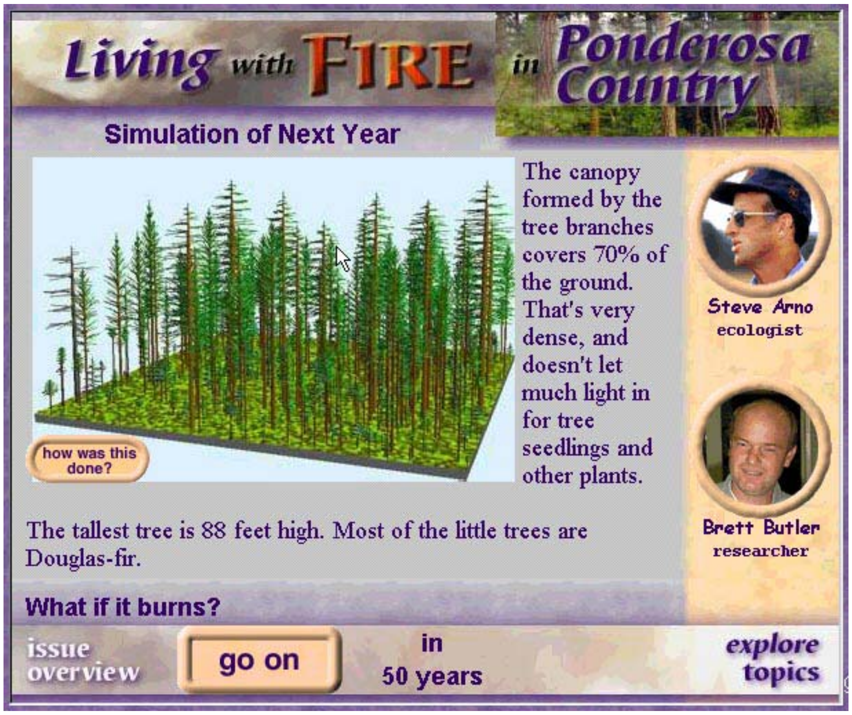


Figure 29—A decision point in the game "Living with Fire."

What's the Point?

Fires have shaped the wildlands of North America for thousands of years, but fire has been excluded from many of these ecosystems for nearly a century. Does it matter? One of the consequences of fire exclusion, scientists believe, is a change in the fire behavior likely when a fire does finally occur—a change in the *fire regime*. In this activity, students play a simulation game to explore the effects of various management choices (*treatments*) on the behavior of a subsequent wildland fire in ponderosa pine/western larch/Douglas-fir forests (fig. 29). They use the CD-ROM *Living with Fire,* which displays data from mathematical models of tree growth and fire spread in a "cartoon forest" format, to make management choices and view the consequences. *Living with Fire* is limited to ponderosa pine/larch/Douglas-fir forests; students will not learn about lodgepole pine or whitebark pine forests in this activity.

Living with Fire requires a computer with CD reader and Internet Explorer 4.0 or higher. The CD in the *Teacher Box* can be loaded on multiple computers. **If you prefer to have students access the game on the Internet, its address is**

http://www.fs.fed.us/rm/fire_game

Living with Fire can be used individually or by teams of two students. The teacher introduces the activity and assignment and then schedules students to use the computer and complete the work. Class discussion of results follows completion of the activity

Teacher's Map:

Objective: Given a simulation game that predicts effects of forest management on fire behavior, students can identify the effects of treatment weather on behavior of a subsequent wildland fire.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Social Studies, Technology, Workplace Competencies

Duration: 10 minutes to introduce, 15 to 20 minutes/computer teams, 10 minutes to conclude

Links to Standards[71]:

National Science Teachers' Association—Grades 5-8:

A1) Identify questions that can be answered scientifically
A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations
D3) Describe interaction of organisms with atmosphere
E1) Identify a need for technological design; plan, implement and evaluate design
E3) Demonstrate risks and tradeoffs in technological design
E4) Recognize that technology produces benefits and also unintended consequences
F1) Identify potential for accidents, make choices that minimize risk of injury
F3) Recognize sources and challenges of natural and human-induced hazards
F6) Recognize difference between science questions and other questions
G3) Recognize that uncertainty, debate, further investigation, and evaluation are part of science

National Science Teachers' Association—Grades 9-12:

E1) Identify need for technological design; plan, implement, evaluate design, communicate
F1) Identify hazards, make choices that minimize risk of injury to self and others
F4) Recognize role of active debate among scientists and the public about decisions
F3) Recognize extent, sources and challenges of natural and human-induced hazards
F5) Incorporate quantitative understanding of risk in decisions on science and technology
G1) Understand science as career and hobby

North American Association for Environmental Education—Grades 5-8:

1D) Judge weaknesses and strengths of the information they are using
2.4A) Understand that human-caused changes affect environment
2.4D) Understand human ability to control environment as function of knowledge, technology
3.1A) Use information to investigate environmental issues
3.1B) Identify consequences of specific environmental issues
3.1C) Develop action strategies for addressing particular issues
3.2A) Develop personal views on environmental issues
3.2B) Evaluate need for action

North American Association for Environmental Education—Grades 9-12:

0A) Identify several plants and animals common to local ecosystems, describe concepts
0B) Investigate short- and long-term environmental changes
1D) Apply logic to assess completeness and reliability of information
2.3A) Understand influence of individual and group actions on environment
2.4A) Understand that humans change environment and environment has limited ability to adjust
2.4D) Examine social and environmental impact of various technologies
3.1A) Investigate environmental issues
3.1B) Evaluate consequences of specific environmental changes, conditions and issues for humans and ecosystems
3.2C) Decide whether action is needed in a situation

Vocabulary: prescribed fire, surface fire, thin, treatment

[71] See Appendix 4 for links to Montana educational standards, grades 5-8, 9-12.

Materials

In this trunk…	*… where?*[72]	*You must supply*
Living with Fire CD-ROM	Teacher/C	Personal Computer or Macintosh with CD drive and Internet Explorer 4.0 or higher
		One copy of Student Page 25, *Living with Fire,* for each student or team

Procedure

1. Explain: The assignment will give students a taste of some of the choices that land owners, firefighters, and managers of public lands make when they work in forests where fire has been an important force. They will use the CD to answer questions.
2. Explain your strategy, the schedule for computer use, and when the assignment is due.
3. Explain the basic structure of the CD—There is an introductory section with background information. Then they make choices and view consequences. **For your information** (it probably is not necessary to share this with the students—they'll figure it out), the CD is organized with 5 levels of choice:
    - A. Choose a kind of ponderosa pine forest—old growth or second growth (60 years after clearcut).
        - B. Choose to manage passively (no action) or actively (thin small trees and/or underburn with surface fire).
            - C. Choose to wait 1 or 50 years before a wildland fire burns into the forest.
                - D. Choose weather during the fire—moist conditions, moderate, or very dry and windy. View potential fire behavior.
                    - E. Choose how to manage the fire—with monitoring alone, or with aggressive fire suppression
4. Have students use the CD-ROM and complete the worksheet (Student Page 25).

Evaluation: Use Student Page 25.

Closure: Use a few minutes of class time to discuss:
1. What was the most severe ("scary?" "destructive?" "dramatic?") fire behavior found?
2. What conditions led to the severe fire behavior?
3. Were the game results always what you expected, or were there some surprises? Explain.
4. Were the results from your choices believable? What made the information on the CD believable… or not?
5. How important is scientific information to decisions like the ones used in this game? What other information is important for making those decisions?

Extensions

1. Look up some of the information in the "Menu" section of the CD and report back to the class.
2. The CD shows predictions for forests dominated in past centuries by ponderosa pine. What about lodgepole pine forests, whitebark pine forests, and the dozens of other kinds of

[72] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

wildlands that occur in your local area? Do library research, use the Fire Effects Information System (www.fs.fed.us/database/feis), and talk to local experts: Learn the effects of various kinds of forest treatment, including the use of no treatment at all, on potential fire behavior. Write a summary or present your findings to the class.

4. In a team of students, read several parts of the lengthy *Evergreen* magazine article "Montana's forests: Paradise Lost or Paradise Found" in the *FireWorks Library*. Give a panel presentation to the class describing what you have learned or critiquing the articles.

Student Page 25

Living with Fire
Name ______________________

1. Circle the kind of forest you choose to work in:

Old growth ponderosa pine back in the woods far from human settlement	Young ponderosa pine closer to settled areas near homes & buildings

2. Circle **two** treatments you choose to compare:

No treatment: Let nature take its course	Thin small trees from under the larger ones	Thin small trees from under the larger trees, then burn with surface fire

3. Compare the appearance of your forest one year after the two treatments. Do the two cartoon forests look alike? Can you see some differences?

4. Find out how a wildland fire will behave after each of your treatments. In the table below, use a few words to describe the flames, the fire's effects on big trees, and the fire's effects on small trees.

Weather conditions	Your first treatment	Your second treatment
Low-danger weather	Flames:______________ Big trees: ____________ Small trees: __________	Flames:______________ Big trees: ____________ Small trees: __________
Moderate-danger weather	Flames:______________ Big trees: ____________ Small trees: __________	Flames:______________ Big trees: ____________ Small trees: __________
High fire danger weather	Flames:______________ Big trees: ____________ Small trees: __________	Flames:______________ Big trees: ____________ Small trees: __________

5. Describe one benefit and one disadvantage of each treatment.

6. On the back, write a paragraph that explains when you think it is a good idea to "just monitor" a wildland fire, and when it is good to use all-out suppression efforts. Explain your reasons.

Activity 8-4. Smoke: In or Out?

Grade levels:
X Middle
X High

What's the Point?

There's no wildland fire without smoke, but the amount of smoke produced and the way in which it disperses differ from one fire to another.

Smoke production depends on two factors: the amount of fuel consumed and the fuel moisture. To reduce smoke production, managers use prescribed fire at times when the duff and large fuels are moist. Because only the small fuels burn, fuel consumption is relatively low in these fires. Then why do fires built with moist fuels look so smoky? because moisture reduces burning *efficiency*—that is, it increases the smoke produced *per gram of fuel consumed*. In **Demonstration 1, students investigate the effects of fuel consumption and moisture on smoke production. This activity is smoky; it should be done under a hood or outdoors.**

Weather conditions determine where the smoke from a fire goes—into the upper atmosphere, where it is dispersed over a large area, or into neighboring valleys, where it can settle for hours or days. When managers use prescribed fire to benefit plants and animals or to reduce the risk of severe fire, they try to burn during times when smoke will disperse well. **Demonstration 2 investigates how smoke disperses**. **This activity requires stable air conditions; it should be done indoors.**

Teacher's Map:

Objective: Given a description of a forest and burning conditions, students can predict the relative amount of smoke that will probably be produced and describe how the smoke is likely to disperse.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Social Studies, Technology, Health Enhancement, Workplace Competencies

Duration: 30 minutes for Demonstration 1, 20 minutes for Demonstration 2.

Links to Standards[73]:

National Science Teachers' Association—Grades 5-8:

A1) Identify questions that can be answered scientifically
A2) Design and conduct a scientific investigation
A3) Develop explanations and predictions using evidence
A4) Think critically to establish relationships between evidence and explanations
A5) Communicate procedures and explanations
A6) Use mathematics in science
B1) Understand properties of matter
B2) Describe physical and chemical changes
B4) Identify ways in which energy moves in and out of a system
D3) Describe interaction of organisms with atmosphere

[73] See Appendix 4 for links to Montana educational standards, grades 5-8, 9-12.

cont'd.

F5) Recognize that scientists and engineers work in many different settings
F6) Recognize difference between science questions and other questions

National Science Teachers' Association—Grades 9-12:

A1) Formulate testable hypothesis and obtain relevant knowledge
A2) Design and conduct experiment, use mathematics and models to explain results
A3) Communicate and defend a scientific argument
A4) Use technology, mathematics, logic and previous research in investigations
B2) Understand physical change and chemical bonds
D1) Understand nature of geochemical cycles and the role of energy in these cycles
E2) Understand interaction of science and technology in producing new knowledge
F1) Identify hazards, make choices that minimize risk of injury to self and others
F3) Recognize extent, sources and challenges of natural and human-induced hazards
F4) Recognize role of active debate among scientists and the public about decisions in science, technology
G1) Understand science as career and hobby
G3) Recognize role of society in directing or shaping science investigations

North American Association for Environmental Education—Grades 5-8:

1A) Develop, focus and explain questions about environment
1B) Design investigations to answer questions
1C) Locate and collect reliable information about environment
1E) Classify and order data, organize and display information
1G) Synthesize observations into coherent explanations
2.1A) Undestand most physical processes that shape the earth
2.1C) Understand energy transfer
2.2D) Understand how energy and matter flow in environment
2.4D) Understand human ability to control environment as function of knowledge, technology
3.1A) Use information to investigate environmental issues
3.1B) Identify consequences of specific environmental issues
3.1C) Develop action strategies for addressing particular issues

North American Association for Environmental Education—Grades 9-12:

0B) Investigate short- and long-term environmental changes
1A) Develop and explain questions about environment
1B) Design investigations to answer particular questions
1C) Collect reliable information, using technology as needed to gather and display data
1E) Organize and display information
1G) Use evidence and logic to develop hypotheses
2.2C) Understand the living environment as comprised of interrelated, dynamic systems
2.2D) Use interaction of matter and energy to explain environmental characteristics
2.4A) Understand that humans change environment and that there are limits to ability of environment to absorb these impacts
3.1B) Evaluate consequences of specific environmental changes, conditions and issues
3.1C) Identify action strategies likely to be effective in particular situations

Vocabulary: condensation, control, dispersion, fuel, inversion, meteorologist, PM-2.5, PM-10, prescribed fire, stable conditions, sublimation, unstable conditions

Materials

In this trunk...	***...where?*[74]**	***You must supply***
burning trays (4)	Main/A	12 newspaper squares, about 20X20 cm, crinkled a bit, then flattened
Smoke slides in *FireWorks* slide carousel	Main/C	Copy of Student Page 26, *Smoke Measurements*, for each student team
dead, dry ponderosa pine needles	*Fuels Box*, Main/B	matches
Managing Wildland Fire: Balancing America's Natural Heritage and the Public Interest booklets	*FireWorks Library*, Main/B	One 10-gallon aquarium tank
		Small twigs, .5 cm diameter or less—about 200 g—" a small bucket full"
spray bottles, with water ashtrays (4) digital thermometer/thermocouple freezer containers (2)	*Hardware Box*, Main/A	dry ice 1 qt boiling water
		Slide projector
Class page 14, *Smoke Recipes* Class page 15, *How Smoky?*	*Visual Aids*, Teacher/C	balance and trays to hold materials being weighed
fire extinguisher	Main/B	overhead projector, pens

Preparation

A day before the activity, place 1 c water in a freezer container and freeze it.

Collect small twigs, 0.5 cm diameter or less—a small bucket full. Break into lengths less than 20 cm. Leave in a warm, dry place for 1-2 days. You may need more pine needles.

Make sure the newspaper and pine needles that you will use are air-dry.

Make sure the thermometer's battery works. Have a spare on hand.

Assemble balance(s) and any trays needed for weighing fuels.

Decide how to organize the class. Demonstration 1 is written for a minimum of 4 student teams; if time and equipment permit, use more teams and obtain replicate measurements.

Procedure

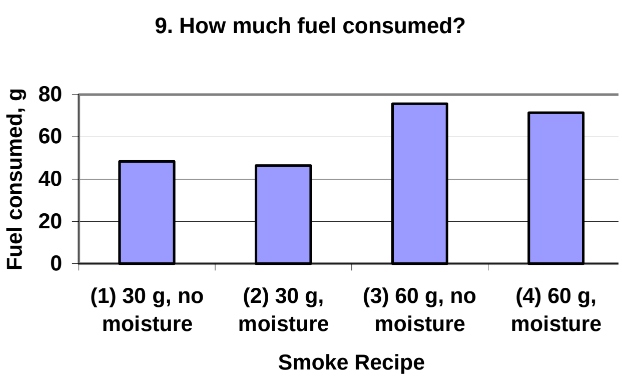
DEMONSTRATION 1— HOW MUCH SMOKE?

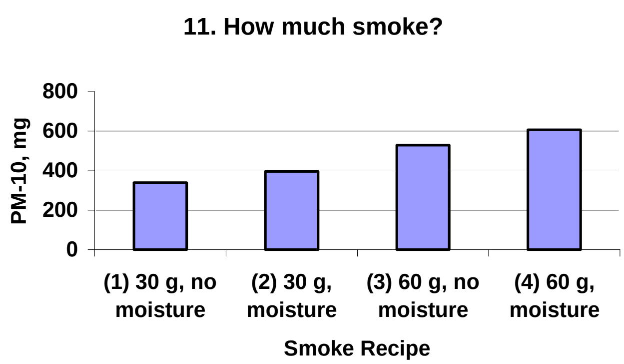
Do this outdoors—with minimal wind-- or under a hood!

1. Ask students: What is smoke? (Smoke consists of unburned and partially burned products of combustion. Fires release these products in tiny particles—micrometers across—which are light enough to circulate in the atmosphere instead of settling immediately to earth, as ash would do.)
2. Explain: One way to measure smoke is by measuring the weight of particles per unit volume of air. This measurement is expressed as *PM-2.5* or *PM-10*, meaning micrograms of particulate matter less than 2.5 (or 10) microns in diameter per cubic meter of air. Show the illustration at the top of Class Page 14 ("ingredients") so students can see how small a particle 2.5 microns in diameter would be relative to an average-sized grain of sand and particle of flour; about 70 percent of PM-10 is *less* than 2.5 microns in diameter.

[74] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

3. View the five slides in the *Smoke* section of the slide carousel. (These slides are also included in the *Living with Fire* CD-ROM and the videotape *Managing Wildland Fire—a Matter of Choice*.) Note how increasing quantities of particulates (this time measured in PM-10) decrease visibility.
4. Explain: In this demonstration, students estimate the amount of smoke released by fire. They estimate the *total* amount produced rather than amount *per unit volume of air*, because the smoke will disperse as it is produced. Ask what variables affect smoke production in a campfire. (Heat production and moisture will probably be mentioned. Fire managers use the same concepts; they would say that the amount of fuel consumed and the efficiency of combustion affect smoke production.)
5. Discuss the four recipes listed under "Measurements and Procedures" on Class Page 14. Ask which variables remain the same and which change with each experiment. (This is a *controlled experiment* because you *control* what changes. Only one variable changes at a time—first moisture, then fuel quantity.) Ask the class to guess which fire will produce the most smoke and which will produce the least. Record their guesses (hypotheses) on the board.
6. Divide the class into four teams. Give each team a copy of Student Page 26, *Smoke Measurements.* Ask each team to prepare a burning tray using one *Smoke Recipe* from the transparency, which you will assign. They should follow steps 1-6 on the Student Page. You can either have them ignite their smoke recipe when ready or wait for the class to view it.
7. Ignite the smoke recipes. As each one burns, ask the team to assess—qualitatively, in words--the amount of smoke being produced and record it as step 7 on their Student Page.
8. After the four burns are completed, ask students to finish their calculations. Have students graph the class's results for questions 9 and 11 (Student Page 26) on the transparency for Class Page 15, *How Smoky?* Results will vary considerably. Here is a sample data set:





9. Discuss observations:
   - Question 9: Which recipe burned the most fuel? Which burned the least?
   - Question 11: Which recipe produced the most and least smoke?
   - How does fuel moisture affect smoke production?
   - How does fuel quantity affect smoke production?

INFO SPARK: When more fuel burns, more smoke is produced. Therefore, recipe 3 is likely to produce more smoke than recipe 1, and 4 more than 2. We know that moist fuels burn less readily and less completely than dry fuels. If smoke production were determined *only* by fuel consumed, then recipe 2 would produce less smoke than recipe 1, and 4 less than 3. But moisture also reduces the *efficiency* of combustion; that means less fuel is converted to carbon dioxide and more is converted to ash and smoke. When a fire burns in moist fuels, it produces more smoke per unit of fuel consumed than a fire in dry fuels. Therefore, recipe 2 may produce more smoke than recipe 1 (and 4 more than 3). On the other hand, the moisture in recipes 2 and 4 may extinguish the fires so very little total smoke is produced.

10. Ask students to brainstorm for ways in which fire managers can plan prescribed fires to produce a minimum of smoke and still "get the job done." (They may try to minimize the acreage burned. They may use prescribed fire at times when the duff and large fuels are moist; fuel consumption is relatively low in these fires because only the small fuels burn. Other techniques include removing large fuels before igniting a fire, using mowing or grazing to reduce fuels, and igniting a fire in patterns that increase combustion efficiency.)

DEMONSTRATION 2—WEATHER CONDITIONS AND SMOKE DISPERSAL

1. Ask students what weather conditions they associate with "clean" and "dirty" air. What times of day are likely to have clean or dirty air? What seasons of the year?
2. Explain: When air is still, it "traps" pollutants in the air layer that we breathe instead of letting them *disperse* upward. This usually happens when cold air on the earth's surface is trapped under a layer of warm air. This activity demonstrates how such a condition traps pollutants in the lower atmosphere and why the condition is called an *inversion*.
3. Discuss the nature of *stable* and *unstable* atmospheric conditions. Ask: If you climb a mountain, do you expect it to be warmer or cooler at the top? (Cooler. During the day, the air is usually warmer on valley bottoms than at higher elevations. The warm air expands, rising and cooling as it does so. It cools at a rate of about 10 degrees C/1,000 m elevation. *Meteorologists* call this rate of cooling the "adiabatic lapse rate.")
4. Explain: Air heated by the earth's surface rises and is constantly replaced by cool air flowing down from higher elevations. These forces keep the air in motion, so we call the atmosphere *unstable*. If the earth's surface is too cold to heat the air at its surface, the dense valley-bottom air cannot rise; we call the atmosphere *stable* then, because air will not begin moving until the surface air warms up or is disturbed by wind. We call this condition an *inversion*, because the usual temperature gradient (warm below, cold above) is reversed.
5. Place the freezer container holding ice, and an empty freezer container, on a desk or table. Label the container with ice "#1" and the empty container "#2." Pour 1 c of boiling water into container 2.
6. Write the following table on the board. *Leave the data out*; they are only one example:

Classroom temperature (^{o}C): 22.0		
	Container 1: Ice	**Container 2: Boiling water**
^{O}C, level with top of container, above center	21.8	24
^{O}C, inside container, 0.1 cm above ice or water	9.9	31

7. Using the thermocouple, record temperature in the classroom.
8. Then record temperatures at these locations in container 1:
   - Level with top of container, over its center
   - Inside container, about 0.1 cm above surface of ice (not touching ice)
9. Record temperatures in these locations in container 2:
   - Level with top of container, over its center
   - Inside container, about 0.1 cm above surface of boiling water (not touching water)

10. Ask: Which tank has an *inversion*? (Container 1, because warm air is lying on top of cold air.) Which tank has *stable* conditions? (Container 1, because the cold air cannot escape until it is warmed to the temperature of the air above.) Which tank has *unstable* conditions? (Container 2, because the air at the bottom of the container is warmer than that above, so it is free to expand and move upward.)
11. Now you can make an inversion that is *visible* to students. Place crushed dry ice in the bottom of the aquarium. Pour water over the dry ice. The resulting fog will fill the tank but not rise out of it. Use the thermometer to record temperatures in this inversion.

> **INFO SPARK:** Dry ice is frozen carbon dioxide (CO_2), which is subliming constantly from solid to gaseous phase. Water accelerates the *sublimation*. The fog is water vapor, which condenses from the air next to the dry ice. The water vapor is mixed with invisible, gaseous CO_2. This mixture is denser than air, both because it is cold and because CO_2 is heavier than air. (See page 39 for calculation of the molecular weights of carbon and oxygen.

12. Ask students what information a fire manager would need to decide how well the smoke from a prescribed fire will disperse. (Air temperature patterns, wind patterns, snow cover, and likelihood of an inversion are important facts.) Ask how that information could be obtained and how accurate it is likely to be. (Obtain the information from local *meteorologist*s. Their predictions are based on science, many years' records, and lots of experience, but forecasts are always uncertain. A short term forecast—1 hour or 1 day—is much more certain than a longer term forecast.)

Evaluation: On the board, write "**Is smoke from wildland fires any more acceptable than cigarette smoke?"** Ask students to read and think about the bullet points regarding smoke on pp. 5-7 of the booklet *Managing Wildland Fire: Balancing America's Natural Heritage and the Public Interest* (in the *FireWorks Library*). Ask them to respond to the question above, either with their opinion and and explanation, or with a discussion of the information needed before the question can be answered.

Closure: Discuss: Suppose a fire manager starts a prescribed fire on a day when smoke is predicted to disperse well. Then the weather changes, and smoke settles into the town. During the night, 3 children go to the hospital with asthma attacks. Discuss: Were the asthma attacks caused by the smoke? Should the fire manager be held responsible for the sick children? What additional information might you want before answering these questions?

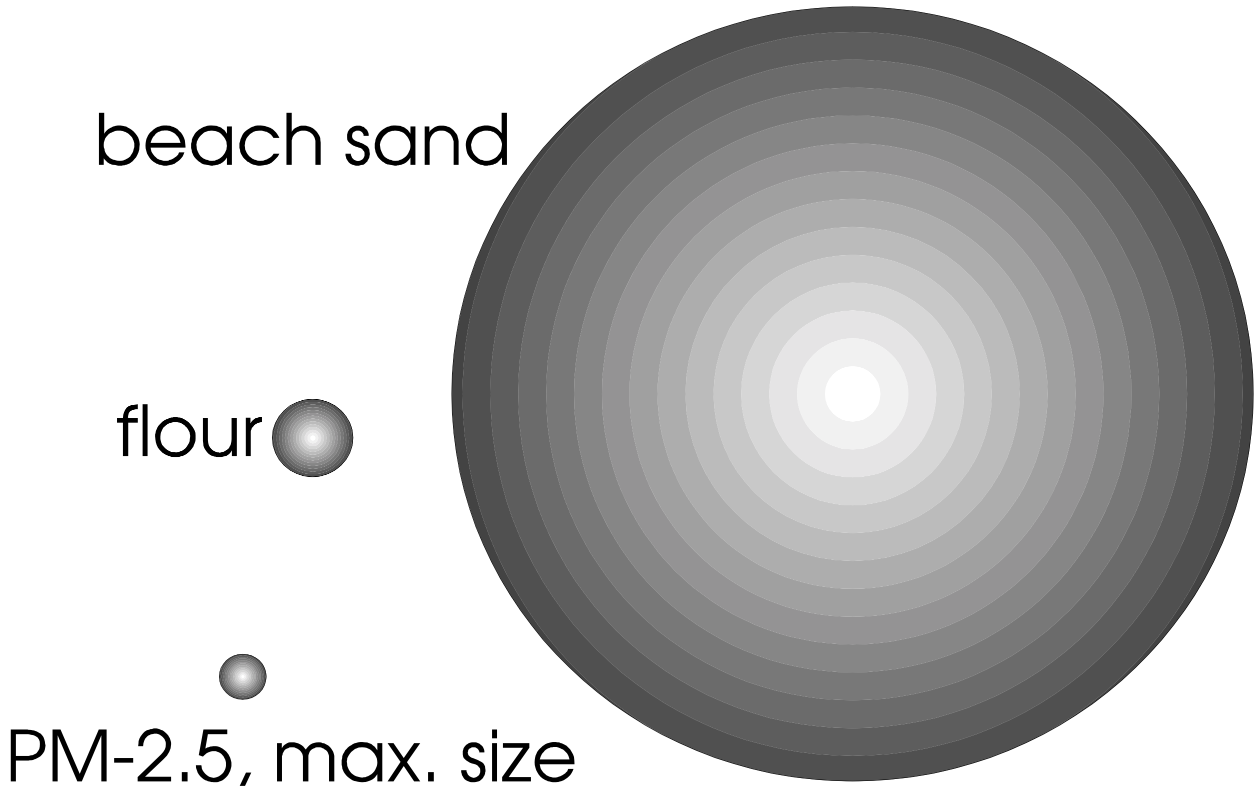
Extensions

1. Repeat Recipes 2 and 4 of Demonstration 1, but use twigs that have been soaked in water for 5 minutes. What results do you expect? Compare results with the data already collected for the demonstration.
2. Investigate the similarities and differences between smoke from wildland fires and smoke from cigarettes. Describe both chemical composition and concentration. Report to the class.
3. Use the procedures Activity 3-4 (the matchstick forests) or Activity 3-7 (tinker trees) to determine the effect of fuel arrangement on fuel consumed and smoke produced. Then vary the fuel moisture in your activity and measure its effects on your experimental fires.

Smoke Recipes

Class Page 14

Ingredient size:



Measurements and Procedures:

Recipe 1. 30 grams twigs, <u>no moisture added</u>

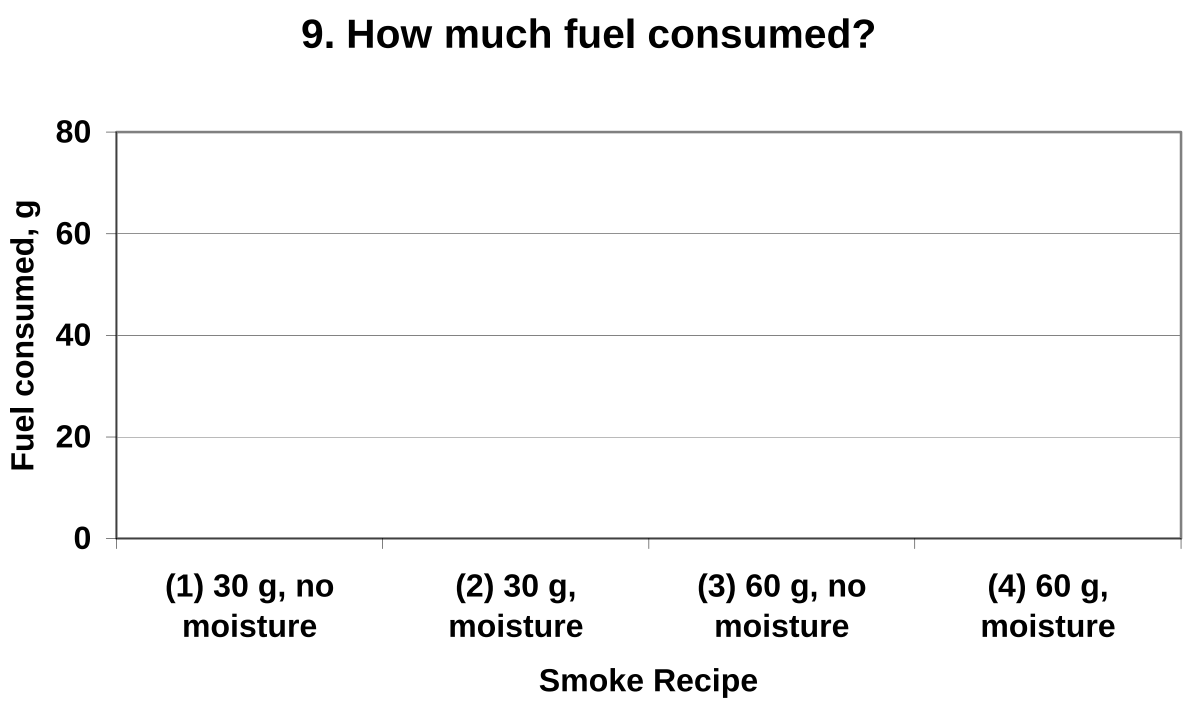
Recipe 2. 30 grams twigs, <u>moisture added</u>

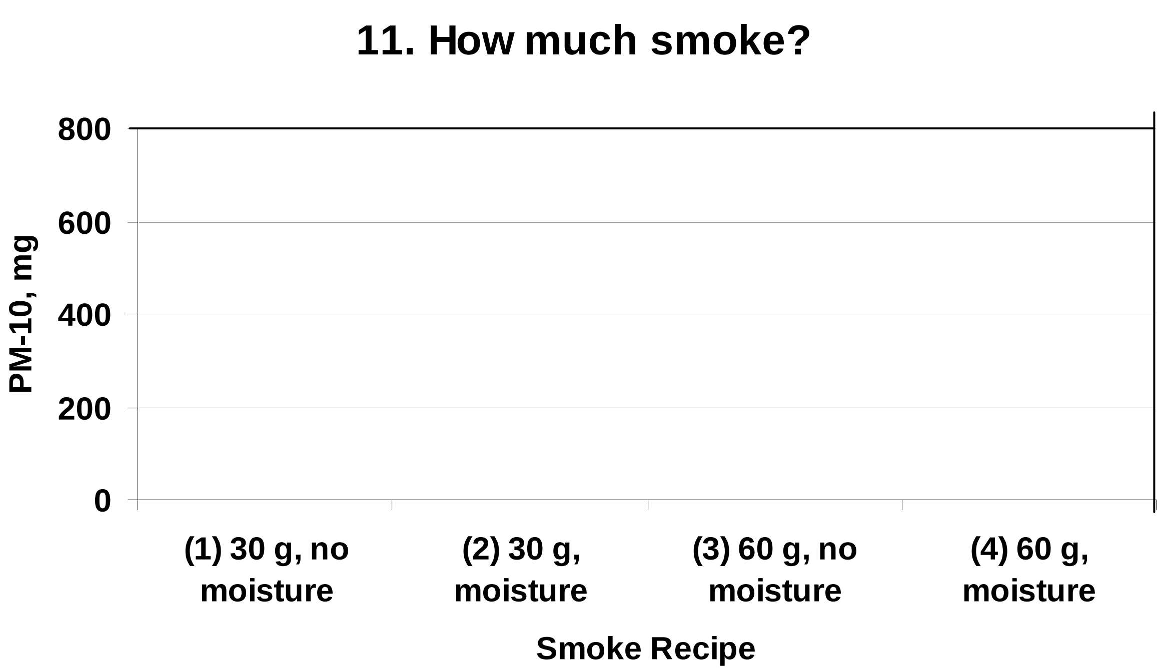
Recipe 3. 60 grams twigs, <u>no moisture added</u>

Recipe 4. 60 grams twigs, <u>moisture added</u>

How Smoky?

Class Page 15





Student Page 26

Smoke Measurements

Names ________________________

Record the *Smoke Recipe* assigned to you:

Smoke Recipe #_____,
using ______ g of twigs
and adding or not adding moisture (circle one).

1. Weigh your burning tray and record. ______ g
2. Weigh 3 pieces of newspaper and record. Crinkle & then flatten out. Place on tray. ______ g
3. Weigh out 10 g of dry pine needles. Place on newspaper. __10__ g
4. Weigh out the amount of twigs needed for your *Smoke Recipe.* ______ g
5. Don't put the twigs on top of the pine needles yet. If you are assigned a recipe that requires adding moisture, spray the twigs (not the other fuels) until they are quite moist. (25 squirts should do it for 30 g of twigs, 50 squirts for 60 g of twigs.) Then put the twigs on top of the pine needles. Intermix a few needles with twigs to get a mix that will burn as well as possible.
6. Calculate total preburn weight (#1+#2+#3+#4). ______ g
7. When the class and teacher are ready to observe your demonstration, light the 4 corners of newspaper and observe the fire. Would you call it a fairly clean fire (producing little smoke) or a pretty smoky fire? ____________________
8. After the fuels cool, weigh the tray and record what is left. ______ g
9. How much fuel was consumed in your demonstration (subtract #8 from #6)? ______ g
10. Enter the emission factor for your demonstration:
    a. 7.0 mg of PM-10 per g of dry twigs burned or
    b. 8.5 mg of PM-10 per g of moist twigs burned ______mg/g
11. Calculate the smoke (PM-10) produced by your demonstration fire (#9X#10) ______ mg
12. Do you still agree with your smoke assessment above (#7)? Explain.
13. Make sure fuels are extinguished. Clean up.

Activity 8-5. You Decide!

Grade levels:
X Middle
X High

What's the Point? ________

In this activity, students "go to work," role playing as forest owners and managers. Each of five student teams is assigned a land area and given a brochure describing the "neighborhood," the land's fire history, and what it is like right now. Then the teams discuss and set goals for their land and develop a 10-year plan for managing it. They balance concerns about safety, esthetics, animal habitat, and expenses as they make plans for their land (fig. 30).

Figure 30—Two students discuss goals for the old-growth ponderosa pine forest that they are responsible for managing.

Teacher's Map:

Objective(s): Given a description of a wildland area, students can work in teams to select management goals and plan ways to meet them.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Social Studies, Technology, Library Media, Health, Workplace Competencies

Duration: 2 hours or more of preparation time by students, 15 minutes for each student presentation (up to 5 presentations)

Links to Standards[75]:

National Science Teachers' Association—Grades 5-8:

E3) Demonstrate risks and tradeoffs in technological design
E4) Recognize that technology produces benefits and also unintended consequences
F1) identify potential for accidents, make choices that minimize risk of injury
F3) Recognize sources and challenges of natural and human-induced hazards
F4) Make personal and social decisions based on perceptions of benefits and risks
F6) Recognize difference between science questions and other questions

National Science Teachers' Association—Grades 9-12:

C5) Recognize ways in which human-caused changes differ from other changes in ecosystems
F1) Identify hazards, make choices that minimize risk of injury
F3) Recognize extent, sources and challenges of natural and human-induced hazards
F4) Recognize role of active debate among scientists and public about decisions
G1) Understand science as career and hobby

North American Association for Environmental Education—Grades 5-8:

[75] See Appendix 4 for links to Montana educational standards, grades 5-8, 9-12.

2.3C) Understand political and economic systems and relationship to environment

cont'd.

2.4D) Understand human ability to control environment as function of knowledge, technology
3.1A) Use information to investigate environmental issues
3.1B) Identify consequences of specific environmental issues
3.1C) Develop action strategies for addressing particular issues
3.2A) Develop personal views on environmental issues
4D) Understand and accept personal responsibility for actions
North American Association for Environmental Education—Grades 9-12:
0B) Investigate short- and long-term environmental changes
2.3A) Understand influence of individual and group actions on environment
2.3C) Understand how political and economic systems affect resources and environment
2.4D) Examine social and environmental impact of various technologies
3.1A) Investigate environmental issues
3.1B) Evaluate consequences of specific environmental changes, conditions and issues for humans and ecosystems
3.1C) Identify action strategies likely to be effective in particular situations
3.2A) Communicate, evaluate, and justify views on environmental issue
3.2B) Decide whether action is needed in a situation
3.2C) Plan for and act on issue, if appropriate
4A) Analyze influence of shared and conflicting social values
4D) Accept responsibility for effects of actions

Vocabulary: fire management, management goals, management plan

Materials

In this trunk...	*...where?*[76]	*You must supply*
Pathways in Time booklets (3)	*FireWorks Library*, in Main/B	calculators or computers with spreadsheet program installed
FireWorks Notebook	Teacher/C	
You Decide! kit: 5 brochures, one for each student team	Teacher/C	

Preparation

Decide how to assign projects to students. There are five "management challenges" available:

1. Home in the Pines (ponderosa pine, wildland/urban interface)
2. Cabin in the Woods (lodgepole pine, remote area)
3. Questions in the High Mountains (whitebark pine, public land)
4. Burnt Trees: a Gift (lodgepole pine stand recently killed by crown fire)
5. Caretaker of the Ancient Forest (ponderosa pine old growth in urban area)

You may want to have teams of students work on only two or three of the management challenges, or you may want to have at least one team work on each. You may want to assign two groups of students to each management challenge (sharing materials), then schedule the two

[76] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

teams' presentations together. This would show the class how different management plans can arise from different objectives.

Decide what kind of final product you want. A written report, containing tables and graphs, reviewed by other students and followed by a class presentation would be ideal for student development and would mimic real-world processes. A class presentation followed by discussion and debate would be appropriate if you have more than one group address the same land management scenario.

Procedure

1. Explain: Students will plan how to manage a forested area. They will set goals for their land and prepare a *management plan*. Sometimes land owners and managers use fire on purpose to change the architecture of a forest or improve habitat for a particular species.
2. Explain the assignment: Each team of students is responsible for taking care of a forested area for the next ten years. Some of the areas are private land, and students will be the "owners." Other areas are public land, and students will be the "managers." Their assigned land is described in the *You Decide!* brochure for each team.
3. Explain how much time students have to prepare, whether they will prepare in class or as homework, and what kind of final report/presentation you want.
4. Provide supplies and materials, including calculators, and the *Pathways in Time* booklets. Arrange for students to borrow other materials from the *FireWorks Library*.

   For High School students, make computers with spreadsheet programs available for student use. Suggest they consult the Fire Effects Information System (www.fs.fed.us/database/feis) for information about species occurring on their land. Ask them to interview local experts before making land management decisions.
5. Schedule due date for draft report and final report with presentation.
6. When preparation time is over, have students edit each other's draft reports
7. At due date, have students give presentations and hand in reports.
8. **OPTIONAL:** At some point toward the end of this activity, use Smokeygram #4 (fig. 31). It is just a reminder that management of wildland fire is professional work, a potential career but not a hobby for untrained people.

Evaluation: Assess presentations and reports.

Closure: Ask students about the process of doing this activity. Here are some lead questions:
1. Which process was more difficult—setting goals or finding ways to meet them?
2. Did anyone find it difficult to plan for meeting goals that you didn't agree with?
3. How easy is it in the "real world" to change goals for private land? (In a legal sense, it's very easy unless it interferes with laws for public protection. However, you may want to consult your neighbors, your attorney, and your insurance agent about any dramatic changes you envision.)
4. How easy is it to change goals for public land? (Usually this requires legislative change or directions from appointed officials. Research and public discussions are often required.)
5. Explain: For real land managers, safety is the first, most important goal. They don't want visitors or workers getting hurt—now or fifty years from now—because of the way the land is managed. In a forested area where people live, it may be very difficult to keep the forest safe. The people who live there have to help by being careful with fire and by reducing fire

hazards around their homes. In places far from people's homes, particularly large wilderness

---Smokeygram #4

Dear Class,

You know a lot now about wildland fire. I hope your knowledge helps you be more careful than ever. Scientists and land managers use fire in our forests and grasslands to improve habitat, protect endangered species, and improve safety. That's their job, after college and a lot of work experience. Your job, until you become scientists and land managers, is to do your very best to prevent fires in the forests and grasslands, my home. Thanks!

Sincerely yours,

Figure 31—Smokeygram #4, for use at end of Activity 8-5.

areas, managers can work toward other goals—improving habitat quality or protecting plant species that depend on fire, for example—while still providing for safety.

Extensions

1. Ask a local public land manager or a homeowner who lives in a forested area to review and comment on students' management plans; then have students revise them incorporating the reviewer's comments.
2. The moisture content of vegetation influences fire behavior strongly. Learn about the "greenness" of vegetation throughout the United States using the maps used by managers at the Internet site

   www.fs.fed.us/land/wfas/map_list.html
3. Learn more about how managers plan prescribed fires at the National Interagency Fire Center's Internet site:

   fire.nifc.nps.gov/fire/ecology/docs/trippbn.htm
4. If you wanted to become a fire ecologist or wildland fire manager, what would you need to study in high school? What would you need to study in college? If possible, ask a fire specialist or career counselor about the skills and education needed for this field.
5. Read and report to the class or critique one of the articles describing actual fire management problems and potential solutions in *The Use of Fire in Forest Restoration,* in the *FireWorks Library.*

Activity 8-6. Value Choices

Grade level:
X High

What's the Point?

We learn information and critical thinking skills so we can make valid judgments. In value judgments, we also incorporate our personal experiences, values, and feelings. It is a complicated process, and there are usually no single "right" answers. In this activity, students consider and compare things they might experience in relation to wildland fire. They choose experiences they "can live with" as opposed to those they find unacceptable. **The objective of the game,** unknown to students at the start, is to get some of them frustrated enough at the limited options available that they object and say they can't participate anymore. That sets the stage for a discussion of ways in which people work together and make group decisions, a comparison of *majority rule* with *consensus*. At the end of this discussion, students apply the two decision-making concepts to fire management choices.

Teacher's Map:

Objective: Confronted with decision-making scenarios in which there may be no "perfect" options available, students choose between alternatives and explain their reasoning.

Subjects: Science, Speaking and Listening, Social Studies, Health, Workplace Competencies

Duration: 30 minutes

Links to Standards[77]:

National Science Teachers' Association—Grades 9-12:

F4) Recognize the role of active debate among scientists and the public about decisions in science and technology
G3) Recognize role of society in directing or shaping science investigations

North American Association for Environmental Education—Grades 9-12:

2.3A) Understand influence of individual and group actions on environment
2.3C) Understand how political and economic systems manage and affect environment
2.3E) Understand functioning of public processes for managing change and conflict
3.1B) Evaluate consequences of specific environmental changes, conditions and issues
3.1C) Identify action strategies likely to be effective in particular situations
3.2A) Communicate, evaluate, and justify views on environmental issue
3.2B) Decide whether action is needed in a situation
4A) Analyze influence of shared and conflicting social values
4B) Understand importance of exercising rights and responsibilities of citizenship

Vocabulary: value

[77] See Appendix 4 for links to Montana educational standards, grades 9-12.

Materials

In this trunk…	*… where?*[78]	*You must supply*
Value Choices Kit	Teacher/C	Copy of Student Page 27 (*Calling Washington*) for each pair of students

Preparation

Select 6 to 11 "experience cards" from the *Value Choices* Kit in the Teacher's Box.

Procedure

1. Select 6 to 11 students to face you and the class in a half-circle.
2. Give each student one laminated "experience card."
3. Have the students read their experience card to the class.
4. Ask the rest of the students to decide individually which experience they find most acceptable (phrases they might use include "I can live with that" and "It's least objectionable") and then stand in a line behind the person holding that card. **EXPLAIN THAT THERE ARE NO RIGHT OR WRONG ANSWERS.**
5. When every student has made a choice, ask the card holders if they would like to move to another group; if so, they can give their card to someone else in line and move. If no one else is in that line, take the card and put it away.
6. Ask members of each group to give reasons for their choices. After they do so, let students move to different groups if they want to.
7. Take away the experience card from the largest group and disband them. Explain that the option they have chosen is no longer available. Tell them they have to choose another group, and give them a minute or so to do so.
8. Take away the experience card from the smallest group. Tell them that option is not available, so they must choose another group.
9. Repeat steps 7 and 8 until someone complains, "I can't accept any of those!" If no one expresses frustration about the limited options, stop the activity after 10 minutes or so and ask if anyone feels that way. Then it's time for discussion:
10. Explain: When people disagree in value judgments and cannot accept any of the alternatives offered, the group can choose various courses of action. One course is to go by *majority rule.* In this case, the largest group "has things its way," and members of other groups have to go along. Majority rule is an efficient way to make a decision, but it may leave many people unsatisfied with the results, and they may find ways to block the action outside of this group (such as court injunctions and lawsuits). Another course of action is to continue discussion and seek agreement; this is sometimes called *consensus building*. It can take a very long time, but its huge benefit is that no action is taken until all participants decide they can accept the results. Its disadvantage is that outside circumstances may change while people are trying to reach consensus, closing off some options that are currently available.
11. Ask:
    - Would you prefer to use majority rule or consensus building to reach decisions on wildland fire?

[78] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

- If you choose majority rule, can the people who did not agree with the decision do anything to change it?
- If you choose consensus building, do you think there is any risk that a decision won't be made before nature produces a wildland fire with effects that *nobody* wanted?

Evaluation: Ask the class to complete Student Page 27, *Calling Washington*, in pairs. Students take on the role of a citizen calling his or her U.S. Senator or Congressperson to support or object to a fire management choice.

Closure: Ask the students to recommend a few students who made excellent phone calls. Have the pairs role-play the calls for the class, and let students critique the role-plays.

Extension

Survey students in your school or adults in your community to learn their feelings about wildland fire. Pages 59 and 60 in *Ecosystem Matters* (in the *Teacher Box*) offer suggestions about how to design and complete such a survey.

Student Page 27

Calling Washington

Take turns being the citizen caller and the Congressperson answering. Congressperson, circle and add up points for the caller. Be polite; this is a possible vote.

1. Caller:_______________ Congressperson: _____________

		No	Sort of	Yes
1.	Did the caller identify himself or herself at the beginning of the call?	0	1	2
2.	Did the caller explain clearly why he/she was calling?	0	1	2
3.	Did the caller state his/her viewpoint clearly?	0	1	2
4.	Did the caller provide supporting facts or explanations?	0	1	2
5.	Did the caller end the phone call politely, thanking you for your attention?	0	1	2

Total Points: _____________

---

2. Caller:_______________ Congressperson: _____________

		No	Sort of	Yes
1.	Did the caller identify himself or herself at the beginning of the call?	0	1	2
2.	Did the caller explain clearly why he/she was calling?	0	1	2
3.	Did the caller state his/her viewpoint clearly?	0	1	2
4.	Did the caller provide supporting facts or explanations?	0	1	2
5.	Did the caller end the phone call politely, thanking you for your attention?	0	1	2

Total Points: _____________

Chapter 9.
In the Woods

FireWorks is designed for learning in the classroom. But field experience is essential to environmental education, so students can see and touch and smell and study the natural environment themselves. In the field, students can apply what they have learned in *FireWorks* and learn from first-hand experience. This chapter describes two field trips for students who have studied *FireWorks.* The first is an open-ended "scavenger hunt" designed for Elementary students. The second is a very structured activity that can be used for both instruction and evaluation in the field; it is written for Middle School students. These programs can be adapted for other grade levels. If possible, combine your field activity with an outdoor talk or tour guided by a forestry, fire, or wildlife professional who can describe real-world application of ecological understanding to field problems.

Background

The *FireWorks* programs for Elementary and Middle School use (tables 3 and 4) provide background for these activities.

Chapter Goals

1. To provide opportunities for students to apply classroom learning in the field by demonstrating and explaining what has been learned
2. To increase student understanding of concepts covered in *FireWorks* by introducing them to a professional land manager or researcher at a field site

Chapter Activities

Activity 9-1. Burned Area Scavenger Hunt	(E)
Activity 9-2. Woods Hunt	(M)

Activity 9-1. Burned Area Scavenger Hunt[79]

Grade level:
X Elementary

What's the Point?

Students explore a recently burned area, looking for items that indicate what kind of fire occurred, what species live there, and how the area's inhabitants respond to fire.

Teacher's Map:

Objective: In a recently burned area, students can find and plants, animals, and animal sign, and use them to infer characteristics of the fire and the ecosystem.

Subjects: Science, Speaking and Listening, Workplace Competencies

Duration: 1 hour in the field

Links to Standards[80]:

National Science Teachers' Association—Grades K-4:

A5) Communicate investigations and explanations
C1) Identify needs of various organisms
C2) Identify structures of various organisms and the needs they serve
F1) Understand and make choices for safety and preventing injury
F4) Understand that changes in environments can be natural or influenced by people
F5) Understand that changes in environments can be slow or rapid, and rate has consequences
G2) Recognize that many people choose science careers and enjoy science

National Science Teachers' Association—Grades 5-8:

C1) Describe structure and function in a living system
C4) Recognize that ability to obtain and use resources, grow, reproduce… are essential for life
F1) Identify potential for accidents, make choices that minimize risk of injury
F3) Recognize sources and challenges of natural and human-induced hazards

North American Association for Environmental Education—Grades K-4:

0A) Identify basic kinds of habitat and plants and animals living there
0C) Describe aspects that change on temporal basis
1C) Collect information about environment
2.2A) Understand similarities and differences among variety of organisms. Understand habitat
2.2C) Understand basic ways organisms are related to environment and other organisms
3.1B) Sort out consequences of issues

North American Association for Environmental Education—Grades 5-8:

0A) Classify local ecosystems. Create food webs
1C) Locate and collect reliable information about environment
2.2A) Understand biotic communities and adaptations
2.2C) understand interactions among organisms and populations
2.2D) Understand how energy and matter flow in environment
3.1B) Identify consequences of specific environmental issues

Vocabulary: field site

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[79] Adapted from *Getting to Know Wildland Fire.* See Appendix 3.
[80] See Appendix 4 for links to Montana educational standards, grades K-4, 5-8.

Materials

No equipment is needed from the *Fireworks* Trunk.

You must supply
Copy of Student Page 28, *Scavenger Hunt Checklist*, for each student team
pencils (1 per student team)
After returning from field trip: card stock cut into postcard size (4X6 inches), one per student

Preparation

Locate a field site. This should be a forest burned in the past 5 years or so. It need not be severely burned; it could be an area prescribed burned by local land managers to meet objectives such as improvement of wildlife habitat. Local managers can probably help you find a good field site. Visit it ahead of time, if possible, to determine how to set boundaries on the scavenger hunt **so no one gets lost!**

Find helpers. Since students will be working in teams, you may want to have an adult accompany each team in the field.

Procedure

1. Talk with the class and volunteers in regard to safety and procedures (team assignments, buddy system, etc.).
2. Travel to field site.
3. Explain the boundaries of the area to be searched on the Scavenger Hunt.
4. Give each team a copy of Student Page 28, *Scavenger Hunt Checklist.* Instruct each team to find and check off as many items as possible. Explain that students should not *collect* the things they discover, just observe and describe them.
5. Give a time limit and a signal for when teams should gather, and tell them where to meet.
6. Tell students to begin the scavenger hunt.
7. At the end of the time limit, signal students to gather together.
8. When all have gathered, ask students to describe what they found for each item listed on the checklist. If the discoveries are nearby, have the "discoverers" share them with the rest of the class.

Closure: If possible, have a professional fire manager, forester, or ecologist to join the class and do a short presentation or some activities with them.

Evaluation: After returning to the classroom, provide card stock paper and have each student make a postcard to send to the land owner of the area visited or the person who made a presentation. Show them how a postcard is designed—a short note on the left side, an address on the right side, and a picture on the reverse.

Extensions

1. If collecting is appropriate at your field trip's location, ask students to collect leaves while on the field trip. When you return to school, use the prints to make rubbings or placemats from the leaves.
2. Tour a virtual forest on the Bureau of Land Management's Internet site www.blm.gov/education/ecosystem/handland/tours.html

Student Page 28

Burned Area Scavenger Hunt

adapted from *Getting to Know Wildland Fire*

Team Members: ____

Burned areas can be exciting places to explore. They can also be dangerous. Don't ever go into an area burned by crown fire on a windy day. Listen and watch for falling trees.

See how many of these things you can find in the burned forest.
Check them off as you find them.

1.______ Find a place where the fire burned tree crowns. Then find a place where it only burned on the ground or in grass and shrubs.

2.______ Find a tree's cone. What is the species of tree?________________
Does this cone need fire to open it? __________

3.______ Find a tree seedling. What kind of tree? ________________

4.______ Find a shrub or small plant that sprouted roots after the fire.
How can you tell it was burned?__________________________________

5.______ Find a tree that burned but did not die. What kind of tree? _____________________

How can you tell it burned? _________________

6.______ Find a place where an animal was feeding.
What was it feeding on—plant or animal, grass, shrub, or tree? ________________

7.______ Find animal tracks. Draw them on the back.
What kind of animal made them? ___________________

8.______ Find animal scat. Draw it on the back.
What kind of animal left it here? ___________________

9.______ Find a place where an animal burrowed underground.
How big is the entrance?_________________________

10.______ Find a tree killed by fire. Describe what is left:_________________________

11.______ Find evidence that insects fed on a burned tree.
Draw what you observe.

Activity 9-2. Woods Hunt

Grade level:
X Middle

What's the Point? ______________

In this activity, students work in teams of 5. Each team walks to six information stations; at each station, each team member answers one question about fire ecology (fig. 32). This activity was developed as an assessment tool by University of Montana scientists Linda Thomas and James Walsh (Thomas and Walsh 2000). It has since been revised for use by school classes.

Figure 32—Seventh grader thinks hard before answering a *Woods Hunt* question. Photo by Kinnerly Smith.

Teacher's Map:

Objective: In a field setting, students can demonstrate their learning about fire behavior, wildlife and plants, tree identification, fire history, homes and fire, and several kinds of forest.

Subjects: Science, Speaking and Listening, Social Studies, Health, Workplace Competencies

Duration: 80 to 90 minutes in the field for a class of about 30 students

Links to Standards[81]:

National Science Teachers' Association—Grades 5-8:

C7) Recognize nature of energy and food webs
E1) Identify a need for technological design...
E3) Demonstrate risks and tradeoffs in technological design
F1) Recognize potential for accidents, make choices that minimize risk of injury
F3) Recognize sources and challenges of natural and human-induced hazards
F4) Make personal and social decisions based on perceptions of benefits and risks

North American Association for Environmental Education—Grades 5-8:

0A) Classify local ecosystems. Create food webs
2.2A) Understand biotic communities and adaptations
2.2C) Understand interactions among organisms and populations
2.4A) Understand that human-caused changes affect environment
2.4D) Understand human ability to control environment as function of knowledge, technology
3.1B) Identify consequences of specific environmental issues
3.1C) Develop action strategies for addressing particular issues

[81] See Appendix 4 for links to Montana educational standards, grades 5-8.

Vocabulary: field site

Materials

In this trunk...	*...where?*[82]	*You must supply*
Ponderosa pine cone	*Tree Cones Box*, Main/A	Wire or tape for hanging station numbers
		Posts for arrow signs
		Thumbtacks
		Hammer
"Woods Hunt" Kit: 6 laminated question cards 6 laminated number signs 6 laminated arrow signs	Teacher/C	1 copy of Class Page 16, *Woods Hunt Details*. Cut off upper table (full of numbers), and cut it into 6 vertical strips.
		pencils (30)
		Hole punches (6)
		Copy of response card for each student (fig. 33)—find master copy in *Woods Hunt* Kit
		6 copies of Stationmaster Instructions (Student Page 29)
		calculator
		Permanent marker (6)
		Award(s) for winning team(s)

Planning

You will need the following:

Field site: A ponderosa pine/Douglas-fir forest near at least one residence. Local land managers can probably suggest a site. The forest should include at least one fire-scarred ponderosa pine and some Douglas-fir dwarf mistletoe. Engelmann spruces and cottonwoods should not be present. One "prop" is needed for the Woods Hunt: a ponderosa pine cone.

Helpers: Locate at least six volunteers to act as "stationmasters," interviewing students at each of six information stations, assessing student answers, and

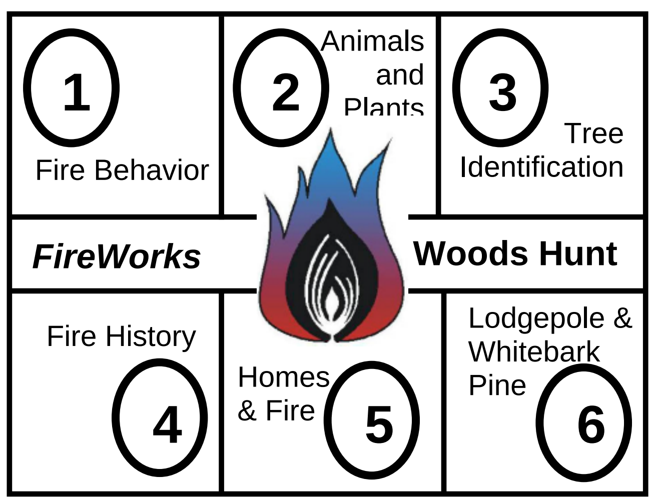

Figure 33—Student response card, from *Woods Hunt Kit* in *Teacher Box.*

[82] Entry to left of slash is for Packing Arrangement 1 (large tub plus Teacher Box); Main=Main Trunk, Teacher=Teacher Box. Entry to right of slash is for Packing Arrangement 2 (three cartons, labeled by letter).

punching student response cards. You may also use six volunteer "herders," one to accompany each team of 5 students.

Time: You will need about 30 minutes to set up the site, about 1.5 hours for a group of 30 students to do the entire "Woods Hunt," extra time for transportation, and other field time.

Preparation

1. Select and set up the field site. You'll need six Information Stations within easy walking distance of each other (but not within easy earshot), with the following characteristics:
   - Fire Behavior Station. Area with substantial surface fuel, some seedling or sapling ladder fuels, and a fairly steep hillside somewhere in view.
   - Wildlife & Plants Station. Area with shrubs and herbs obvious. Also, some mistletoe-infested Douglas-firs should be visible.
   - Tree Identification & Adaptations. Near a mature ponderosa pine and a mature Douglas-fir.
   - Fire History. Near a fire scarred ponderosa pine or stump.
   - Homes & Fire. Area with at least one home visible in a forested environment.
   - Lodgepole & Whitebark Pine. Some lodgepole pine forest or some high slopes with dense tree cover should be visible.
2. Make copies of the Response Card (a master copy is in the *Woods Hunt* Kit) on card stock so each student can have one. Note that each page of the master has four copies of the Response Card.
3. Make 6 copies of Student Page 29 (*Stationmaster Instructions*) and one copy of Class Page 16, *Woods Hunt Details* (per class of 30). Cut off the upper table on Class Page 16 and cut it into 6 vertical strips, one for each student team.

Procedure

1. Prepare stationmasters. Assign each stationmaster one Woods Hunt Station and give each a question card. Have stationmasters read their questions and the correct answers; answer any questions they have. Give the ponderosa pine cone to Stationmaster #6.
2. Give each stationmaster a copy of *Stationmaster Instructions* (Student Page 29) and go over them. **If you are using the field activity as a test,** to evaluate student learning, explain that the stationmasters have to treat every team in exactly the same way, using exactly the same questions, offering minimal clues, and NOT explaining answers or discussing whether the students answered correctly or not until all students have answered in a group.
3. Travel to the Woods Hunt site.
4. Give each stationmaster a laminated station number, arrow sign, some wire or tape, a post and thumbtack, marker, and hole punch. Have stationmasters set up their stations. This will take 20-30 minutes.
5. Divide class into six teams, each with 5 students. Have students select a name for their team. Give a Response Card to each student. Have students write their names and their team name on the backs of their cards.
6. Give each team a list of stations numbers in the order they should be visited (one column of the upper table on *Woods Hunt Details,* Class Page 16).

7. Tell student teams to visit the stations *in the order listed* on the strip you just gave them, then return to you at a central location. They need no more than 10 minutes for each station and they should “hustle” between stations.
8. Tell teams to begin.
9. When all teams have completed all stations and gathered at a central location, collect their cards ,checking for name and team name on back of each, and give them another assignment. This would be a great time to have a professional land manager give them a tour of the site or some other activity.
10. While students are busy, have one or two stationmasters fill out the table at the bottom of Class Page 16. Count the number of correct answers for each team. Write down the number of questions asked each team (30, unless the team had fewer than 5 students). Compute each team’s score as a percent. The team with the highest percentage wins.

Evaluation: **If you are using this activity as a test,** Keep and grade students’ individual response cards; record as part of each student’s grade on the *FireWorks* unit.

Closure: When students convene from their other activity, announce the winning team and award prizes.

Class Page 16

Woods Hunt Details

Order of Information Stations

Cut the following table into 6 vertical strips, and give one strip to each student team.

Visit the Information Stations in this order:	Visit the Information Stations in this order:	Visit the Information Stations in this order:	Visit the Information Stations in this order:	Visit the Information Stations in this order:	Visit the Information Stations in this order:
1	6	5	4	3	2
2	1	6	5	4	3
3	2	1	6	5	4
4	3	2	1	6	5
5	4	3	2	1	6
6	5	4	3	2	1

Team Scores for Woods Hunt

Use this table to compute team scores for the Woods Hunt and select the winning team.

Team Name	Number Correct Answers	Total Number Questions Asked	Team Score (%)
		30?	
		30?	
		30?	
		30?	
		30?	
		30?	

Student Page 29

Instructions for Woods Hunt
Stationmasters

This field exercise can be used either as a test, to evaluate student learning, or as a competition between student teams—or both**. If it is a test,** please treat every team in exactly the same way: Use the same words from the question sheet for each team. Do not explain answers until all members of a team have answered their questions. Ask the teacher if you should discuss answers after the whole team has finished your station, before they move on to the next.

Procedures:

1. Set up your Information Station. Hang the number up high, so students can see it from far away. Put the post in the ground in an open area, pointing to your station, and tack the arrow to it.

2. During the Woods Hunt, teams of 5 students will visit your station. If one team approaches while you're talking with another, ask the second team to stand back so they won't hear the questions and answers.

3. When a team arrives, introduce yourself. Tell them your station number and the topic for your station (at the top of the question card).

4. Ask each student to pick a letter between A and E, preferably not the letter they had at the last station.

5. For each letter, A through E:
    - Ask for the student with that letter
    - Take his or her Response Card and mark the letter chosen (A, B, C, etc.) in the box with your station number.
    - Ask that student the question. Other students are not permitted to help; if anyone does, give that student a "wrong" punch.
    - If the answer is acceptable, punch out the number for your station on his or her card.
    - If the answer is not acceptable, punch the box for your station in the corner *opposite* the number, leaving the number intact.
    - When every students on the team has answered a question, send the team on to their next Information Station.

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Appendices

Appendix 1—Common and Scientific Names of Plants and Fungi

Common name	Scientific name
Armillaria root rot	*Armillaria ostoyae*
Arrowleaf balsamroot	*Balsamorhiza sagittata*
Beargrass	*Xerophyllum tenax*
Douglas-fir (Rocky Mountain variety)	*Pseudotsuga menziesii* var. *glauca*
Douglas-fir dwarf mistletoe	*Arceuthobium douglasii*
Fireweed	*Epilobium angustifolium*
Glacier lily	*Erythronium grandiflorum*
Grouse whortleberry	*Vaccinium scoparium*
Lodgepole pine (Rocky Mountain variety)	*Pinus contorta* var. *latifolia*
Pinegrass	*Calamagrostis repens*
Ponderosa pine (Pacific variety)	*Pinus ponderosa* var. *ponderosa*
Saskatoon serviceberry	*Amelanchier alnifolia*
Smooth woodrush	*Luzula hitchcockii*
Snowbrush ceanothus	*Ceanothus velutinus*
Subalpine fir	*Abies lasiocarpa*
White pine blister rust	*Cronartium rbicola*
Whitebark pine	*Pinus albicaulis*
Wild onion	*Allium* species

Appendix 2—Common and Scientific Names of Animals

Common name	**Scientific name**
American marten	*Martes americana*
Black-backed woodpecker	*Picoides arcticus*
Clark's nutcracker	*Nucifraga columbiana*
Elk	*Cervus elaphus*
Flammulated owl	*Otus flammeolus*
Grizzly bear	*Ursus arctos*
Mountain pine beetle	*Dendroctonus ponderosae*
Pileated woodpecker	*Dryocopus pileatus*
Red squirrel	*Tamiasciurus hudsonicus*
Red-backed vole (southern)	*Clethrionomys gapperi*

Appendix 3—Other Curricula on Wildland Fire

Amazing Blazes! A three-hour field experience for 5th and 6th graders with a classroom introduction. From the Tinderbox Project, developed by Ashley Emerson for The Glacier Institute and the U.S.D.A. Forest Service. Contact The Glacier Institute, P.O. Box 7457, Kalispell, MT 59904.

Branching Out to the Youth of America. 1995. Produced by Northeastern Forest Experiment Station; Northeastern Area State & Private Forestry. NE/NA-116R-96. Radnor, PA: U.S. Department of Agriculture, Northeastern Forest Experiment Station; Northern Area State & Private Forestry. 39 p.

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Fire Ecology Resource Management Education Unit[83]. Produced by the Interagency Fire Education Initiative. Contact Ecological Communications Lab, School of Natural Resource, The Ohio State University, 2021 Coffey Road, Columbus, OH 43210.

Fire in Florida's Ecosystems[84] Educator's Guide, Grades 4-8. Edited by Jim Brenner, Fire Management Administrator, Division of Forestry, Florida Department of Agriculture & Consumer Services. Contact Florida Department of Agriculture and Consumer Services, Forest Protection Bureau, Division of Forestry, 3125 Conner Blvd, Tallahassee, FL 32399-1650.

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Getting to Know Wildland Fire: *a teacher's guide to fire ecology in the Northern Rocky Mountains.* By Ellen Petrick-Underwood. Sponsored by the U.S.D.I. National Park Service and the U.S.D.A. Forest Service. Contact Division of Interpretation, National Park Service, P.O. Box 168, Yellowstone National Park, Wyoming 82190.

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[83] in the *FireWorks Teacher Box*

[84] in the *FireWorks Library*

Appendix 4—Links to Montana State Educational Standards

This appendix lists the Montana education standards met by activities in *FireWorks*. Benchmarks for students completing grade 4 are listed in table A-1; for students in grade 8, table A-2; for students in grade 12, table A-3.

Table A-1--Links of *FireWorks* activities to Montana standards for grades K-4[85]

Chapter	Ch.2	Ch.3			Ch.4				Ch.5	Ch.6						Ch.7		Ch.8	Ch.9
Activity	**2**	**1**	**3**	**5**	**1**	**2**	**3**	**4**	**1**	**1**	**2**	**3**	**5**	**6**	**7**	**1**	**3**	**2**	**1**
Science Standard 1. Design, conduct, evaluate, communicate scientific investigations																			
1) Plan & conduct investigations with identified variables		X	X	X				X					X						
2) Measure, process & analyze results		X	X	X			X	X					X						
3) Communicate evidence of investigations		X	X	X			X	X	X				X		X				
4) Record changes & change patterns									X										
5) Construct models, compare to reality	X	X			X		X				X			X					
6) Communicate results	X	X	X	X			X		X					X	X				
Science Standard 2. Understand physical & chemical systems																			
3) Model & explain states of matter		X	X																
4) Identify what changes & doesn't change		X																	
6) Describe characteristics of light, heat			X	X													X		
Science Standard 3. Understand living things																			
1) Identify plant & animal structures & systems	X					X	X	X	X	X	X	X	X	X	X	X			X
3) Develop models that trace life cycles					X									X			X		
4) Explain cause & effect					X				X	X	X	X	X	X	X	X	X		X
5) Classify						X	X	X				X		X			X		X
Science Standard 5. Understand how science & technology impact society																			
2) Communicate ideas & solutions				X										X				X	
3) Make inferences or propose solutions				X						X	X	X	X	X				X	

[85] Standards are included only if they apply to *FireWorks* activities. Most are paraphrased or abridged from the original. Complete standards are available (Montana Office of Public Instruction [no date]).

Chapter	Ch.2	Ch.3			Ch.4				Ch.5	Ch.6						Ch.7		Ch.8	Ch.9
Activity	**2**	**1**	**3**	**5**	**1**	**2**	**3**	**4**	**1**	**1**	**2**	**3**	**5**	**6**	**7**	**1**	**3**	**2**	**1**
Science Standard 6. Know about history of science & technology																			
2) Describe how science has produced knowledge																		X	
Mathematics Standard 1. Problem solving, reasoning																			
1) Solve problems using variety of strategies								X											
2) Use estimation				X					X										
3) Communicate				X					X					X					
4) Recognize relevance of mathematics				X					X					X					
5) Select & use appropriate technology			X					X					X						
Mathematics Standard 2. Understanding of numbers, operations																			
1) Connect concrete & symbolic representation		X	X			X													
2) Count, group, apply place value									X				X						
3) Use basic facts & operations, +-									X				X	X					
4) Explain */														X					
Mathematics Standard 4. Understanding of shape & geometry																			
1) Describe 2- & 3-dimensional shapes		X		X															
2) Investigate shape changes		X																	
Mathematics Standard 5. Use measurement																			
1) Measure length, time, temp.			X				X	X											
2) Relate measurement & units of measure			X					X						X					
3) Apply measurement skills			X				X	X											
Mathematics Standard 6. Use data analysis, probability, statistics																			
1) Collect, organize, display data								X	X				X						
2) Use displays of data								X	X				X						
3) Formulate & solve problems with data									X				X	X					
Reading Standard 1. Construct meaning																			
1) Connect new material & experience		X			X		X	X								X	X	X	
2) Apply new information					X	X	X	X		X						X		X	
3) Respond to ideas & feelings generated															X				

Chapter	Ch.2	Ch.3			Ch.4				Ch.5	Ch.6						Ch.7		Ch.8	Ch.9
Activity	**2**	**1**	**3**	**5**	**1**	**2**	**3**	**4**	**1**	**1**	**2**	**3**	**5**	**6**	**7**	**1**	**3**	**2**	**1**
4) Understand main ideas						X						X			X	X	X	X	
5) Retell key elements						X	X					X			X	X		X	
Reading Standard 2. Apply range of skills& strategies																			
1) Decode unknown words					X	X	X	X				X		X	X	X		X	
2) Adjust reading style to material						X		X				X			X	X		X	X
6) Develop vocabulary	X	X			X	X	X	X	X		X	X	X	X	X	X	X	X	X
7) Apply reading strategies												X				X			X
8) Ask questions, check predictions												X			X	X			
Reading Standard 4. Use material for variety of purposes																			
1) Identify variety of purposes												X							
2) Answer question through reading								X							X	X		X	
3) Use reading for variety of purposes					X	X		X							X	X	X		X
6) Read from technical documents					X	X	X	X				X			X	X	X	X	X
Reading Standard 5. Use variety of sources, synthesize, evaluate, communicate findings																			
2) Integrate information, multiple sources						X	X					X				X			
Writing Standard 1. Write clearly & effectively																			
1) Organize in paragraphs								X							X			X	
2) Use supporting details			X	X				X		X					X	X		X	X
4) Follow conventions			X	X				X							X	X		X	X
Writing Standard 2. Apply range of skills & strategies																			
1) Plan																		X	
2) Write a draft															X			X	
3) Revise using feedback															X				
4) Edit															X				
5) Share final product															X				
Writing Standard 3. Evaluate writing skill																			
2) Share, listen to responses, offer comments	X														X				
Writing Standard 4. Write for variety of purposes & audiences																			
1) Identify & write for purpose	X							X										X	X
3) Write descriptive genre								X							X				X
Writing Standard 6. Use inquiry, problem-solving, & resources to synthesize & communicate																			
2) Use technologies & resources															X				

Chapter	Ch.2	Ch.3			Ch.4				Ch.5	Ch.6						Ch.7		Ch.8	Ch.9
Activity	**2**	**1**	**3**	**5**	**1**	**2**	**3**	**4**	**1**	**1**	**2**	**3**	**5**	**6**	**7**	**1**	**3**	**2**	**1**
4) Share information appropriately	X														X				X
Speaking & Listening Standard 2. Use appropriate types of speaking & listening for variety of purposes																			
2) Demonstrate appropriate behaviors	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3) Speak & listen effectively	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4) Use storytelling, narrative, description			X		X	X						X		X	X	X	X		
5) Use different types of listening	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Speaking & Listening Standard 3. Apply range of skills & strategies																			
1) Communicate in focused, organized way			X	X		X	X	X	X	X		X	X	X	X	X		X	
2) Use appropriate language	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	
3) Enhance presentations, manage anxiety						X		X				X		X	X	X	X		
5) Distinguish fact from opinion	X																	X	
6) Connect own experience with others'	X			X	X				X							X			
Speaking & Listening Standard 4. Identify, analyze, &evaluate effective speaking, evaluative listening																			
3) Show respect for feelings, values of others					X									X					
Social Studies Standard 1. Access, synthesize, & evaluate information																			
2) Support statements, use group decision making																		X	
Social Studies Standard 2. Understand operation of government																			
5) Identify individual's responsibilities												X						X	
Social Studies Standard 3. Make informed decisions based on geographic understanding																			
5) Describe physical changes & impact on ecosystems									X		X	X			X	X	X	X	X
Social Studies Standard 4. Understand effect of time, continuity of change																			
1) Use various sources to reconstruct past									X								X		
Technology Standard 4. Use technology responsibly																			
1) Safely use technology				X					X										
Technology Standard 6. Apply technology to construct new personal understanding																			

Chapter	Ch.2	Ch.3			Ch.4				Ch.5	Ch.6						Ch.7		Ch.8	Ch.9
Activity	**2**	**1**	**3**	**5**	**1**	**2**	**3**	**4**	**1**	**1**	**2**	**3**	**5**	**6**	**7**	**1**	**3**	**2**	**1**
1) Apply information to develop understanding									X										
4) Apply understanding & technology to solve problem														X					
Library Media Standard 1. Access, evaluate & use information																			
2) State question												X				X			
3) Locate probable sources of information												X				X			
5) Use information to create product												X				X			
Library Media Standard 2. Demonstrate responsibility in using information																			
3) Use information sources responsibly												X				X			
4) Share information												X				X			
Arts Standard 1. Create, perform, & respond in the arts																			
1) Identify own ideas & images								X			X	X				X			
2) Use variety of materials & sources	X				X		X	X			X	X		X		X			X
3) Present work	X				X			X				X		X		X			X
Arts Standard 2. Apply concepts, structures, & processes in arts																			
1) Perform																X			
2) Demonstrate storytelling, dramatics						X										X	X		
Arts Standard 3. Use art skills to express ideas																			
2) Use subject matter & symbols to communicate meaning	X				X			X				X		X					X
4) Use mind, voice & body to tell stories						X				X						X	X		
Arts Standard 5. Understand role of arts in society																			
5) Demonstrate appropriate audience behavior					X							X		X		X	X		
Health Enhancement Standard 1. Understand concepts that promote comprehensive health																			
4) Identify injury prevention strategies		X	X															X	X

Chapter	Ch.2	Ch.3			Ch.4				Ch.5	Ch.6						Ch.7		Ch.8	Ch.9
Activity	**2**	**1**	**3**	**5**	**1**	**2**	**3**	**4**	**1**	**1**	**2**	**3**	**5**	**6**	**7**	**1**	**3**	**2**	**1**
Workplace Competencies Standard 1. Allocate workplace resources																			
1) Manage time effectively			X	X	X	X	X	X	X		X	X	X	X	X	X			X
3) Use materials & space efficiently		X	X	X	X		X	X	X	X	X	X	X	X	X	X			X
Workplace Competencies Standard 2. Acquire & demonstrate workplace skills																			
1) Practice team player role		X	X	X	X		X		X			X		X	X	X	X	X	X
3) Practice leadership			X		X			X				X							X
Workplace Competencies Standard 4. Understand how social &organizational systems work																			
1) Identify components of communities					X			X											
2) Model how components of systems interact										X									
Workplace Competencies Standard 5. Work with variety of workplace technologies																			
2) Solve problems alone & with others				X					X		X	X	X	X				X	X
5) Care for technological tools									X				X						
Workplace Competencies Standard 6. Develop skills in career planning & workplace readiness																			
2) Show positive ways of working				X							X	X	X	X				X	X
3) Describe how decisions affect self, others																		X	

Table A-2—Links of *FireWorks* activities to Montana standards for grades 5-8[86].

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
Science Standard 1. Design, conduct, evaluate, & communicate scientific investigations																																
1) Design & conduct experiments, predict outcomes, analyze results				X		X	X	X	X						X			X	X										X			
2) Measure, process & analyze data						X	X					X	X	X	X			X	X										X			
3) Communicate & question results of investigations		X		X		X	X	X	X			X	X	X	X														X			
4) Infer cause & effect						X	X	X	X				X	X				X	X									X	X		X	
5) Construct models & use to predict change				X	X		X		X		X							X						X				X	X			
6) Distinguish between controlled & uncontrolled																													X			
Science Standard 2. Understand physical & chemical systems																																
3) Explain that states of matter depend upon energy						X																							X			
4) Identify what changes & doesn't change						X																							X			
6) Define energy, compare types					X	X												X											X			

[86] Standards are included only if they apply to *FireWorks* activities. Most are paraphrased or abridged from the original. Complete standards are available (Montana Office of Public Instruction [no date]).

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
Science Standard 3. Understand living things																																
2) Explain how living things obtain & use energy										X	X			X		X				X		X	X	X	X							X
4) Explain interdependence in biol. systems & how they are affected by people	X	X	X							X			X										X		X	X	X	X			X	X
5) Classify local plants & animals		X								X		X			X		X			X	X				X						X	X
Science Standard 5. Understand how science & technology impact society																																
1) Identify occupations in science													X	X	X		X		X							X		X	X	X	X	
2) Model collaborative problem solving & critiquing science						X		X	X			X		X	X		X	X		X						X	X			X		
3) Investigate local problems & propose solutions																			X							X	X	X	X	X		X
4) Apply science to issues & events		X					X						X		X				X	X						X	X	X	X	X	X	X
Mathematics Standard 1. Problem solving, reasoning																																
2) Use estimation													X	X																X		
3) Communicate math. ideas & logical arguments				X											X			X	X	X									X	X		
4) Recognize & investigate relevance of mathematics				X									X	X	X			X	X	X									X	X		

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
5) Select & use appropriate technology				X		X						X	X	X	X			X	X										X	X		
Mathematics Standard 2. Understanding of numbers & operations																																
1) Use +-*/														X	X				X	X									X	X		
3) Apply ratio, proportion, %								X						X																X		
Mathematics Standard 3. Use algebraic concepts, processes, language																																
1) Understand variable, expression, equation														X																		
2) Use tables, graphs, verbal rules, equations, models														X	X			X	X	X									X	X		
Mathematics Standard 4. Understanding of shape & geometry																																
4) Explore properties & transformations of shapes				X	X	X		X					X												X							
5) Use geometry to describe physical world				X	X	X		X					X																			
Mathematics Standard 5. Use measurement																																
1) Use measurements to compare & contrast						X			X			X						X	X	X									X			
2) Select & use appropriate measurements						X						X						X											X			
3) Apply concepts: weight, mass, time, temp.						X		X	X						X			X		X									X	X		

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
Mathematics Standard 6. Use data analysis, probability, statistics																																
1) Collect, organize, display data		X				X									X			X	X										X	X		
2) Construct & use displays of data															X			X	X										X	X		
3) Evaluate arguments based on measures of central tendency															X																	
5) Make predictions based on observations							X	X				X	X		X			X											X			
Mathematics Standard 7. Use patterns, relations & functions																																
2) Describe relationships with tables, graphs, rules							X			X								X	X										X	X		
Reading Standard 1. Construct meaning																																
1) Connect new material & experience										X		X	X			X						X	X	X	X		X	X		X		
2) Compare new information with existing knowledge apply										X						X											X	X				
3) Respond to ideas & feelings generated, compare with peers																					X											
4) Understand main ideas, select important facts & details											X						X				X	X	X	X	X		X	X				

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
5) Provide accurate, detailed summaries		X									X						X					X	X	X								
Reading Standard 2. Apply range of skills & strategies																																
1) Decode unknown words											X	X	X	X			X			X	X	X	X		X		X	X	X	X	X	
4) Use features & organization to comprehend																	X				X	X	X		X			X	X	X	X	
5) Adjust reading style to material									X	X	X	X	X	X	X		X				X	X	X				X	X	X	X	X	
6) Develop vocabulary		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	
7) Use variety of reading strategies						X			X		X	X		X			X				X	X	X						X		X	
8) Ask questions, check predictions, summarize														X			X					X	X						X			
Reading Standard 4. Use material for variety of purposes																																
1) Establish & adjust purposes for reading						X	X					X					X				X		X						X	X		
2) Read to organize, understand, investigate						X	X		X		X	X		X			X				X	X	X		X		X	X	X	X		
3) Read for specific tasks						X	X		X	X	X	X		X			X	X	X	X	X	X	X	X	X		X	X	X	X	X	
7) Identify, read & interpret information from variety of sources							X							X			X					X	X		X			X		X		

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
Reading Standard 5. Use variety of sources, synthesize, evaluate, communicate findings																																
2) Make connections, explain relationships among variety of sources																X					X		X							X		
5) Express & defend point of view																			X													
Writing Standard 1. Write clearly & effectively																																
1) Use paragraphs, transitions, logical sequence			X		X	X		X						X							X					X	X	X	X	X	X	
2) Use supporting details to develop main idea			X		X	X		X	X					X		X			X		X	X	X			X	X	X	X	X	X	
4) Follow conventions			X		X	X		X	X					X					X		X	X	X			X	X	X	X	X	X	
Writing Standard 2. Apply range of skills & strategies																																
1) Plan												X		X													X	X	X	X		
2) Write 1 or more drafts												X		X													X	X	X	X		
3) Revise using feedback												X		X																		
4) Edit														X																		
5) Share final product																					X										X	
Writing Standard 4. Write for variety of purposes & audiences																																
1) Identify & write for purpose					X	X								X				X			X	X				X	X		X	X	X	
3) Write narrative genre																		X			X					X			X		X	
Writing Standard 6. Use inquiry problem-solving, & resources to synthesize & communicate																																

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
1) Pose questions																										X				X		
2) Use technologies & resources																										X		X		X		
3) Draw a conclusion		X													X				X							X	X	X	X	X		
4) Share information appropriately		X										X		X													X	X	X	X	X	
Speaking & Listening Standard 2. Use appropriate types of speaking & listening for variety of purposes																																
2) Demonstrate appropriate behaviors with various audiences				X			X				X	X	X	X	X	X	X		X	X	X	X	X	X		X	X		X	X	X	X
3) Speak & listen effectively	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X		X	X	X	X
4) Use reports, drama, persuasive appeal																				X	X	X	X	X								
5) Use different types of listening	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X		X	X		X	X	X	X

Speaking & Listening Standard 3. Apply range of skills & strategies																																
1) Communicate in focused, organized way, with support				X		X	X	X		X	X	X	X	X	X	X	X		X	X		X	X			X	X	X		X		X
2) Use appropriate language	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X			X	X			X	X	X
3) Enhance presentations, manage anxiety				X							X	X					X			X	X	X	X	X						X		X
5) Distinguish information from persuasion, logic from emotion	X	X	X																							X						

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
6) Connect own experience with communicated message		X	X	X		X		X	X	X			X			X				X			X	X		X	X		X	X		X
Speaking & Listening Standard 4. Identify, analyze, & evaluate effective speaking, evaluative listening																																
1) Apply effective speaking & evaluative listening				X								X	X				X			X		X				X				X		
Social Studies Standard 1. Access, synthesize & evaluate information																																
2) Support conclusions, use group decision making																											X	X		X		
3) Help make decisions in real world scenarios															X												X	X	X	X		X
Social Studies Standard 2. Understand operation of government																																
6) Describe factors that contribute to conflict, cooperation																														X		
8) Explain how citizens drive & define policy																										X						
Social Studies Standard 3. Make informed decisions based on geographic understanding																																
1) Interpret geographic relationships		X					X			X										X					X	X						
2) Explain effects of diverse land use on environment							X																					X	X	X	X	
5) Describe physical processes' effect on ecosystem patterns		X					X		X	X				X			X	X		X	X	X	X		X	X		X	X	X	X	X

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
Social Studies Standard 4. Understand effect of time, continuity & change																																
1) Use historic sources to make decisions															X											X		X				
2) Describe significant historical periods														X																		
Social Studies Standard 5. Make informed decisions based on economic principles																																
5) Illustrate how money is used by individuals, businesses, institutions, governments																				X										X		
Technology Standard 1 & 2. Demonstrate understanding of basic operations of technologies																																
1) Use & refine skills														X				X										X	X	X		
2) Apply technology in a product														X	X			X	X									X	X	X		
Technology Standard 5. Apply variety of technologies to solve problems																																
2) Create original works using various technologies																										X						

Technology Standard 6. Apply technology to construct new personal understanding																																
1) Apply information to develop understanding				X									X					X										X				
4) Apply understanding & technology to solve problem				X									X						X	X								X	X			

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
Library Media Standard 1. Access, evaluate & use information																																
1) Use steps of inquiry to answer questions																	X															
2) Formulate specific questions, identify information need																	X					X	X									
3) Select multiple sources																	X					X	X									
5) Use information in product or presentation																	X				X	X	X									
Library Media Standard 2. Demonstrate responsibility in using information																																
2) Avoid plagiarism & cite sources, use bibliographic form																														X		
3) Use information sources responsibly																	X					X	X							X		
4) Acknowledge others' contributions																														X		
Library Media Standard 4. Use current & emerging technology in inquiry																																
1) Use appropriate media & technologies																														X		
2) Use appropriate search strategies																						X								X		
3) Assess quality of information																														X		
Arts Standard 1. Create, perform, & respond in the arts																																
1) Create own ideas & images		X										X		X			X			X		X	X			X					X	

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
2) Select variety of materials & sources										X		X		X			X			X		X	X			X					X	
3) Rehearse & revise own work												X											X									
4) Collaborate with others										X	X					X				X			X	X								
Arts Standard 2. Apply concepts, structures, & processes in arts																																
1) Produce & perform in theatrical presentation																					X		X	X								
2) Use 2- & 3-dimensional art forms		X								X		X					X			X		X	X	X							X	
3) Demonstrate storytelling & improvisation											X					X					X	X	X	X								
Arts Standard 3. Use art skills to express ideas																																
2) Use subjects, themes & symbols to communicate meaning							X			X		X				X	X			X				X		X						
4) Use sound, costume & makeup to communicate																						X	X									
Arts Standard 5. Understand role of arts in society																																
5) Demonstrate appropriate audience behavior																	X			X	X	X	X	X		X					X	

Media Literacy Standard 1. Recognize how media messages are constructed																																
1) Analyze how media content is influenced by form																										X						

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
Health Enhancement Standard 1. Understand concepts that promote comprehensive health																																
4) Explain strategies for injury prevention					X		X		X				X														X	X	X	X	X	X
Workplace Competencies Standard 1. Allocate workplace resources																																
1) Manage time & prioritize effectively						X		X	X	X	X	X		X			X		X	X	X	X	X					X		X	X	X
3) Use materials & space efficiently				X		X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	
4) Manage personal & team resources for team goals						X	X	X	X	X		X		X			X	X		X	X		X	X			X	X	X	X	X	X
Workplace Competencies Standard 2. Acquire & demonstrate workplace skills																																
1) Work as member of team				X		X	X	X	X	X		X		X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X
4) Work toward agreements							X	X	X	X		X								X				X	X	X	X	X	X	X		
5) Communicate in serving others												X	X				X			X	X		X	X			X			X		X
Workplace Competencies Standard 3. Acquire & use workplace information																																
3) Select & present information				X		X				X	X	X	X	X		X	X			X	X		X	X		X		X		X		
4) Use information from electronic sources																												X				

Workplace Competencies Standard 5. Work with variety of workplace technologies																																
1) Use technology for learning, communications, productivity														X	X			X								X		X	X	X		

Chapter	Ch.2			Ch.3						Ch.4			Ch.5			Ch.6						Ch.7				Ch.8					Ch.9	
Activity	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**4**	**1**	**2**	**3**	**1**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**
2) Use technology to observe, analyze, & draw conclusions						X	X							X	X			X										X	X			
3) Solve problems with technology														X	X													X	X			
Workplace Competencies Standard 6. Develop skills in career planning & workplace readiness																																
1) Identify how skills taught in school relate to professions															X		X		X										X	X		
2) Show personal qualities needed for work										X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
3) Identify possible outcomes & consequences of decisions													X		X				X	X						X	X	X		X		X
5) Identify variety of occupations not limited by stereotypes										X	X	X					X				X					X		X		X		X

Table A-3-- Links of *FireWorks* activities to Montana standards for grades 9-12[87].

Chapter	Ch.2	Ch.3			Ch.5		Ch.6	Ch.7	Ch.8					
Activity	**1**	**4**	**6**	**7**	**2**	**3**	**4**	**2**	**1**	**2**	**3**	**4**	**5**	**6**
Science Standard 1. Design, conduct, evaluate, & communicate scientific investigations														
1) Identify testable question, design & conduct experiment, analyze results		X	X			X	X					X		
3) Critique conclusions			X			X						X		
4) Apply concepts of change, equilibrium	X											X		
5) Compare observations to model		X		X								X		
6) Investigate & evaluate science studies						X			X		X			
Science Standard 2. Understand physical & chemical systems														
2) Explain physical matter with conceptual models		X		X								X		
3) Analyze relationships of matter & energy			X	X			X					X		
4) Describe chemical reactions with words & equations			X											
Science Standard 3. Understand living things														
4) Model factors that limit populations & contribute to species change								X						
5) Use classification to discuss species divergence in local ecosystems								X						
Science Standard 5. Understand how science & technology impact society														
2) Model collaborative gathering & evaluating information			X		X	X	X	X		X		X	X	
4) Give examples of scientific innovation challenging commonly held perceptions						X			X		X		X	
Mathematics Standard 1. Problem solving, reasoning														
2) Use estimation			X		X	X								
3) Express generalizations, communicate math. ideas & relationships			X		X	X	X					X	X	
5) Select & use appropriate technology					X	X	X					X	X	
Mathematics Standard 2. Understanding of numbers & operations														
1) Use & understand real number system operations, notations					X	X						X		

[87] Standards are included only if they apply to *FireWorks* activities. Most are paraphrased or abridged from the original. Complete standards are available (Montana Office of Public Instruction [no date]).

Chapter	Ch.2	Ch.3			Ch.5		Ch.6	Ch.7	Ch.8					
Activity	**1**	**4**	**6**	**7**	**2**	**3**	**4**	**2**	**1**	**2**	**3**	**4**	**5**	**6**
Mathematics Standard 3. Use algebraic concepts, processes, language														
1) Use algebra to represent patterns of change					X									
2) Use basic operations with algebraic expressions					X							X	X	
Mathematics Standard 5. Use measurement														
3) Investigate derived measures			X		X	X						X	X	
Mathematics Standard 6. Use data analysis, probability, statistics														
2) Apply measure of central tendency, understand variability & correlation					X	X								
3) Evaluate arguments based on measures of central tendency						X								
5) Make predictions based on observations		X		X	X		X					X		
Reading Standard 1. Construct meaning														
1) Describe connections within material & between new material & experience					X			X			X		X	
2) Integrate new information, make application				X				X		X	X	X	X	
3) Respond to ideas & feelings										X				
4) Understand main ideas, formulate arguments with supporting evidence					X			X		X	X		X	
5) Accurately paraphrase					X			X						
Reading Standard 2. Apply range of skills & strategies														
1) Decode unknown words				X	X	X		X		X	X	X	X	
4) Use features & organization to comprehend				X				X			X	X	X	
5) Adjust reading style to material			X	X	X			X		X	X	X	X	
6) Develop vocabulary			X	X	X	X	X	X		X	X	X	X	
7) Use variety of reading strategies			X	X				X				X		
8) Ask questions, check predictions, summarize			X					X		X		X		
Reading Standard 4. Use material for variety of purposes														
2) Read to evaluate resource for specific task								X					X	
3) Locate, read, analyze & interpret for topic or issue								X					X	
4) Read to perform complex tasks			X	X	X		X	X		X	X	X	X	
6) Read & create material related to social & civic responsibilities											X			
7) Locate, read & evaluate information from variety of sources				X				X					X	

Chapter	Ch.2	Ch.3			Ch.5		Ch.6	Ch.7	Ch.8					
Activity	**1**	**4**	**6**	**7**	**2**	**3**	**4**	**2**	**1**	**2**	**3**	**4**	**5**	**6**
Reading Standard 5. Use variety of sources, synthesize, evaluate, communicate findings														
2) Logically synthesize information								X		X			X	
3) Apply basic principles of logic			X						X	X		X		
4) Analyze use of evidence, logic, devices, bias									X					
Writing Standard 1. Write clearly & effectively														
1) Use paragraphs, transitions, logical sequence			X		X			X	X	X	X	X	X	
2) Develop & elaborate main idea			X		X	X		X	X	X	X	X	X	
3) Demonstrate control of personal voice									X	X		X	X	
4) Follow conventions			X		X	X		X	X	X	X	X	X	
Writing Standard 2. Apply range of skills & strategies														
1) Plan			X		X			X	X	X	X	X	X	
2) Write 1 or more drafts			X		X			X	X	X	X	X	X	
3) Revise using feedback			X		X								X	
4) Edit					X									
5) Share final product			X										X	
Writing Standard 3. Evaluate writing skill														
2) Seek & use feedback & offer constructive criticism			X		X									
Writing Standard 4. Write for variety of purposes & audiences														
1) Identify & articulate purpose, write appropriately					X			X	X			X	X	
3) Write narrative genre					X			X	X					
Writing Standard 6. Use inquiry problem-solving, & resources to synthesize & communicate														
1) Pose questions, identify problems								X	X			X		
2) Use technologies & sources				X				X	X		X		X	
3) Investigate alternative explanations, draw conclusion based on analysis & evaluation									X			X	X	
4) Share information appropriately					X			X	X			X	X	
Speaking & Listening Standard 2. Use appropriate types of speaking & listening for variety of purposes														
2) Adjust speaking & listening behaviors to situations	X		X		X	X		X	X	X		X	X	X
3) Speak & listen effectively	X		X		X	X	X	X	X	X		X	X	X
4) Use impromptu, manuscript, interpersonal endeavors			X		X	X	X	X		X			X	X
5) Use different types of listening, including critical			X		X	X		X	X	X		X	X	X

Chapter	**Ch.2**	**Ch.3**			**Ch.5**		**Ch.6**	**Ch.7**	**Ch.8**					
Activity	**1**	**4**	**6**	**7**	**2**	**3**	**4**	**2**	**1**	**2**	**3**	**4**	**5**	**6**
Speaking & Listening Standard 3. Apply range of skills & strategies														
1) Communicate with clear thesis, logical sequence, transitions							X		X	X			X	X
2) Use appropriate language for purpose, audience	X		X		X	X	X	X	X	X	X		X	X
5) Recognize points of view, purposes, emotional appeals, logical fallacies			X						X	X				X
6) Connect own experience with communicated message	X		X					X	X	X	X	X	X	
Speaking & Listening Standard 4. Identify, analyze, & evaluate effective speaking, evaluative listening														
1) Analyze & evaluate persuasive presentations									X					X
3) Analyze legal & ethical issues & responsible communication									X					X
Social Studies Standard 1. Access, synthesize & evaluate information														
2) Synthesize to support convictions, participate in negotiations									X					
3) Help make decisions in real world scenarios or simulations						X			X	X	X	X	X	X
Social Studies Standard 2. Understand operation of government														
6) Describe factors that contribute to conflict, cooperation													X	X
7) Formulate strategies for public discussions on technology-society issues														X
Social Studies Standard 3. Make informed decisions based on geographic understanding														
5) Describe physical processes' effect on creating, sustaining & modifying ecosystems		X	X	X	X	X	X	X	X		X	X	X	
6) Assess connections between physical & human systems		X			X	X			X		X	X	X	X
Social Studies Standard 4. Understand effect of time, continuity & change														
1) Interpret historical sources from multiple perspectives to make decisions					X				X		X			
Social Studies Standard 5. Make informed decisions based on economic principles														
4) Assess how different values & beliefs influence economic decisions													X	
Technology Standard 1 & 2. Demonstrate understanding of basic operations of technologies														
1) Use & refine skills				X			X		X		X	X	X	

Chapter	Ch.2	Ch.3			Ch.5		Ch.6	Ch.7	Ch.8					
Activity	**1**	**4**	**6**	**7**	**2**	**3**	**4**	**2**	**1**	**2**	**3**	**4**	**5**	**6**
2) Integrate technology in products					X	X	X				X	X	X	
3) Match technology to task					X	X			X		X	X	X	
Technology Standard 4. Use technology responsibly														
1) Safely use technology				X								X		
2) Apply high standard of ethics for technology use				X										
Technology Standard 5. Apply variety of technologies to solve problems														
1) Use technology for problem solving					X	X	X				X	X	X	
3) Analyze information from technical sources, communicate findings				X			X				X	X	X	
Technology Standard 6. Apply technology to construct new personal understanding														
1) Evaluate information to develop understanding							X		X		X	X		
Library Media Standard 1. Access, evaluate & use information														
1) Use steps of inquiry to answer individual & group information needs								X						
3) Develop plan to obtain information from multiple sources								X					X	
4) Assess information sources													X	
5) Synthesize information to create new product								X					X	
Library Media Standard 2. Demonstrate responsibility in using information														
3) Use information sources responsibly								X					X	
4) Collaborate to identify information problems, seek solutions, generate new information								X					X	
Library Media Standard 4. Use current & emerging technology in inquiry														
1) Evaluate media & technologies									X					
2) Demonstrate research strategies													X	
3) Assess quality of information									X				X	
Arts Standard 1. Create, perform, & respond in the arts														
2) Demonstrate imagination & technical skill in an art form					X			X	X					
4) Complete collaborative work								X						
Arts Standard 2. Apply concepts, structures, & processes in arts														
1) Produce & perform in theatrical presentation								X						
2) Use 2- & 3-dimensional art forms								X						

Chapter	Ch.2	Ch.3			Ch.5		Ch.6	Ch.7	Ch.8					
Activity	**1**	**4**	**6**	**7**	**2**	**3**	**4**	**2**	**1**	**2**	**3**	**4**	**5**	**6**
3) Demonstrate storytelling & improvisation								X						
Arts Standard 5. Understand role of arts in society														
5) Demonstrate appropriate audience behavior								X	X					
Media Literacy Standard 1. Recognize how media messages are constructed														
1) Evaluate how media product are constructed for specific audiences									X					
Health Enhancement Standard 1. Understand concepts that promote comprehensive health														
4) Develop personal strategies for injury prevention		X								X	X	X	X	
Workplace Competencies Standard 1. Allocate workplace resources														
1) Manage time & prioritize effectively			X	X	X		X	X	X	X	X	X	X	
3) Allocate time & resources		X	X	X	X			X	X	X	X	X	X	
4) Manage team effectively		X	X	X			X	X				X		
Workplace Competencies Standard 2. Acquire & demonstrate workplace skills														
1) Recognize & practice team roles		X	X	X	X		X	X	X		X	X	X	
3) Communicate ideas to persuade		X	X	X				X	X	X		X	X	X
4) Practice & evaluate negotiating		X	X	X					X	X			X	X
Workplace Competencies Standard 3. Acquire & use workplace information														
3) Select & present information			X				X	X	X	X	X		X	
4) Use information from electronic sources				X							X			
Workplace Competencies Standard 4. Understand how social & organizational systems work														
3) Manage existing systems, including optimizing outputs & adjusting				X									X	
Workplace Competencies Standard 5. Work with variety of workplace technologies														
1) Choose procedures & technology to complete task									X			X	X	
3) Solve problems with technology					X	X	X				X	X	X	
Workplace Competencies Standard 6. Develop skills in career planning & workplace readiness														
1) Identify how skills taught in school relate to career goals											X	X	X	
2) Display workplace readiness			X	X	X		X	X	X	X	X	X	X	X

Appendix 5—Glossary

Definitions are taken from Brown and Smith (2000), Brum and McKane (1989), U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2000, July), *New International Webster's Comprehensive Dictionary of the English Language* (1996), Raven and Curtis (1970), Schroeder and Buck (1970), Starr (1991), and Student Page 12 of *FireWorks*.

adaptation: something about an organism that helps it survive and reproduce; an aspect of its form, function, or behavior that helps it out-compete other organisms

animal: organism that eats or absorbs nutrients from other organisms; **heterotroph**

bark: the tissue covering stems, branches, and roots of a tree or shrub, extending from the cambium to the outer surface. *FireWorks* compares a tree's bark to an animal's skin.

botanist: a person who studies plants

branch: limb of a tree or shrub that grows out from the trunk or main stem

broad-leafed: a tree that has wide, flat leaves, as opposed to needle- or awl-shaped leaves. Most broad-leafed trees in the northern U.S. drop their leaves in the fall.

bud: Plants have two kinds of buds. One kind is the flower bud, which is the developing flower—not yet open. The other kind, and the meaning used in *FireWorks*, is any starting point for plant growth. This kind of bud is often called a **growing point**; a technical term for it is **meristem** tissue. It may grow at the tips of tree and shrub branches, at the tips of roots, in the cambium layer of trees, at the bases of flower and plant stems, and in many other locations. Buds are composed of living cells.

bulb: an underground storage organ in a plant. A bulb has roots on its lower surface and fleshy leaves above. Perennial plants are able to reproduce from their bulbs.

burrow: a hole in the ground used by an animal for shelter

cambium: a thin layer of living cells beneath a tree or shrub's bark. The cambium layer produces two kinds of cells: those that carry water and minerals from roots to leaves (**xylem**), and those that carry sugars and other nutrients from leaves throughout the plant (**phloem**).

cavity: a hole in a tree stem; often used by animals for nesting and shelter

cavity nester: an animal that raises its young in a tree cavity

carbon dioxide: one of many gases in Earth's atmosphere. Carbon dioxide is produced by **combustion** and **respiration**

cell: the basic unit of living things, the smallest living part of an organism that can make new living parts. Some organisms have only one cell, but most plants and animals that we are familiar with contain millions of cells. In a complex organism, some cells are alive, and some are no longer alive but are used by the organism for structural support or other functions.

charred fuel: fuel that is partly burned, with its outside surface blackened

chemist: a person who studies the structure and composition of substances and how they interact (chemistry) or uses chemistry in his or her work

combustion: the process of burning; the process of combining a substance with oxygen and a heat source, which produces heat and light

community: in ecology, all of the living things that occupy a habitat; the populations of all species in a given habitat. In social science, all of the people who reside in one area, are subject to the same laws, and have the same interests.

condensation: the change of a gas to liquid or solid form; the change of a liquid to solid form

cone: the "package" in which a conifer stores its seeds; reproductive structure of a conifer

conifer: a cone-bearing tree

control: the aspects of an experiment that are held constant so they will not affect the experiment's outcome; a standard of comparison against which scientists check the outcome of experimental **treatments**

convection: the diffusion of heat through a liquid or gas by means of molecular motion. Because gases expand when heated, much of the heat from a fire diffuses upward from a burning surface through the process of convection.

corm: an underground storage organ of a plant. Perennials may reproduce from corms.

crown: a tree's top, where most of the leaves and above-ground buds are found

crown fire: fire that spreads in the crowns of trees and shrubs. Crown fires are usually ignited by surface fire. They are common in coniferous forests and chaparral-type shrublands.

deciduous: a kind of plant that is able to shed its leaves in the fall or when it becomes very dry

dendrochronology: the use of tree growth rings to learn about the approximate dates of past events

density: the number of plants or animals in a given area, for instance, trees/m^2

dispersion: the process of scattering or spreading, often used to refer to the way in which smoke disperses through the atmosphere

duff: partially decomposed organic matter lying beneath the litter layer and above the mineral soil

ecologist: a person who studies the relationships between organisms and their environment

ecosystem: a community of organisms interacting with one another and with their environment through a flow of energy and cycling of materials

elevation: height above sea level, expressed in meters or feet

embryo: a plant or animal in the early stages of development after fertilization.

energy: the power to make things move or change. Physicists call energy the ability to overcome inertia and to do work. Energy is transferred in many ways, including by heat, light, and chemical reactions including those of **photosynthesis** and **respiration**.

exoskeleton: the hard material that forms the outside of an insect's body and provides its support

experiment: an activity in which **observations** are used to test an **hypothesis**. An experiment is often designed with two groups of subjects. One group is subjected to a **treatment** to discover its effects; the other group, the **control**, is not subjected to the treatment and is used as a basis for comparison.

field site: location in an ecosystem where plants and animals can be observed, measured, or studied

filled seed: seed that contains a plant **embryo** so a new plant can grow from it. Unfilled seed did not complete the process of fertilization and embryo development, so it cannot develop into a new plant.

fire management: Actions to prevent wildland fires, suppress them, or manage them for particular purposes, like improvement of wildlife habitat

fire regime: the pattern of fire occurrence, size, and severity in an area or ecosystem. An ecosystem's fire regime is like a story about the forces of fire, climate, human use, and species adaptations—all interacting to affect the ecosystem over thousands of years.

fire scar: a wound at the base of a tree caused by heat damage to the cambium. Fire scars are usually shaped a little bit like triangles. They are often blackened in the center and pitchy around the edges. The tree continues to grow, so its bark gradually curls over the edges of the scar and sometimes buries the scar completely.

fire triangle: the three things necessary for fire: fuel, oxygen, and a source of heat

firestorm: a wildland fire that results from biolent **convection.** This is caused by a very large, intense fire or many fires that burn together. A firestorm usually produces a towering smoke column, **spot fires**, and spinning, tornado-like winds.

flammability: the ease with which something will start on fire

flower: blossom; bloom; the reproductive part of a plant

foliage: the leaves of a plant

food web: a network of organisms that supply and consume energy in an ecosystem; composed of producers, consumers, and decomposers

forester: a person who studies forests and is concerned with their management, use, and enjoyment

fuel: the living and dead vegetation that can be burned in a wildland fire. Fuel includes dead woody material, leaves of trees and shrubs, litter, duff, grasses, and other plants.

fuel moisture: the amount of moisture in fuels, expressed as a percent or fraction of oven dry weight. Fuel moisture is the most important fuel property controlling flammability.

fungus: a consumer organism that decomposes living and dead organisms by digesting their tissues and absorbing the nutrients they contain. Mushrooms and mold are kinds of fungus.

gas: a state of matter in which molecules can move quite freely, can expand indefinitely, and are not bound in a particular structure. If cooled sufficiently, gases form liquids or solids.

ground fire: fire that burns in dead, decomposing fuels on the forest floor, mostly by smoldering combustion. Fires in duff, peat, dead moss and lichens, and punky wood are typically ground fires.

growing point: see **bud**

growth ring: annual layer of growth in a tree. Ecologists and foresters use growth rings to learn about the climate and fire history of a forest.

habitat: the kind of place where an organism normally lives

heartwood: central woody core a tree trunk. Heartwood provides structural support to the tree. It is made up of dead **xylem** cells; it contains no living cells and does not help transport water, as **sapwood** does.

heat: a form of energy that raises the temperature of matter

heterotroph: organism that obtains nutrition from plants and animals; heterotrophs are not capable of **photosynthesis**.

histogram: a graph of the frequency distribution of observations

hypothesis: a tentative explanation for something that is observed and can be tested; a guess at what the outcome of an experiment will be

insulation: material that absorbs heat slowly and releases it slowly, so it can be used to protect an object from rapid heating or cooling

inversion: atmospheric conditions in which temperature increases with height above the ground

ladder fuels: shrubs and small trees that fill the space between the forest floor and tree crowns with flammable material, so a fire might be able to "climb the ladder" from surface fuels into the treetops

leaf: a plant structure that can capture energy from sunlight and store it in the chemical bonds of sugars and similar compounds; the main location of **photosynthesis** in plants

liquid: a state of matter in which molecules can move quite freely and can flow, but do not expand indefinitely, as a **gas** can do. If cooled sufficiently, liquids form **solid**s.

litter: the top layer of the forest floor, not yet rotten. Litter includes freshly fallen leaves, needles, fine twigs, bark flakes, fruits, matted dead grass and other plant parts that are little altered by decomposition.

management goals: the conditions desired for a wildland area in the future

management plan: the methods to be used for meeting **management goals**

maximum: the greatest number in a set of numbers

mean: average; a numerical value intermediate between two extremes, calculated as the sum of all observations divided by the number of observations

median: the middle value in a set of numbers sorted from smallest to greatest

meristem: plant cells that are not specialized yet, so they can develop into many different kinds of cell. **Buds** contain meristem tissue.

meteorologist: a person who studies weather and changes in the atmosphere. Meteorologists sometimes use their skills to forecast weather and fuel conditions that affect wildland fire behavior.

mineral soil: soil that contains no organic matter

minimum: the smallest value in a set of values

model: an object made to represent something that already exists or is being designed, or a set of mathematical equations that represents hypothesized relationships

moisture requirement: the amount of moisture needed for an organism to survive

natural selection: the way evolution works; the process in which organisms that are well suited to their environment reproduce successfully and are more numerous in the next generation, and organisms of that are poorly suited to their environment do not succeed as well

needle: a long, narrow kind of **leaf**

observation: information obtained from an experience, which can be used to test an **hypothesis**. Observations are usually measured and recorded during an experiment, then analyzed to see if they support the hypothesis.

organic matter: the material that comprises living and dead things; also the name for complex chemical compounds that contain carbon. Decaying organic matter is an important part of soil.

oxygen: one of many gases in Earth's atmosphere. Oxygen is produced by **photosynthesis** and is used in both **combustion** and **respiration.**

parasite: an organism that obtains nutrients directly from a host plant or animal. A parasite does not usually benefit its host organism.

phloem: the outer layer of cells produced by a woody plant's **cambium.** Phloem cells carry sugars and other nutrients from photosynthetic tissue (mainly leaves) to other parts of the plant.

photosynthesis: the process in which plants trap energy from sunlight and store it in molecules made from carbon dioxide and water

physicist: a person who studies matter and energy. Physicists investigate light, sound, heat, mechanics, electricity, radiation, and magnetism.

plant: a many-celled organism that uses **photosynthesis** to capture energy from sunlight and store it in the chemical bonds of sugars or other food molecules

PM-2.5, PM-10: the weight (in micrograms) of smoke particles less than 2.5 (or 10) microns in diameter per cubic meter of air

prescribed fire: a wildland fire ignited by managers to meet particular goals. A lot of planning is needed to get ready for a prescribed fire. The people who use prescribed fire usually work closely with neighbors and safety experts to make sure the fire will meet their goals safely.

range manager: a person who manages grasslands or areas containing a lot of grass. Range managers often plan and control grazing of grasslands.

reproduction: the process by which a plant, animal, or fungus produces a new organism of the same species

respiration: the process in which living cells obtain energy by breaking down carbon compounds and combining them with oxygen, releasing carbon dioxide and water

rhizome: a creeping stem of a plant that grows in the duff or soil. Rhizomes contain **buds,** also called **growing points,** from which new plants can grow.

riparian: living near the banks of a river or creek

root: the underground portion of a plant that absorbs moisture, obtains nutrients from the soil (and may store them too), and provides support

safety zone: an area around a building that contains little fuel and is large enough to protect the building from wildland fire

sapling: a young tree

sapwood: the outer woody part of a tree trunk, which surrounds the dead, woody center (**heartwood**)**.** The cells of sapwood, also called **xylem** cells**,** carry nutrients and water up from the roots to branches and leaves.

seed: offspring of a plant. Each seed contains a tiny, living plant called an **embryo** and its protective covering, which is filled with nutrients. If a seed forms without an embryo, it is called **unfilled seed.** Seeds need just the right temperature, water, sunlight, and soil conditions before they can grow; some also need to be heated, cooled, or cracked open before they can grow.

serotiny: a property of tree cones, in which their scales are sealed by resin and they cannot release seeds until the resin is melted by heat

slope: the steepness of a land area
soil: the covering of Earth's surface. Soil consists of fine rock particles mixed with pieces of decayed organisms.
solid: a state of matter in which molecules are bound in a particular structure. If heated sufficiently, solids usually form **liquid**s or **gas**es.
species: a particular kind of living thing; the populations of organisms whose members interbreed under natural conditions and produce fertile offspring
spot fire: a new fire that starts when burning material is carried by wind or convection ahead of an existing fire
sprout: to put forth new growth on a plant; to grow a new plant from **buds** on an existing plant
stable conditions: atmospheric conditions that do not change without energy or disturbance from outside. An atmospheric **inversion** is very stable.
stem: the part of a plant that holds leaves and flowers up and connects them to roots. Most stems are found aboveground but some, like **rhizomes,** occur belowground.
sublimation: the process in which matter changes from **solid** form to **gas** form
succession: the process of change in a community. After a severe fire, this is the way succession often works: Grasses and wildflowers may be the most obvious plants for a few years; then shrubs dominate, and finally trees. The first tree species to occur may be replaced by other species as succession continues.
surface area: the total area of the outside of an object
surface fire: a fire that burns in the **litter, duff,** grasses, and wildflowers on the forest floor but does not burn in the crowns of trees. In *FireWorks,* we use the term to describe fires that do not kill the mature trees in a forest.
survival: length of life; ability to outlive other organisms
temperature: hotness or coldness of an object
thermocouple: a tool used to measure temperature. A thermocouple is a junction of two metals whose voltage varies with temperature.
thermometer: a tool used to measure temperature
thin: to cut some, but not all, trees in an area. **Forester**s often thin trees that are growing slowly so the remaining trees can grow more vigorously and better resist insects and fungi that would kill them or decay their wood.
trait: an inherited characteristic
treatment: the aspect of an experiment that is changed so its effects can be observed and measured; usually compared with an experimental **control**, in which the same aspect of the experiment is kept constant for a standard of comparison
tree: a woody plant that, when fully grown, has a large central stem called a **trunk**
trunk: central woody stem of a tree
unfilled seed: seed that forms without an embryo and therefore cannot grow into a new plant
unstable conditions: atmospheric conditions that change readily, without energy or disturbance from outside. Thunderstorms develop in unstable conditions.
value: the desirability or worth of a thing
viable: capable of living and developing normally
visibility: a condition of the atmosphere that describes the ease with which objects at a distance can be seen and identified

volatile: evaporating rapidly at room temperature
volume: the amount of space occupied by an object
wildland: an area where the species present and the processes occurring are relatively unchanged from times before settlement by European Americans. Wildlands are often contrasted with agricultural and urban lands.
wildland fire: any fire, other than **prescribed fire**, occurring in a wildland
wildlife biologist: a person who studies wild animals and their habitat
wood: the tough, fibrous material that comprises tree stems and branches under the bark
xylem: the inner layer of cells produced by a woody plant's **cambium.** Also called **sapwood.** Xylem cells carry water and nutrients (mainly minerals) from roots to leaves.
zoologist: a person who studies animals

Appendix 6—List of *FireWorks* Handouts

Here is a list of handouts needed for teaching *all* of the activities in *FireWorks.* The list shows the number of copies suggested in the curriculum. However, the number that you actually use depends a lot on your teaching style. You may copy this page and then use the right-hand column to note the number of copies you will need; this can serve as an "order form" for your photocopying needs.

Page No.	Activity and Grade level(s) [88]	Suggested number	No. needed
Student Page 1	2-2 (E)	(1 per student)	____________
Student Page 2	3-2 (M)	(1 per student)	____________
Student Page 3	3-3 (M)	(1 per team, 4 teams)	____________
Student Page 4	3-3 (M)	(1 per team, 4 teams)	____________
Student Page 5	3-4 (M,H)	(1 per team, 4 teams)	____________
Student Page 6	3-6 (H)	(1 per class)	____________
Student Page 7	3-6 (H)	(1 per class)	____________
Student Page 8	3-6 (H)	(1 per class)	____________
Student Page 9	3-6 (H)	(1 per class)	____________
Student Page 10	3-7 (M,H)	(1 per team, 4 teams)	____________
Student Page 1 1	3-7 (H)	(1 per student)	____________
Student Page 1 2	4-2 (E,M)	(1 per student)	____________
Student Page 1 3	4-4 (E,M)	(1 per team, 9 teams)	____________
Student Page 1 4	4-4 (E,M)	(1 per team, 9 teams)	____________
Student Page 1 5	5-2 (M,H)	(1 per tree cookie)	____________
Student Page 1 6	6-4 (M,H)	(depends on teaching method)	__________
Student Page 1 7	6-4 (M,H)	(depends on teaching method)	__________
Student Page 1 8	6-5 (E,M)	(1 per student—optional)	____________
Student Page 1 9	6-5 (E,M)	(1 per student— optional)	____________
Student Page 20	7-1 (E)	(1 per student)	____________
Student Page 21	7-2 (M,H)	(1 per team, 3 teams)	____________
Student Page 22	7-2 (M,H)	(1 per team, 3 teams)	____________
Student Page 23	7-2 (M,H)	(1 per team, 3 teams)	____________
Student Page 24	8-2 (E,M,H)	(depends on teaching method)	_________
Student Page 25	8-3 (M,H)	(depends on teaching method)	_________
Student Page 26	8-4 (M,H)	(1 per student team)	____________
Student Page 27	8-6 (H)	(1 per student pair)	____________
Student Page 28	9-1 (E)	(1 per team, number of teams depends on teaching method)	_______
Student Page 29	9-2 (M)	(6 per class)	____________
Class Page 5	4-4 (E,M)	(1 per class)	____________
Class Page 13	7-1 (E)	(1 per class)	____________
Class Page 14	8-4 (M,H)	(1 per team, 4 teams)	____________
Class page 15	9-2 (M)	(1 per class)	_____________

[88] P=Primary, E=Elementary, M=Middle, H=High School.

Appendix 7—*FireWorks* Contents and Trunk Checklists

FireWorks can be packaged in two ways (at least). We use the following for the trunks assembled in 1998-2000. For up-to-date information, visit the Fire Sciences Laboratory's Web site:

www.firelab.org/fep/research/fireworks/fireworks.htm

or contact the authors.

Packing Arrangement 1: two tubs—one large tub with casters, plus a smaller one without casters. Checklist is on pages 248-252.

Packing Arrangement 2: three cartons (no casters): two are medium-sized, one smaller. Checklist is on pages 253-257.

These checklists and the assembly instructions (Appendix 8) are for the **entire** *FireWorks* trunk as described in this curriculum. If you wish to build a scaled-down trunk—without materials for extension activities, or focused on only one grade level—check this list against the supplies listed for each activity you plan to include, and leave the rest out.

For packing in large tub with casters, plus smaller teacher box:

1) In the Main Trunk—big tub with casters:

Item		Quantity	Checked In
Buried Treasures Box (9 specimens)		1	
Cookie sheet ("*Burning Tray*")		4	
Fire extinguisher		1	
Hair dryer		1	
Mystery Trees Box		1	
Posters	Ancient tree	1	
	Fire Triangle	1	
	Fire Safety	1	
	Tree Portrait	1	
	80 Years of Change	1	
Slide Carousel	Visiting Wildland Fire slides	set of 21	
	You Decide! Smoke Impact slides	set of 5	
	"Wildland Homes" slides	set of 11	
Support Stand Box	Chemistry support stand post	4	
	Support stand base		
	Rod segments, 10-20		
Tree Cones Box (specimens from 9 species)		1	
Tree cookies. Write their numbers below and total at right.			
"Tree Skin" insulation (1 plain & 5 quilted pieces)		1 set	
Tree trunk sections		9	

2) In the *Hardware Box* (inside Main Trunk)**:**

<table>
<tr><th colspan="2">Item</th><th>Quantity</th><th>Checked In</th></tr>
<tr><td colspan="2">Ashtray for burnt matches</td><td>4</td><td></td></tr>
<tr><td colspan="2">Beaker, 500 mL</td><td>8</td><td></td></tr>
<tr><td colspan="2">Candle, votive</td><td>4</td><td></td></tr>
<tr><td colspan="2">Clamp for chemistry support stand</td><td>4</td><td></td></tr>
<tr><td colspan="2">Coffee can (1.5 lb)</td><td>1</td><td></td></tr>
<tr><td colspan="2">Freezer container, 1 qt size</td><td>4</td><td></td></tr>
<tr><td colspan="2">Goggles, safety</td><td>4 pair</td><td></td></tr>
<tr><td colspan="2">Hand lenses</td><td>10</td><td></td></tr>
<tr><td rowspan="3">Matchstick Forest Kit</td><td>Masonite boards, square, drilled (4)</td><td rowspan="3">1 kit</td><td rowspan="3"></td></tr>
<tr><td>6 bolts (3 long), 4 nuts, 4 washers</td></tr>
<tr><td>4 nails</td></tr>
<tr><td colspan="2">Measuring tape</td><td>1</td><td></td></tr>
<tr><td colspan="2">Oven mitt</td><td>4</td><td></td></tr>
<tr><td colspan="2">Pins in film canister</td><td>1 canister</td><td></td></tr>
<tr><td colspan="2">Rod segments with alligator clips</td><td>4</td><td></td></tr>
<tr><td colspan="2">Rulers, plastic, 15 cm</td><td>10</td><td></td></tr>
<tr><td colspan="2">Spray bottle</td><td>2</td><td></td></tr>
<tr><td colspan="2">String</td><td>1 ball</td><td></td></tr>
<tr><td colspan="2">Thermometer, digital</td><td>1</td><td></td></tr>
<tr><td colspan="2">Tongs, for dry ice</td><td>1 pair</td><td></td></tr>
</table>

3) In the *FireWorks Library* (inside Main Trunk)***:***

Title	No.	Checked In
Book of Fire by William H. Cottrell, Jr. (1989)	1	
Discover magazine (July 1997) vol., 18 no. 7: see pp. 100-115, Heaven s New Fires by Carl Zimmer	1	
Evergreen magazine (September/October 1996): see pp. 4-50, Montana s Forests: Paradise Lost or Paradise Found by Jim Peterson	1	
Field Guide to Forest Plants of Northern Idaho by Pattterson, Neiman, & Tonn (1985: U.S.D.A. Forest Service General Technical Report INT-180)	1	
Fire and Vegetative Trends in the Northern Rockies by George E. Gruell (1983: U.S.D.A. Forest Service General Technical Report INT-158.)	1	
Fire, a Force of Nature by Jack de Golia	1	
Fire Ecology of Montana Forest Habitat Types East of the Continental Divide by Fischer & Clayton (1983: U.S.D.A. Forest Service General Technical Report INT-141) and/or ***Fire Ecology of Western Montana Forest Habitat Types*** by Fischer & Bradley (1987. U.S.D.A. Forest Service General Technical Report INT-180.) and/or ***Fire Ecology of the Forest Habitat Types or Northern Idaho*** by Smith & Fischer (1997: U.S.D.A. Forest Service General Technical Report INT-363.)	1	
Fire in Florida s Ecosystems edited by Jim Brenner (1996)	1	
Fire in the Forest by Laurence Pringle (1995)	1	
FireWorks Glossary	1	
Graced by Pines by Alexandra Murphy (1994)	1	
Is Smokey Wrong? by Jimmye L. Turner (1997: From *Fire Management Notes*, vol. 57 no. 3: p. 17)	1	
Legends of Earth, Air, Fire and Water by Eric and Tessa Hadley (1985)	1	
Made for Each Other (about Clark s Nutcracker) by Ronald Lanner (1996)	1	
Managing Wildland Fire booklets	20	
National Geographic vol. 190, No. 3 (Sept. 1996): see pp. 116-139, The Essential Element of Fire by Michael Parfit	1	
National Geographic vol. 175, No. 2 (Feb. 1989): see pp. 255-273, The Great Yellowstone Fires by David Jeffery	1	
Pathways in Time booklet—Ponderosa Pine	1	
Pathways in Time booklet—Lodgepole Pine	1	
Pathways in Time booklet—Whitebark Pine	1	

Plant Survival by Brian Capon (1994)	1	
Protecting Your Home from Wildfire by National Fire Protection Association (1991)	5	
Rocky Mountain Tree Finder by Tom Watts (1972)	4	
The Use of Fire in Forest Restoration edited by Hardy & Arno (1996: U.S.D.A. Forest Service General Technical Report INT-GTR-341)	1	
Tree Basics by Alex L. Shigo	1	
Wildfire by Patrick Cone (1997)	1	
Yellowstone on Fire by the Staff of the Billings Gazette (1989)	1	

4) In the *Fuels Box* (inside main trunk)**—**

Materials in this box need not be returned.

Item	No. packages*	Checked
Dead, dry needles of ponderosa pine	1	
Fine branches (< 1/2 cm thick)	1	
Thick branches (> 2 cm thick)	1	
Duff (peat)	1	
Mineral soil (sand)	1	
Lodgepole pine cones (35 per bag)	1 bag	

* Each package contains enough for 4 teams to complete the experiment.

5) In the Teacher Box*:*

Title		Quantity	Check
"Bucket Brigade" Kit (in brown accordion folder)		1	
Designer Trees Game Kit (in brown accordion folder)		1	
Ecosystem Matters curriculum (1995: U.S.D.A. Forest Service, Rocky Mountain Region)		1	
Exploring Wood by Jean Warren (1993)		1	
"Evaluation" Kit (tests and quizzes from *FireWorks* teachers)		1	
Feltboard Materials	**Feltboard Background** (blue, with hills & sun)	3	
	Roaring Tree-Top Fires *(*Looseleaf Notebook for Lodgepole Pine forest)	1	
	Creepy Crawly Fires (Looseleaf Notebook for Ponderosa Pine forest)	1	
	Rollercoaster Fires (Looseleaf Notebook for Whitebark Pine forest)	1	
Fire Ecology Resource Management Education Unit (1995)		1	
***FireWorks* Cookie Book**		1	
***FireWorks* Curriculum** (bound with black spiral)		1	
FireWorks Notebook (Looseleaf—removable pages in protective sleeves)		1	
Fuels... Tree & Soil Parts, and Fire Targets Labels Kit (in brown folder)		1	
Living with Fire CD-ROM		1	
People in Fire s Homeland photos Kit (set of 22 prints in brown accordion folder)		1	
Puzzling It Out Kit—(4 puzzle sets and 3 keys in brown accordion folder)		1	
Smokeygrams Kit (4 laminated pages in brown accordion folder)		1	
Tinker Trees Kit—(4 badges & 4 rosettes in brown accordion folder)		4 each	
Value Choices Kit (11 laminated pages in brown accordion folder)		1	
Videos	**Fire and Wildlife** (1989)	1	
	International Crown Fire Modelling Experiments (1997)	1	
	"Kinds of Fire" (2000)	1	
	"Managing Wildland Fire: A matter of choice" (2000)	1	
	"Unfinished Song" (1990)	1	
	Yellowstone Aflame (1989)	1	
Visual Aids & Handouts—Looseleaf Notebook with removable pages		1	
Woods Hunt Kit (in brown accordion folder)		1	
Woodsy Owl Activity Guide (1997)		1	
You Decide! Kit—(5 brochures in brown accordion folder)		1	
ZIP Game box		1	

For packing in three plastic cartons:

1) In *Box A:*

Item		Quantity	Checked In
Buried Treasures Box (9 specimens)		1	
Cookie sheet ("*Burning Tray*")		4	
Hair dryer		1	
Support Stand Box	Chemistry support stand post	4	
	Support stand base		
	Rod segments, 10-20		
Tree Cones Box (specimens from 9 species)		1	
"Tree Skin" insulation (1 plain & 5 quilted pieces)		1 set	
Tree trunk sections		9	
Hardware Box (inside Box A)**:**			
Ashtray for burnt matches		4	
Beaker, 500 mL		8	
Candle, votive		4	
Clamp for chemistry support stand		4	
Coffee can (1.5 lb)		1	
Freezer container, 1 qt size		4	
Goggles, safety		4 pair	
Hand lenses		10	
Matchstick Forest Kit	Masonite boards, square, drilled (4)	1 kit	
	6 bolts (3 long), 4 nuts, 4 washers		
	4 nails		
Measuring tape		1	
Oven mitt		4	
Pins in film canister		1 canister	
Rod segments with alligator clips		4	
Rulers, plastic, 15 cm		10	
Spray bottle		2	
String		1 ball	
Thermometer, digital		1	
Tongs, for dry ice		1 pair	

2) In *Box B:*

Item		Quantity	Checked In
Fire extinguisher		1	
Mystery Trees Box		1	
Posters	Ancient tree	1	
	Fire Triangle	1	
	Fire Safety	1	
	Tree Portrait	1	
	80 Years of Change	1	
Tree cookies. Write their numbers below and total at right.			
Fuels Box--use what you need, return the rest (inside Box B)**:**			
Dead, dry needles of ponderosa pine		1	
Fine branches (< 1/2 cm thick)		1	
Thick branches (> 2 cm thick)		1	
Duff (peat)		1	
Mineral soil (sand)		1	
Lodgepole pine cones (30-50 per bag)		1 bag	

FireWorks Library (inside Box B)**:**	No.	Checked In
Book of Fire by William H. Cottrell, Jr. (1989)	1	
Discover magazine (July 1997) vol. 18 no. 7: see pp. 100-115, Heaven s New Fires by Carl Zimmer	1	
Evergreen magazine (September/October 1996): see pp. 4-50, Montana s Forests: Paradise Lost or Paradise Found by Jim Peterson	1	
Field Guide to Forest Plants of Northern Idaho by Pattterson, Neiman, & Tonn (1985: U.S.D.A. Forest Service General Technical Report INT-180)	1	
Fire and Vegetative Trends in the Northern Rockies by George E. Gruell (1983: U.S.D.A. Forest Service General Technical Report INT-158.)	1	
Fire, a Force of Nature by Jack de Golia	1	
Fire Ecology of Montana Forest Habitat Types East of the Continental Divide by Fischer & Clayton (1983: U.S.D.A. Forest Service General Technical Report INT-141)	1	

and/or ***Fire Ecology of Western Montana Forest Habitat Types*** by Fischer & Bradley (1987: U.S.D.A. Forest Service General Technical Report INT-180.) and/or ***Fire Ecology of the Forest Habitat Types or Northern Idaho*** by Smith & Fischer (1997: U.S.D.A. Forest Service General Technical Report INT-363)		
Fire in Florida s Ecosystems edited by Jim Brenner (1996)	1	
Fire in the Forest by Laurence Pringle (1995)	1	
FireWorks Glossary	1	
Graced by Pines by Alexandra Murphy (1994)	1	
Is Smokey Wrong? by Jimmye L. Turner (1997: From *Fire Management Notes*, vol. 57 no. 3: p. 17)	1	
Legends of Earth, Air, Fire and Water by Eric and Tessa Hadley (1985)	1	
Made for Each Other (about Clark s Nutcracker) by Ronald Lanner (1996)	1	
Managing Wildland Fire booklets	20	
National Geographic (Sept. 1996) vol. 190 no. 3: see pp. 116-139, The Essential Element of Fire by Michael Parfit	1	
National Geographic (Feb. 1989) vol. 175 no. 2: see pp. 255-273, The Great Yellowstone Fires by David Jeffery	1	
Pathways in Time booklet—Ponderosa Pine	1	
Pathways in Time booklet—Lodgepole Pine	1	
Pathways in Time booklet—Whitebark Pine	1	
Plant Survival by Brian Capon (1994)	1	
Protecting Your Home from Wildfire by National Fire Protection Association (1991)	5	
Rocky Mountain Tree Finder by Tom Watts (1972)	4	
The Use of Fire in Forest Restoration edited by Hardy & Arno (1996: U.S.D.A. Forest Service General Technical Report INT-GTR-341)	1	
Tree Basics by Alex L. Shigo	1	
Wildfire by Patrick Cone (1997)	1	
Yellowstone on Fire by the Staff of the Billings Gazette (1989)	1	

3) In *Box C:* Teacher Box

Title		Quantity	Checked In
"Bucket Brigade" Kit (in brown accordion folder)		1	
Designer Trees Game Kit (in brown accordion folder)		1	
Ecosystem Matters curriculum (1995: U.S.D.A. Forest Service, Rocky Mountain Region)		1	
Exploring Wood by Jean Warren (1993)		1	
"Evaluation" Kit (tests and quizzes from *FireWorks* teachers)		1	
Feltboard Materials	**Feltboard Background** (blue, with hills & sun)	3	
	Roaring Tree-Top Fires *(*Looseleaf Notebook for Lodgepole Pine forest)	1	
	Creepy Crawly Fires (Looseleaf Notebook for Ponderosa Pine forest)	1	
	Rollercoaster Fires (Looseleaf Notebook for Whitebark Pine forest)	1	
Fire Ecology Resource Management Education Unit (1995)		1	
***FireWorks* Cookie Book**		1	
***FireWorks* Curriculum** (bound with black spiral)		1	
FireWorks Notebook (Looseleaf—with removable pages, each page in a protective sleeve)		1	
Fuels... Tree & Soil Parts, and Fire Targets Labels Kit (in brown folder)		1	
Living with Fire CD-ROM		1	
People in Fire s Homeland photos Kit (set of 22 prints in brown accordion folder)		1	
Puzzling It Out Kit—(4 puzzle sets and 3 keys in brown accordion folder)		1	
Slide Carousel	Visiting Wildland Fire slides	set of 21	
	You Decide! Smoke Impact slides	set of 5	
	"Wildland Homes" slides	set of 11	
Smokeygrams Kit (4 laminated pages in brown accordion folder)		1	
Tinker Trees Kit—(badges & rosettes in brown accordion folder)		4 each	
Value Choices Kit (11 laminated pages in brown accordion folder)		1	
Videotapes	**Fire and Wildlife** (1989)	1	
	International Crown Fire Modelling Experiments (1997)	1	
	“Kinds of Fire” (2000)	1	

	“Managing Wildland Fire: a matter of choice” (2000)	1	
	"Unfinished Song" (1990)	1	
	Yellowstone Aflame (1989)	1	
Visual Aids & Handouts—Looseleaf Notebook with removable pages		1	
Woods Hunt Kit (in brown accordion folder)		1	
Woodsy Owl Activity Guide (1997)		1	
You Decide! Kit—(5 brochures in brown accordion folder)		1	
ZIP Game box		1	

Appendix 8—Assembling a *FireWorks* trunk

FireWorks Trunk Cost Estimate, 1999 prices

and availability. Cost of labor is not included. For up-to-date information, visit the Fire Sciences Laboratory's Web site:

www.firelab.org/fep/research/fireworks/fireworks.htm

or contact the authors.

Items	Low estimate	High estimate
Trunks (Packing Arrangement 1—2 tubs-- is lower cost, Arrangement 2—3 cartons-- is higher)	$113	$171
Containers	47	47
Hardware & supplies	505	505
Books for *FireWorks Library*	150	150
Books & videos for *Teacher Box*	73	73
Color copying (based on $.65/copy at low end, $1/copy at high end)	117	180
Wide laminating (commercial), based on 13' for posters only, 28' for posters plus puzzles	39	84
TOTAL	**$1044**	**$1210**

Steps for Trunk Assembly

1.0 Collect specimens

1.1 **Herbs:** Collect at least one specimen of each species listed below. Wash the arrowleaf balsamroot, beargrass, and serviceberry specimens and air-dry; hanging them upside-down in a warm, dry location for a couple of months works well. Press the other specimens in a plant press. Then mount each on an 8.5 x 11" sheet of clear contact paper and cover with a clear transparency.[89] Label each with permanent marker or a tag, using the code letters below. When specimens are dry, store in your **Buried Treasures Box**. While only one specimen of each species is needed for a *FireWorks* trunk, it is handy to have a few extras prepared in case a specimen needs replacing.

Arrowleaf balsamroot	Plant 1
Beargrass	Plant 2
Fireweed	Plant 3
Glacier lily	Plant 4
Pinegrass	Plant 5
Saskatoon serviceberry (collect root crown only)	Plant 6

[89] COST SAVING TIP: Use one layer of clear contact paper and one sheet of the acetate film used in "thermofax" machines to make transparencies; most offices have some stored and do not use it anymore.

Smooth woodrush	Plant 7
Snowbrush ceanothus (leaves)	Plant 8
Wild onion	Plant 9

1.2 **Flowers, seeds, cones:** Collect 2 to 4 specimens from each tree species listed below (cones from conifers, flowers from deciduous species). Press black cottonwood and quaking aspen catkins in a plant press, then mount inside a 3.5 x 5 inch shadow box. Label the box with the tree's letter code (below). Dry the subalpine fir cone(s) in a warm, dry location, then place them in a shadow box with the cardboard backing inverted so the pieces are loose; label the box with the code for subalpine fir, the letter "C." For the other species, insert a small eye-screw in each cone, then attach the species code label using a 4- to 6-inch length of lanyard. When all cones are ready, store in your **Tree Cones Box**.

Black cottonwood	Tree B
Douglas-fir	Tree V
Engelmann spruce	Tree H
Lodgepole pine	Tree E
Quaking aspen	Tree L
Ponderosa pine	Tree O
Subalpine fir	Tree C
Western larch	Tree T
Whitebark pine	Tree J

Put a ponderosa pine cone in a bag labeled “For Woods Hunt” in **Tree Cones Box**.

1.3 **Foliage:** Collect at least one specimen of branch and foliage, no larger than 8 x 12 inches when pressed, of each tree species listed in 1.2 above. Press in a plant press. Then make each specimen into a "sandwich" between two layers of clear "Contact" paper.[90] Using a permanent marker, label each specimen with the one-letter tree species code above. Only one specimen is needed in the trunk, but it is handy to have extras around because these specimens are somewhat fragile.

1.4 **Tree trunk sections:** Collect at least one specimen of tree bole from each species listed in 1.2 above. Dimensions can vary, but length around 10 inches and width about 6-10 inches seem to work well. Using a permanent marker, label each specimen with its one-letter tree species code (1.2 above). Dry the specimens. If the bark comes loose, use wood glue and clamps to re-attach it.

1.5 **Tree cookies:** Collect ONLY 1 of each.

Species

Any species, unscarred

Ponderosa pine, 2+ fire scars

Lodgepole pine, 2+ fire scars

Whitebark pine

A whitebark pine cookie is not essential for teaching *FireWorks*. However,

[90] COST SAVING TIP: Use one layer of clear contact paper and one sheet of the acetate film used in “thermofax” machines to make transparencies; most offices have some stored and do not use it anymore.

it is helpful to include so students can compare it with ponderosa and lodgepole pine cookies.

If tree cookies are fragile, severely checked, or just seem likely to break, be assured they will. Use body putty (“Bondo”) to attach to a piece of ¼-inch plywood. Cookies look best and weigh least when the plywood is cut to approximately the same outline as the cookie and its edges are sanded smooth.

Write the tree species name on the back of each cookie. On the unscarred cookie, write "Demonstration" to indicate that the teacher should use this cookie to explain tree growth rings. Sand or plane the front of each cookie to make scars and rings easier to identify. Spray each with lacquer finish. Using a hand lens or microscope, record the tree's history using the format shown in Appendix 9. Your collection of tree cookie records will become the *FireWorks Cookie Book* in your trunk.

1.6 **<u>Fuels and Lodgepole Pine Cones:</u>** Collect enough of each of these that you can restock the trunk after every loan with a baggie full:

- closed cones of lodgepole pine (use about 35/bag)
- dead, dry ponderosa pine needles
- fine branches (<1/2 cm)
- thick branches (>2 cm)
- peat moss (serves as duff)
- sand (serves as mineral soil)

2.0 Obtain containers

This table describes the boxes and containers, approximate dimensions, and source(s) used for *FireWorks* trunks and the boxes that go inside them. Label each container—preferably using a laminated label, taped down along all four edges.

Container	Dimensions*	Possible Source	Est. Cost
Trunk			
<u>Option 1-- Packing Arrangement 1 (see Appendix 7):</u>			
Main Trunk: Large tub (shipping trunk) with 4 casters and hardware at 2 ends	23W x 35L x 18H	Regal Plastics, 4405 E. 11th St., Kansas City MO 64127 (800-852-1556, FAX 816-483-7948)	$159
Teacher Box	15W x19L x 16H	Local hardware or discount store	$12
<u>Option 2—Packing Arrangement 2 (see Appendix 7):</u>			
Two large cartons (*Boxes A and B*)	19W x 26L x 15H	Hinged distribution containers from Consolidated Plastics	$42.85 ea
One small carton	18.5W x 22L	Hinged distribution	27.50

(*Teacher Box, Box C*)	x 12H	containers from Consolidated Plastics	
*Hardware Box***	12W x 15.5L x 10H	Local hardware or discount store	$8
FireWorks Library	9.5W x 14.5L x 6.5H	Local hardware or discount store	$5
*Fuels Box***	9.5W x 14.5L x 6.5H	Local hardware or discount store	$5
Cones Box	5.5W x 12L x 3.5H	Local hardware or discount store	$4
Mystery Trees Box	9W x 13L x 3.5H	Local hardware or discount store	$4
Buried Treasures Box	9W x 13L x 3.5H	Local hardware or discount store	$4
Photo Album for *People in Fire's Homeland*	holds 4x6" photos	Local discount store	$5
THREE shadowboxes for aspen and cottonwood flowers, and fir cones	3x5"	Local discount store	$4 ea

* approximate inside dimensions (inches)
** Does not need a cover

3.0 Obtain hardware, laboratory materials, and fabrics

Purchase the following items. Some items need to be modified before placing in the trunk; instructions for these are referenced in the table by a number in square brackets [], and directions are given below. Label completed items and put in appropriate boxes.

Item [key to instructions]	Possible Source	no./ trunk	Cost each	Total $
Alligator clips [3.1]	Local hardware store	8	$0.65	$5.20
Ashtray for burnt matches	Local hardware store	4	$0.59	$2.36
Baggies, 1 pint size, for fuels and lodgepole cones	Local discount store	Need about 2 boxes/year		$3.00
Baggies, 1 quart size, heavy, for matchstick forest kit and hand lenses	Local discount store	2-- Get from somebody's kitchen!		
Beaker (plastic), 500 mL	Apple Scientific, Inc. 8378 Mayfield Rd Chesterland, OH 44026 440-729-3056	8	$3.40	$27.20
Candle, votive	Local discount store	4	$0.69	$2.76
Clamp for chemistry support stand	Fischer Scientific 711 Forbes Ave.,	4	$7.29	$29.16

	Pittsburg, PA 15219-4785 800-766-7000			
Coffee can (1.5 lb)	Someone’s recycling shelf	1	$0.00	$0.00
Cookie sheet ("burning tray")	Local discount store	4	$4.49	$17.96
Fire extinguisher-- get a rechargeable one, check it after every trunk loan, and have it checked professionally and recharged, if necessary, once a year (cost: about $9/year)	Local hardware store	1	$29.99	$29.99
Fabric and fabric paint for feltboards	Local fabric or craft store			$25.00
Freezer container, 1 qt size	Local hardware store	4	$4.79	$19.16
Goggles, safety	Fischer Scientific 711 Forbes Ave., Pittsburg, PA 15219-4785 800-766-7000	4	$6.66	$26.64
Hair dryer	Local discount store	1	$9.99	$9.99
Hand lenses [3.2]	College or university bookstore	10	$7.65	$76.50
Match-stick Forest Kit [3.3]: Masonite boards, square, drilled (4); 6 ¼-inch bolts (three 4” long and three 2.5” long), 4 nuts, 4 washers; 4 nails	Local hardware & lumber stores	1 kit	$1.60	$1.60
Measuring tape, 1 m+ in length	Fabric or discount store	1	$1.86	$1.86
Oven mitt	Local discount store	4	$2.61	$10.44
Pins-- straight or quilting (30+) in film canister	Fabric or discount store	1 canister	$0.10	$0.10
Rod segments [3.1, 3.4]		15 ft		$1.50
Rulers, plastic, 15 cm	Local discount store	10	$0.49	$4.90
Spray bottle	Local hardware store	2	$1.79	$3.58

String		Local hardware store	1 ball	$1.29	$1.29
Support Stand Box [3.4]	Chemistry support stand post, 15 to 16 inches tall	Apple Scientific, Inc. 8378 Mayfield Rd Chesterland, OH 44026 440-729-3056	4	$19.93	$79.72
	Support stand base				
Supplies for sanding & lacquering tree cookies		Local hardware store	about $30		
Thermometer, digital Catalog # ZEH 421305 (heavy duty, single input)		Davis Instruments, 4701 Mount Hope Drive, Baltimore, MD 21215 800-269-0299	1	$79.00	$79.00
Tongs for handling dry ice		local hardware or discount store	1		$4.00
"Tree Skin" fabric and quilting (1 plain & 5 quilted pieces) [3.5]		Local fabric store	1 set		about $10
Welding rod, 0.95" diameter [3.1, 3.4]		Welding/bolts store	9, 3' lengths		about $1

3.1 **Alligator clips/Welding rod:** Using a wire cutter, cut 4 lengths of welding rod, each about 8" long. (Thicker rod of some kind would also work.) Attach an alligator clip to both ends of each piece of rod. If the clip has an adjustable screw for tightening, use it. To fasten more firmly, obtain a small container of “water glass” from a chemistry laboratory. This is an alkaline solution of sodium silicate. Place a few drops on the barrel of each alligator clip to “glue” it in place on the welding rod. Store in a short mailing tube.

3.2 **Hand lenses:** Tie a piece of lanyard 8 to 10 inches long on each one. This makes them a little easier to keep track of in a classroom. Package in a large baggie.

3.3 **Matchstick Forest Kit:** The kit goes into a large, heavy-duty baggie.

Cut four squares of 1/4-inch masonite, 6" on a side. Centered on this 6-inch square, use a 1/8 inch (or #30) bit to drill 7 rows of holes, 7 holes/row, 5/8" apart. These are to hold matches. In one of the margins, centered from left to right, drill a 1/4" hole. This is to hold the 1/4" bolt that leans the piece of masonite on its edge, giving it slope.

Put the four masonite pieces into a large baggie. Add bolts, nuts, and washers. Add four nails, to poke burned match bases out of the masonite pieces.

3.4 **Support stand box:** Make each support stand box into a “Tinker Tree”:

For each support stand, two, 3-foot lengths of welding rod (0.95" diameter) are needed. From each piece of welding rod, use wire cutters to cut the following lengths:

one 12"
one 10"
one 8"
one 6"

In each support stand post, at 2-cm intervals from bottom to top, drill a hole big enough for the welding rod to go through easily. We used a drill bit 0.1" in diameter. Line holes up vertically, one above the other. This is not easy to do because the surface is curved. Here's how we do it:

1) Mark the locations for drilling with a felt tip pen.
2) Use a spring-loaded punch to notch the post at each drill spot.
3) Place in a vise and use a drill press.
4) Drill.
5) Check for shavings & file off rough edges.

3.5 **"Tree Skin" Insulation:** The materials go into a plastic shopping bag to be packed into the trunk. Cut out the following materials, all 6" by 18": six pieces of brown cotton or cotton-polyester fabric to serve as a thin outer layer of bark, and 30 pieces of cotton quilt batting to serve as inner bark.

Leave one piece of brown fabric plain; this will represent very thin tree bark. Assemble the remaining pieces of brown fabric with 2, 4, 6, 8, and 10 layers of quilt batting to represent bark of various thicknesses. Lay the batting down, place the brown fabric on top, and tack together by stitching at 8-12 locations.

4.0 Obtain Books and Videotapes

4.1 *FireWorks Library*

4.1.1 Purchase

Title (Source)	No.	Cost
Discover magazine (July 1997) vol. 18, no. 7: see pp. 100-115: "Heaven's New Fires" by Carl Zimmer. Order from Discover Magazine (attn: back issues), P.O. Box 37283, Boone, IA 50037; call 1-800-416-5140.	1	$3.95
Fire, a Force of Nature by Jack de Golia (Las Vegas: KC Publications, Box 15630, Las Vegas, NV 89114; ISBN 0-88714-038-6)	1	$10.00
Fire in Florida's Ecosystems edited by Jim Brenner. (1996. Florida Department of Agriculture and Consumer Services, Forest Protection Bureau, Division of Forestry, 31225 Conner Blvd., Tallahassee, FL 32399-1650)	1	$0
Fire in the Forest by Laurence Pringle (1995. New York: Atheneum Bookos for Young Readers; ISBN 0-689-80394-X)	1	$16.00

Graced by Pines by Alexandra Murphy (1994. Missoula, MT: Mountain Press Publishing Co.; ISBN 0-87842-307-9)	1	$10.00
Legends of Earth, Air, Fire and Water by Eric and Tessa Hadley (1985. New York: Press Syndicate of the University of Cambridge; ISBN 0-521-26311-5). Out of print. We got our last copy by checking barnesandnoble.com, where we learned about a bookstore in Michigan that had a used copy for $9.	1	$15.95
Made for Each Other (about Clark's Nutcracker) by Ronald Lanner (1996. New York: Oxford University Press; ISBN 0-19-508903-0)	1	$15.95
National Geographic (Sept. 1996) vol. 190 No. 3: pp. 116-139, "The Essential Element of Fire" by Michael Parfit. Order from National Geographic, P.O. Box 63001, Tampa, FL 33663-3001; call 1-800-777-2800.[91]	1	$5.00
National Geographic (Feb. 1989) vol. 175 No. 2: pp. 255-273, "The Great Yellowstone Fires" by David Jeffery. Order from address above.[1]	1	$5.00
Plant Survival by Brian Capon (1994. Portland, OR: Timber Press, Inc.; ISBN 0-88192-283-8)	1	$24.95
Rocky Mountain Tree Finder by Tom Watts (1972. Rochester, NY: Nature Study Guild; ISBN 0-912550-05-8)	4@$3.00 ea	$12.00
Wildfire by Patrick Cone (1997. Minneapolis, MN: Carolrhoda Books Inc.; ISBN 1-57505-027-7)	1	$7.95
Yellowstone on Fire by the Staff of the Billings Gazette (1989. Billings, MT: The Billings Gazette; ISBN 0-9627618-7-7)	1	$14.95

4.1.2 Obtain from Forest Service

Publications in print can be obtained at no cost from: Publications Department, Rocky Mountain Research Station, 240 West Prospect Road, Fort Collins, CO 80526-2098. Phone: 970-498-1392.

Title (Source)	No.
Field Guide to Forest Plants of northern Idaho by Pattterson, Neiman, & Tonn (1985. Ogden, UT: U.S.D.A. Forest Service, Intermountain Research Station. General Technical Report INT-180)	1
The Use of Fire in Forest Restoration edited by Hardy & Arno (1996. Ogden, UT: U.S.D.A. Forest Service, Intermountain Research Station. General Technical Report INT-GTR-341)	1

4.1.2 Current source uncertain

Contact Fire Sciences Laboratory for copy or information on obtaining one.

[91]Don't order this right away! First, check 2nd-hand stores in your area; they often carry a lot of old National Geographics, which you can pick up for $.25 or so.

Title (Source)	**No.**	**Cost**
Book of Fire by William H. Cottrell, Jr. (1989. Missoula, MT: Mountain Press; ISBN 0-87842-255-2). Currently out of print and Fire Lab is out of copies. Contact the author at El Dorado Publishing, P.O. Box 840, Comino, CA 95709. Phone: 503-644-8448 or email: whc@innercite.com	1	$9.00
Evergreen magazine (September/October 1996): pp. 4-50, "Montana's Forests: Paradise Lost or Paradise Found" by Jim Peterson. Order from Evergreen Magazine; phone: 541-773-2247... but call the Fire Lab first, to see if we have extras.	1	$2.00
Fire and Vegetative Trends in the Northern Rockies by George E. Gruell (1983. Ogden, UT: U.S.D.A. Forest Service, Intermountain Forest and Range Experiment Station. General Technical Report INT-158.) Out of print--obtain a master copy from the Fire Lab.	1	$0
Fire Ecology of Montana Forest Habitat Types East of the Continental Divide by Fischer & Clayton (1983. Ogden, UT: U.S.D.A. Forest Service, Intermountain Research Station General Technical Report INT-141) Out of print—obtain a master copy from the Fire Lab. and/or ***Fire Ecology of the forest Habitat Types of Northern Idaho*** by Smith and Fischer (1997). Ogden, UT: U.S.D.A. Forest Service, Intermountain Research Station. General Technical Report INT-363. In print—obtain from Rocky Mountain Research Station. and/or ***Fire Ecology of Western Montana Forest Habitat Types*** by Fischer & Bradley (1987. Ogden, UT: U.S.D.A. Forest Service, Intermountain Research Station. General Technical Report INT-180.) Out of print—obtain a master copy from the Fire Lab.	1	$0
"Is Smokey Wrong?" by Jimmye L. Turner (1997. Fire Management Notes, vol. 57 no. 3; p. 17). Obtain a copy from the Fire Lab.	1	$0
Protecting Your Home from Wildfire by National Fire Protection Association (1991. Quincy, MA: National Fire Protection Association, ISBN) Order from: International Association of Wildland Fire. Phone: 504-283-2397. (Fire Lab has a limited supply—check before ordering!)	5	25/$40
Tree Basics by Dr. Alex L. Shigo. (Date? Shigo and Trees, Associates, P.O. Box 769, Durham, NH 03824-0769; ISBN 0-943563-16-X). Order from the publisher. Phone: 603-868-7459. $4.90/copy when bought in package of 10. Fire Lab has a limited number of copies.	1	$4.90 plus shipping

4.2. *Teacher Box*

Title		Quantity	Cost
Ecosystem Matters Curriculum. (1995. Denver, CO: U.S.D.A. Forest Service, Rocky Mountain Region)		1	$0
Exploring Wood by Jean Warren (1993. Everett. WA: Warren Publishing House, Inc.; ISBN 0-911019-60-X). Out of print. Fire Lab has a limited number of copies.		1	$3.00
FireWorks featuring Ponderosa, Lodgepole, and Whitebark Pine Forests. (2000. Fort Collins, CO: U.S.D.A. Forest Service, Rocky Mountain Research Station)[92]		1	$0
Fire Ecology Resource Management Education Unit (1995. Order from: Ecological Communications Lab, Ohio State University, 2021 Coffey Rd, Columbus, OH 43210)		1	$0
"Living with Fire" CD-ROM. (2000. Missoula, MT: U.S.D.A. Forest Service, Rocky Mountain Research Station, Fire Effect Research Unit). Obtain from Fire Sciences Laboratory.		1	$0
Video-tapes	**"Fire and Wildlife"** (1989. Lolo, MT: Stoney-Wolf Video Productions.)	1	$24.95
	"International Crown Fire Modelling Experiments" (1997. Missoula, MT: U.S.D.A. Forest Service, Montana Technical Development Center)	1	$0
	"Kinds of Fire" (2000. Missoula, MT: U.S.D.A. Forest Service, Fire Effects Research Unit). Obtain from Fire Sciences Laboratory.	1	$0
	"Managing Wildland Fire: A Matter of Choice" (2000. Missoula, MT: U.S.D.A. Forest Service) Obtain from Fire Sciences Laboratory.	1	$0
	"Unfinished Song" (1990. U.S.D.I. National Park Service Production distributed by Yellowstone Association, P.O. Box 117, Yellowstone National Park, WY 82190; phone: 307-344-2293)	1	$19.95 plus shipping
	"Yellowstone Aflame" (1989. Order from Finley-Holiday Film Corp., P.O. Box 619, Whittier, CA 90608)	1	$25
Woodsy Owl Activity Guide (1997. U.S.D.A. Forest Service and Children's Television Workshop). Contact Gloria Weisgerber, Forest Service Northern Region, to obtain a copy; phone: 406-329-3094.		1	$0
"ZIP Game" box (U.S.D.I. National Park Service). Order from Pat Durland, Fire Management Specialist, Bureau of Land Management, 3833 S. Development Ave., Boise, ID 83705; phone: 208-387-5162; fax: 208-387-5179.		1	$0

[92] Order from Rocky Mountain Research Station (Publications Department, Rocky Mountain Research Station, 240 West Prospect Road, Fort Collins, CO 80526-2098. Phone: 970-498-1392).

5.0 Obtain color graphics and slides[93]

5.1 **Posters:** Request posters (Fire Triangle, Fire Safety, Tree Portrait, 80 Years of Change, and Ancient Tree) to be printed at the Fire Sciences Laboratory. Laminate at an office supplies/copier business. Cost of laminating is approximately $3/ft; you'll need about 13 feet of laminating.

5.2 **Slides:** Request originals of slides from the Fire Sciences Laboratory. Place in carousel, labeling the separate parts--"Visiting Wildland Fire", "Smoke", and "People in Fire's Homeland." Also, make two color prints from each "homeland" slide to place in the "People in Fire's Homeland" kit in the *Teacher Box*.

5.3 **Copies--color and black-and-white:** Request a set of masters from the Fire Sciences Laboratory. You'll need to make about 270 black-and-white copies and 180 color copies. Shop around for a good price on color copying; prices can be as low as $0.65/page, but it's usually closer to $1. Make copies & assemble according to the directions that come with the masters. Products made by copying include:

"Is Smokey Wrong?" in the *FireWorks Library*
"Pathways in Time" booklets (3) in the *FireWorks Library*
Most of the kits in the *Teacher Box*
Portions of looseleaf notebooks (3) for feltboards
FireWorks Notebook and *FireWorks Glossary* for the *Teacher Box*

5.4 **Jigsaw puzzles for "Puzzling It Out":** Request puzzles to be printed at the Fire Sciences Laboratory. Laminate. Commercial laminating on a 24" laminator, at a price of about $3/foot, totals about $45. You can use a smaller laminator by cutting one row of pieces apart from the others, laminating the smaller pieces, then trimming the cut edges. Cut out and place each set of three puzzles in a manila envelope; label it "Puzzling It Out" kit.

6.0 Assemble *FireWorks Library* using checklist in Appendix 7. Label the box.

7.0 Assemble *Teacher Box* using checklist in Appendix 7. Label the box. If you need accordion folders, looseleaf notebooks, file folders, or other office supplies, DO NOT BUY THEM YET! Look for re-usable supplies from agency offices. In the Northern Region, contact Mary Manning (mmanning@fs.fed.us).

8.0 **Assemble materials in *Hardware Box*** and label it.

9.0 **Obtain directions and patterns for feltboard materials** from the Fire Sciences Laboratory. Cut out materials. Assemble feltboard notebooks (3), feltboard portion of *Mystery Trees Box*, and feltboard backgrounds (3).

10.0 **Finish assembly.** Check that all boxes are labeled.

[93] Many of these materials are also available on CD-ROM from the Fire Sciences Laboratory.

Appendix 9—Blank Form for *FireWorks Cookie Book*

Complete the form on the next page for each tree cookie in your *FireWorks* trunk. Add lines to the table if your cookie has more than 7 fire scars. Label the collection *FireWorks Cookie Book,* bind it, and put in your *Teacher Box.*

Data about Tree Number _____

What kind of tree? ___________________________

Where was it found? __________________________

How many fire scars? _______________

How many years before the first scar? __________

What are the intervals between scars
from the earliest one to the most recent?

1	
2	
3	
4	
5	
6	
…	
Median:	
Total:	
Average:	

How many years since the most recent scar? __________

Other information:

"Burning Issues" Supplement to *FireWorks*

Jun. 19, 2001

After *FireWorks* went to press, a CD-ROM called *Burning Issues*[1] was released by the U.S. Department of the Interior, Bureau of Land Management. It is now included, with the Field Notebook (both the Educator's Guide and Student's Edition) in the *Teacher Box* of *FireWorks* trunks. *Burning Issues* is a multimedia program containing video segments describing the natural history of four ecosystems in the U.S. and simulations for investigating and managing them. Through these four "EcoVentures," students learn about wildland fire in the longleaf pine forests of the Southeast, California chaparral, ponderosa pine forests, and sagebrush steppe in the Interior West. *Burning Issues* can be used for class presentations at the middle and high school levels, and portions of the CD make excellent extensions for *FireWorks* activities. Several are listed here. Each will require a minimum of ½ hour of computer time.

More Plants & Animals: Extension to Activities 6-3 through 6-7 or 7-1

- Use the "Resource Room" on the *Burning Issues* CD-ROM to investigate one organism that is **not** included in *FireWorks*. Summarize what you learn about the organism's habitat and its relationship to fire.

Cheatgrass Threatens Raptors in Sagebrush: Extension to Activity 7-2 or 8-4

- Whitebark pine forests are threatened by a non-native fungus, white pine blister rust. Learn about another ecosystem threatened by a non-native species—the sagebrush steppe of the western states, where an imported annual grass is degrading habitat for predatory birds. Do the "Golden Eagle EcoVenture" on the *Burning Issues* CD-ROM. Write a letter to managers of the Snake River Birds of Prey Wildlife Refuge explaining what you think they should do to protect raptors.

Professionals in Fire Suppression: Extension to Activity 8-1

- Learn about the many kinds of work involved in fire suppression by doing the "Fire Suppression EcoVenture" on the *Burning Issues* CD-ROM. Tell the class about **one** kind of fire suppression work that you didn't know about before.

Protecting Homes from Fire in Chaparral: Extension to Activity 8-2

- Learn about home safety in the California chaparral ecosystem by completing the "I-Zone EcoVenture" on the *Burning Issues* CD-ROM. Tell the class how fire in chaparral differs from fire in the three forests you have learned about in *FireWorks.*

Fires Save Longleaf Pine Forests in the South: Extension to Activity 8-3

- Learn about the longleaf pine forests of the southeastern U.S. by doing the "Fire Power EcoVenture" on the *Burning Issues* CD-ROM. Write a 1-page essay that compares longleaf pine forest with the ponderosa pine forest featured in *FireWorks.*

[1] *Burning Issues* can be ordered from: Florida State University, C2200 University Center, Tallahassee, FL 32306-2641; phone 850-644-0707; email imsp.fsu.edu.

The *FireWorks* curriculum
With color graphics
is on-line at
http://www.fs.fed.us/rm/pubs/rmrs_gtr65.html

The Authors

Jane Kapler Smith is an Ecologist in the Prescribed Fire and Fire Effects Research Group at the Rocky Mountain Research Station's Fire Sciences Laboratory, Missoula, MT. She has written "Fire Ecology of the Forest Habitat Types of Northern Idaho" and edited "Wildland Fire in Ecosystems—Effects of Fire on Fauna." She manages the Fire Effects Information System and develops and assesses communications programs relating to wildland fire. She has worked in fire management and studied fire behavior and fire effects in aspen stands of north-central Colorado. She has taught biology and biostatistics and conducted research on succession and acid rain in the hardwood forests of western New York. Jane has a B.A. from Alverno College, Milwaukee, Wisconsin and an M.S. in Forest Ecology from Colorado State University.

Nancy E. McMurray is a Biological Technician in the Prescribed Fire and Fire Effects Research Group at the Rocky Mountain Research Station's Fire Sciences Laboratory, Missoula, MT. She maintains the Citation Retrieval System, the bibliographic database for the Fire Effects Information System, and develops and assesses communications materials relating to wildland fire. Nancy has worked on wildlife and forestry research projects, including grizzly bear research, for the U.S.D.A. Forest Service and the University of Montana. Nancy has a B.S. in Wildlife Biology from the University of Montana.

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Rocky Mountain
Research Station

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of forests and rangelands. Research is designed to meet the needs of National Forest managers, federal and state agencies, public and private organizations, academic institutions, industry, and individuals.

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*Station Headquarters, 2150 Centre Avenue, Building A, Fort Collins, CO 80526