FireWorks Curriculum For Elementary School

Featuring Lower and Upper Sierra Nevada Mixed Conifer Forests

2017

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Produced by:

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The *FireWorks* program was originally completed and the curriculum published in 2000 (Smith and McMurray 2000). This version incorporates new science, new teaching techniques, and new standards, and is adapted for Sierra Nevada ecosystems.

***FireWorks*: Why?**

Change is an integral part of a healthy, enduring ecosystems in most temperate regions of the world. *FireWorks* provides students with interactive, hands-on materials to study the forces that cause change, particularly wildland fire. The program is based on the science of wildland fire, a highly interdisciplinary field, so it provides a context for learning about properties of matter, chemical and physical processes, ecosystem fluctuations and cycles, habitat and survival, and human interactions with ecosystems. These concepts are considered important for science literacy (American Association for the Advancement of Science 1993). Students using *FireWorks* ask questions, 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).

Goals

FireWorks aims to increase understanding

- of the physical science of combustion, especially in wildland fuels
- that an ecosystem has many kinds of plants and animals, which change over time and influence one another
- that fire is an important natural process in many ecosystems
- that native plants and animals have ways to survive fire or reproduce after fire, or both
- that people influence the fire-dependent ecosystems where they live, and they always have done so

Meeting these goals helps implement the vision of the National Cohesive Wildland Fire Management Strategy (U.S. Department of Agriculture, Forest Service; Department of the Interior, Office of Wildland Fire Coordination. 2011) "*To safely and effectively extinguish fire when needed; use fire where allowable; manage our natural resources; and as a nation, to live with wildland fire*."

FireWorks also 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).

Local learning:

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).

This version of *FireWorks* focuses on selected *ecological communities* in the Sierra Nevada–forests dominated by conifers. These communities are often called lower and upper *mixed conifer* or lower and upper *montane* communities. These lower and upper montane mixed-conifer forests have a long, intimate relationship with fire. The photo presentation created for Activity 1 in the Elementary and Middle School curricula shows many inhabitants of these communities and the different types of fire that occur in them.

Lower montane forests grow just uphill from the grassy and shrubby *foothill* communities in the Sierra Nevada. Thus they occur at relatively low elevations, not high in the mountains. Lower montane forests are dominated by oaks, ponderosa pine, sugar pine, white fir, Douglas-fir, and incense-cedar. Many of these forests, especially in historical times, were dominated by pines. They had an open structure, with old, large trees spaced far apart and a few young trees. They had many kinds of grasses, wildflowers, and shrubs in the understory. A few of these old-growth, pine-dominated forests remain today. In the past, fires in this kind of forest tended to spread through the surface fuels. They rarely jumped into the tree crowns. Even when they did, they could not spread from crown to crown because most of the trees were spaced far apart. Because these forests are relatively dry, they typically burned frequently. Repeated fires keep the forest structure open. They favor grasses, wildflowers, and shrubs that can sprout easily after fire, and they provide habitat for mammals and birds that need large, old trees and an open understory.

Upper montane forests occur at fairly high elevations, but not all the way up on mountainsides. These forests are usually dominated by Jeffrey pine, red fir, and lodgepole pine. There is a lot of overlap between lower and upper montane forests, so species from these communities often intermix. Because upper montane forests grow higher in the mountains, they are colder, receive more snow, and have a shorter growing season. Thus historical fires generally burned less frequently than in lower montane communities, although there is considerable variability. In the past, fires in upper montane forests tended to spread through the surface fuels but sometimes also jumped into the tree crowns. Fires killed trees in small patches, but most large trees survived.

Mixed-conifer forests in the Sierra Nevada have experienced very few low-severity fires in the past century. Because of this, the forests tend to be very dense and have a lot of litter, logs, and *ladder fuels* (shrubs and young trees that increase in the absence of fire and enable fires burning on the forest floor to climb into the tree tops). The forest canopy is fairly continuous (*closed*), and trees that grow well in shade are more common than they were historically. This is true throughout the mixed-conifer forests, but especially so in lower montane communities. When fires burn through dense forests during hot, dry, windy conditions, they tend to burn in the tree crowns more often than they did when the forest structure was open. Crown fires kill more large trees than the frequent surface fires of the past. Nowadays, it is common to see large patches of *stand-replacing fires* in forests that used to experience stand-replacing fire in small, isolated patches.

High in the mountains of the Sierra Nevada are the subalpine forests, dominated by lodgepole pine, western white pine, mountain hemlock, and whitebark pine. This curriculum does not cover the high-elevation forests, but they are very important to the ecology of the Sierra Nevada and to the quality of life of its plants and wildlife, and to the human communities living in the watersheds below.

Table I-1—Summary of ecology and "fire story" of some forest communities of the Sierra Nevada

		Lower montane mixed conifer	Upper montane mixed conifer
Shade-intolerant tree species (grow well in sunny, open areas with bare soil)		Ponderosa pine Sugar pine California black oak	Jeffrey pine Sierra lodgepole pine
Shade-tolerant tree species (grow better than pine in shady places)		Douglas-fir White fir Incense-cedar	Red fir
Historical fire frequency	Crown fire	Infrequent, except in small patches	Infrequent, except in small to medium-sized patches
	Low-severity surface fire	4-14 per century	2-4 per century
Some animals		Mule deer Western gray squirrel Dusky-footed woodrat California spotted owl American black bear	Mule deer California spotted owl Yellow-legged frogs American black bear
Disturbances besides fire		Bark beetles White pine blister rust Drought	Bark beetles Drought

Design and Layout of Lessons in This Curriculum

Each activity has the following sections:

Lesson Overview
Lesson Goal
Objectives
Teacher Background
Materials and Preparation
Procedure
Assessment
Evaluation

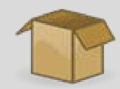
Subjects: Science, Writing, etc…

Duration:

Group size:

Setting:

FireWorks vocabulary (first introduced in to this activity):



Instructions for each activity also include a text box (example above) that lists subjects covered, the possible duration of the activity (a guess –take this with many grains of salt), group size, setting (laboratory, classroom, outdoors, etc.), and *FireWorks* vocabulary (list of terms in the *FireWorks Glossary* that are first introduced in this activity). The text box may also contain one or two icons – a red-and-white flame if the activity uses fire, and a brown box if the activity requires materials from a *FireWorks* trunk.

Handouts and other materials meant for students all begin with a large, bold-face header in **blue font**. Handout answer keys and other materials meant for teachers all begin with a large, bold-face header in **maroon font**. In the Procedures section and in handout answer keys for teachers, answers to questions are given in red font.

Links to Educational Standards

FireWorks need not compete with core curriculum for classroom time. Instead, it can help teachers cover core concepts and improve student skills by using hands-on materials based on science from their own local area. To help teachers identify the ways in which *FireWorks* can be used to meet their curriculum requirements, each activity is linked to educational standards.

FireWorks is correlated to the Common Core State Standards in English Language Arts (CCSS-ELA), Math (CCSS-Math), History and Social Studies, Science, and Technical Subjects; the Next Generation Science Standards (NGSS); the Excellence in Environmental Education: Guidelines for Learning standards (EEEGL); and the C3 Framework: College, Career and Civic Life for Social Studies State Standards (C3 SSSS)[1].

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[1] Abbreviations and links to standards:

- CCSS-ELA: Common Core State Standards—English Language Arts (http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf)
- CCSS-Math: Common Core State Standards—Math (http://www.corestandards.org/wp-content/uploads/Math_Standards.pdf)
- NGSS: Next Generation Science Standards (http://www.nextgenscience.org/sites/ngss/files/NGSS%20DCI%20Combined%2011.6.13.pdf)
- EEEGL: Excellence in Environmental Education: Guidelines for Learning (http://resources.spaces3.com/89c197bf-e630-42b0-ad9a-91f0bc55c72d.pdf)
- C3 SSSS: College, Career and Civic life for Social Studies State Standards (http://www.socialstudies.org/system/files/c3/C3-Framework-for-Social-Studies.pdf)

Each lesson has been correlated to the relevant standards. If a lesson does not have standards listed from a particular standard framework, then it probably does not meet standards in that framework. However, teachers are encouraged to reinterpret standards and lessons and also to adapt lessons to meet their educational objectives and particular standards.

First, find the relevant grade(s).

Standards	Section	Sixth	Seventh	Eighth
Common Core ELA	Writing	4,10	4,10	4,10
	Speaking/Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language Standards	1,2,3,6	1,2,3,6	1,2,3,6
	Reading Standards Science/Tech	4,7,9	4,7,9	4,7,9
	Writing Standards Science/Tech	4,7,10	4,7,10	4,7,10
NGSS	Structures/Properties of Matter		PS3.A	
	Energy		PS3.A	
	Waves/Electromagnetic Radiation		PS4.B	
EEEGL	Strand 1		A,C,E,F,G	

Second, find the relevant standards and access a copy of the respective publication.

Third, open standards publication to the appropriate grade and section.

Fourth, locate these numbers and read the associated standard.

Safety

Many of the experiments in this curriculum use fire and natural fuels in the classroom or laboratory. In these structured, well supervised environments, students can make discoveries about fire and improve their habits regarding fire safety. Help students learn about safe laboratory practices, such as using protective eyewear and wearing appropriate clothing. Help them learn that professional skills and years of experience are needed to use fire safely in wildlands. The following steps will help your students grow in responsibility and competence regarding lab safety and fire:

- Inform your maintenance staff about activities in which you will use fire.
- Inform your local fire protection unit if you plan to use fire outdoors.
- Consider informing parents about your plans and goals for teaching about fire.
- Choose your work space carefully, especially if you will not be using a laboratory. The fire engine must respond to every alarm, even if you tell them it's "only" an experiment.
- If you are working outdoors, watch carefully to prevent smoldering material from igniting schoolyard vegetation.
- Keep 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 a fire extinguisher ready for use. Know how to use it. If you discharge a fire extinguisher, refill or replace it immediately. Don't burn anything without a charged fire extinguisher in the room.
- If you or any of your students have asthma or other respiratory problems, consider having them wear protective masks while working with fire.

Literature cited

American Association for the Advancement of Science. 1993. Benchmarks for science literacy. New York: Oxford University Press. 418 p.

Lindholdt, Paul. 1999. Viewpoint: writing from a sense of place. Journal of environmental education: 30(4): 4-10.

Moreno, Nancy P. 1999. K-12 science education reform—a primer for scientists. BioScience. 49(7): 569-576.

National Research Council. 1996. National science education standards. Washington, DC: National Academy Press. 262 p.

North American Association for Environmental Education. 1999. Excellence in EE—guidelines for learning (K-12). Rock Spring, GA: NAAEE Publications and Membership Office. 107 p.

Smith, Jane Kapler; McMurray, Nancy E. 2000. FireWorks curriculum featuring ponderosa, lodgepole, and whitebark pine forests. Gen. Tech. Rep. RMRS-GTR-65. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 270 p.

U.S. Department of Agriculture, Forest Service; Department of the Interior, Office of Wildland Fire Coordination. 2011. A national cohesive wildland fire management strategy. Washington, DC: Wildland Fire Leadership Council. 43 p.

This table summarizes the content for each activity at each grade level. Read across the table to find similar activities for students at other grade levels.

Unit & Theme	ELEMENTARY	MIDDLE	HIGH
Unit I. Introduction to Wildland Fire	E01. Visiting Wildland Fire in the Sierra Nevada	M01. Visiting Wildland Fire in the Sierra Nevada	H01. Introduction to Wildland Fire in the Sierra Nevada
Unit II. Physical Science of Wildland Fire	E02. Making Fires Burn or Go Out 1: Introduction to the Fire Triangle	M02. Where Does Heat Go? The Heat Plume from a Fire	H02. The Fire Triangle: Fuel, Heat, and Oxygen
	E03. Making Fires Burn or Go Out 2: Demonstrating the Fire Triangle and Heat Plume	M03. What Makes Fires Burn? The Fire Triangle 1—Heat and Fuel	H03. The Fire Triangle, Combustion, and the Carbon Cycle
		M04. What Makes Fires Burn? The Fire Triangle 2—Oxygen	H04. Heat Transfer
Unit III. The Wildland Fire Environment			H05. Fuel Properties
			H06. Pyrolysis
			H07. Fire Spread Processes: Putting it all together: Heat transfer, fuel properties, and pyrolysis
	E04. How Wildland Fires Spread 1: Experiment with a Matchstick Forest	M05. How Do Wildland Fires Spread? The Matchstick Forest Model	H08A. Fire Environment Triangle and Fire Spread: The Matchstick Model
			H08B. Fire Environment Triangle and Fire Spread: The Landscape Matchstick Model
		M06. Ladder Fuels and Fire Spread: The Tinker Tree Derby	H09. Ladder Fuels and Fire Spread
	E05. Fuel Properties: The Campfire Challenge	M07. Fuel Properties: The Campfire Challenge	See H05.
	E06. Effect of Wind: How Wildland Fires Spread	M08. Fire Behavior, Fire Weather, and Climate	H10. Fire Behavior, Fire Weather, and Climate

Unit IV. Fire Effects on the Environment	E07. Smoke from Wildland Fire: Just Hanging Around?	M09. Smoke from Wildland Fire: Just Hanging Around?	H11. Smoke from Wildland Fire: Just Hanging Around?
		M10. Fire, Soil, and Water Interactions	H12. Fire, Soil, and Water Interactions
Unit V. Fire's Relationship with Organisms and Communities	E08. Who Lives Here? Adopting a Plant, Animal, or Fungus	M11. Who Lives Here? Adopting a Plant, Animal, or Fungus	H14. Researching a Plant, Animal, or Fungus
	E09. Tree Parts and Fire: The Class Models a Living Tree	M12. Tree Parts and Fire: "Working Trees" Jeopardy-style Game	
	E10. Tree Identification: Using a Key to Identify "Mystery Trees"	M13. Tree Identification: Figure out the "Mystery Trees"	H13. Tree Identification: Create a Dichotomous Key
	E11. Recipe for a Baker Cypress Grove: Serotinous Cones		
		M14. Who Lives Here and Why? Modeling Forest Communities	H15. Forest Communities and Climate Change
		M15. Bark and Soil: Nature's Insulators	
	E12. Buried Treasure: Underground Parts that Help Plants Survive Fire	M16. Buried Treasures: Identifying Plants by their Underground Parts	
Unit VI. Fire History and Succession	E13-1. My Tree Autobiography: Seeing History through Trees' Growth Rings		
	E13-2. Story of a Fire-Scarred Tree	M17. Fire History 1: Long Stories Told By Old Trees	H16. Fire History 1: Long Stories Told by Old Trees
		M18. Fire History 2: History of Stand Replacing Fire	H17. Fire History 2: History of Stand Replacing Fire
	E14. Story Time: Fire and Succession	M19. Drama in the Forest: Fire and Succession, a Class Production	H18. Fire History 3: Fire Regime across a Sierra Nevada Landscape
Unit VII. People in Fire's Homeland	E15. Homes in the Forest: An Introduction to Firewise Practices	M20. Homes in the Forest: An Introduction to Firewise Practices	
	E16. Revisiting Wildland Fire	M21. Revisiting Wildland Fire	H19. Sierra Nevada Forests Today

Unit I.
Introduction to Wildland Fire

1. Visiting Wildland Fire in the Sierra Nevada

Subjects: Science, Writing, Speaking and Listening, Arts, Environmental Education

Duration: one half-hour session

Group size: Whole class

Setting: Indoors

New FireWorks vocabulary: *fire behavior, wildland, wildland fire*

Lesson Overview: Students view a narrated photo presentation that shows wildland fires and some of the plants and animals they are going to learn about. The photos and narrative are at the end of the lesson and on a PowerPoint. During the presentation, students record their observations about fire behavior. Afterwards, they discuss their observations and feelings about the presentation. The presentation's narrative is brief because this activity is meant to orient the students and let them express their feelings about fire – not to teach science content.

Lesson Goal: Increase students' understanding that wildland fire is a complicated process that can benefit ecosystems.

Objectives:

- Students can draw different kinds of fire behavior.
- Students can write about similarities and differences among kinds of fire behavior.
- Students can describe their feelings about wildland fire.

Standards		1st	2nd	3rd	4th	5th
CCSS	Writing	8	8	8	8	8
	Speaking and Listening	2,3,4,5,6	2,3,4,5,6	2,3,4,6	2,3,4	2,3,4
	Language	1,2	1,2	1,2	1,2	1,2
NGSS	Structure and Property of Matter		PS1.B			
	Interdependent Relationships in Ecosystems		ETS1.B			
	Weather and Climate			ESS3.B		
	Earth's Systems: Processes that Shape the Earth				ESS3.B	
EEEGL	Strand 1	A,C,E				A,C,E
	Strand 2.2	C				C

Teacher Background: If you walk through a recently burned area, you might encounter some places where all the vegetation looks dead and other places that have a lot of green vegetation left. You might see deep holes in the ground where roots have burned away, and you might see patches of leaf litter that is just lightly scorched. Fire behavior and fire effects vary with topography, weather, and vegetation. As a result, some patterns are typical of certain kinds of landscapes and vegetation. For example, steep hillsides are more likely to support fast-moving fires than flatlands or moist ravines, and forests with trees close together are more likely to support crown fires (spreading through the tree canopy) than forests where the trees are far apart. As an introduction to the study of wildland fire, this photo presentation highlights <u>variation</u> in fire behavior and its <u>relationship to specific plants and animals</u>.

This version of FireWorks focuses on ecological communities in the Sierra Nevada– forests dominated by conifers. These communities are often called lower and upper mixed conifer or lower and upper montane. See the **Introduction** (pp. ii-iii) for an overview of these Sierra Nevada ecological communities.

If you plan to teach the units on fire ecology (Units V and VI), consider having your students adopt a plant, animal, or fungus NOW, so they have time to prepare and you can spread their presentations out over several days instead of having them all at once. See Activity 8, "Who Lives Here: Adopting a Plant, Animal, or Fungus" for further details.

Materials and preparation:

- Load photo presentation *E01_M01_VisitingWildlandFire.pptx*
- Copy Handout E01-1 for each student
- Make a sketch of Handout E01-1 on the board—all three sections—or project it
- Set up flipchart or other media for recording questions and feelings. You'll want to look at this list at the end of the unit on fire: Lesson E16, "Revisiting Wildland Fire"
- Have students get out crayons or markers, clean paper, and pen or pencil.

Procedure:

1. Explain to students: They will watch a presentation that shows fires in *wildlands*. You will stop several times during the presentation so they can discuss what they see and make drawings to record their observations. After the presentation, you will ask them to describe what they have observed and also describe their feelings about the presentation.

2. Give out copies of Handout E01-1. Explain that you'll let students know when you'd like them to draw.

3. Show the presentation. You can use the narrative in the presentation notes below or give your own narrative, but keep it brief. Welcome students to discuss and ask questions about what they see. Record the questions on a flipchart or other medium, but don't necessarily try to answer them during the presentation. Instead, explain that the class will seek the answers during this unit on *wildland fire*.

4. When you show Slide 1, the first photo that shows *fire behavior*, pause. Explain that it is time to record some observations so they can learn how wildland fires vary. Do the first one (A) together, and then they will do 3 more on their own. Ask the students to look carefully at the flames in the photo and describe them to the class. (How long are the flames? What

parts of the plants are they burning? What “layer” of vegetation is burning – just material on the ground? … only the tree tops?) On the board, sketch the flames shown in the photo.

5. Ask the students to make their own sketches of the fire behavior in Part A on their handouts. They should draw flames only in the parts of the vegetation that they see on fire in the photo. After they’ve done so, continue with the presentation.
6. Stop at the cues for sketching fire behavior (slides 8, 14, and 21) and have students sketch the fire behavior on their handouts (B, C, and D).
7. Prepare for writing assignment: Ask the students to look at the first two kinds of fire behavior (A and B). Write “Same” and “Different” next to them, and ask students to describe to the class some ways in which the two kinds of fire are similar and different. Note some of their comparison/contrast phrases on the board.
8. Ask the students how they feel about the fires that they saw in the presentation. Record their “feeling words” on a flipchart or other medium so you can discuss them again at the end of the curriculum. Explain that people’s feelings often differ without being “right” or “wrong,” so all of the feelings from class members are valid and deserve respect.
9. Keep the flipcharts that list students’ questions and feelings. You will use them for Activity 16, “Revisiting Wildland Fire.”

Assessment: Ask the students to write on the handout or a clean sheet of paper:

1. At least one sentence about how fires B and C are the same.
2. At least one sentence about how fires B and C are different.
3. At least two words that describe their feelings in response to the photo presentation.

Evaluation:

	Present	Not-Present
1. Fire Similarity Sentence(s)		
2. Fire Contrasting Sentence(s)		
3. Fire Feelings		

Slides and Narrative for *E01_M01_VisitingWildlandFire.pptx*

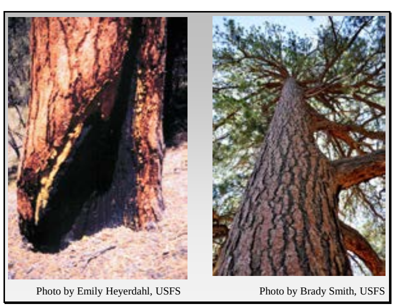
Slide 1

Here is a fire burning in a forest of the Sierra Nevada. *Observe and sketch it (A)*

Slide 2

This is what the land looks like after that kind of fire.

Slide 3



Here are some plants that live in the forest after fire:
… A ponderosa pine tree that has survived many fires

Slide 4

… Mariposa lily, a wildflower that survives fire and then grows really well.

Slide 5

… A California black oak that sprouts after fire.

Slide 6

Here are some animals that live in the forest after fire:
… Pileated woodpecker, which loves big, old trees that have survived fires long ago.

Slide 7

… Western gray squirrels that eat the seeds of trees that have survived the fire.

Slide 8

Here is another kind of fire in the Sierra Nevada. *Observe and sketch it (B).*

Slide 9

This is what the land looks like after that kind of fire.

Slide 10

Or this.

Slide 11

Here are some plants and animals that thrive after that kind of fire:
… A beetle with heat sensors, so it can find fires and lay its eggs in just-burned trees.

Slide 12

… A black-backed woodpecker, which arrives soon after the fire to eat the beetles.

Slide 13

… Deer brush, whose seeds germinate after fire cracks open its hard seedcoats.

Slide 14

Here is another kind of fire in the Sierra Nevada. *Observe and sketch it (C).*

This is a mixture of the two kinds of fire you've already observed. Many of those plants and animals can live here after fire.

Slide 15

Fire behavior and fire effects vary with topography, weather, and vegetation. Here are examples of fire behavior fires in the Sierra Nevada.

Slide 16

Slide 17

Slide 18

Slide 19

Slide 20

Slide 21

Fires in our forests can burn for a long time after the flames have passed. They may burn in tree trunks, roots, or in the soil itself.

Here is what a fire may look like after most of the flames have moved on (left photo). *Observe and sketch it (D).*

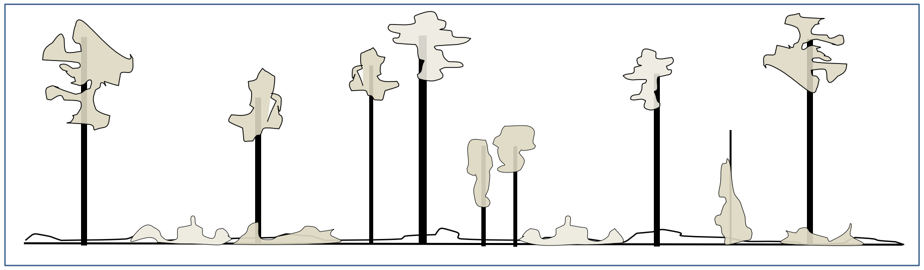
Wildland fires cause changes that last a long time, sometimes for hundreds of years. We'll learn more about all kinds of fire in the activities to come.

Handout E01-1.

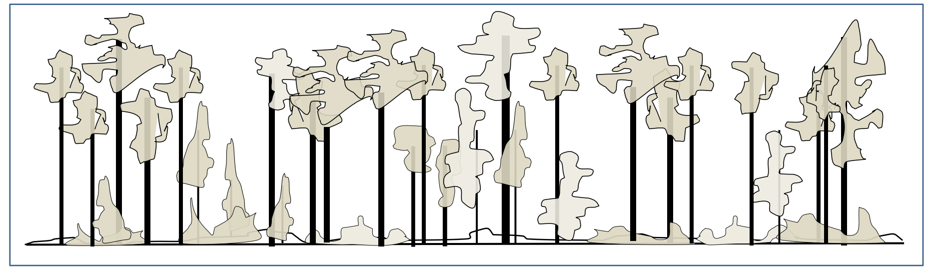
Name _______________________________

1. **Color each sketch to show what part of the forest is burning (for example, soil, surface plants, or tree tops). Add a few words to describe fire behavior if you wish.**

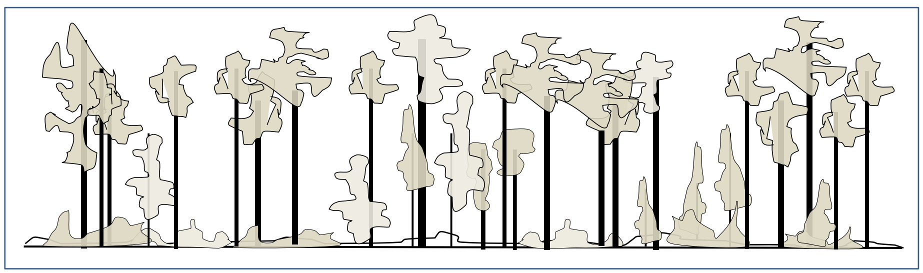
A.



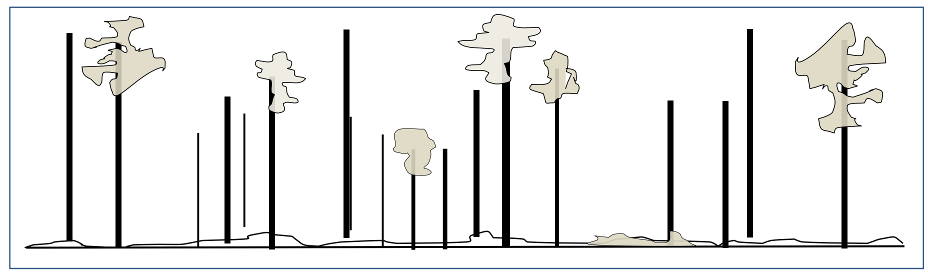
C.



B.



D.



2. **Write:**

   At least one sentence about how fires B and C are the same.

   At least one sentence about how fires B and C are different.

   At least two words that describe their feelings in response to the photo presentation.

Unit II.
Physical Science of Wildland Fire

2. Making Fires Burn or Go Out 1: Introduction to the Fire Triangle

Lesson Overview: In this activity, students describe and organize what they already know about fire so it fits into the conceptual model of the *Fire Triangle*. They examine the stability of a triangle and how that geometric property applies to fire.

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

Duration: one half-hour session

Group size: Whole class. Students work in groups of 2-3.

Setting: Indoors

New FireWorks vocabulary: *Fire Triangle, fuel, heat, ignition, oxygen, model*

Lesson Goal: Increase students' understanding of how fires burn and why they go out.

Objectives:

- Students can construct a triangle out of toothpicks and gumdrops, and can label its legs with the three components of the Fire Triangle.
- Students can demonstrate that removing one side of the triangle makes it collapse.
- Students can identify the component(s) of the Fire Triangle that are removed in various scenarios, and explain how this makes the fire go out.

Standards:		1st	2nd	3rd	4th	5th
CCSS--ELA	Writing	3,7,8	3,7,8	3,7,8	3,7,8	3,7,8
	Speaking and Listening	1,2,3,5,6	1,2,3,5,6	1,2,3,5,6	1,2,3,5,6	1,2,3,5,6
	Language	1,2,6	1,2,6	1,2,6	1,2,6	1,2,6
CCSS--Math	Geometry	1.G2	2.G2	3.G1		
NGSS	Structure and Property of Matter		PS1.A			
	Engineering Design		ETS1.B			ETS1.B,C
EEEGL	Strand 1	A,B,C,E,F,G				A,B,C,E,F,G
	Strand 2.1	D				C

Teacher Background: This activity explores the chemistry of combustion as described by a conceptual model called the Fire Triangle. A fire cannot start without three things: fuel, oxygen, and a heat source. If a fire runs out of any of these things, it will stop. The three requirements for fire are conceptualized in the Fire Triangle. This is an appealing model because the geometric properties of the triangle are analogous to the requirements for combustion: A triangle is very stable as long as all three legs are present, and it collapses if one leg is removed.

Fuel + Oxygen + Heat ⟶ Carbon dioxide + Water + Heat&Light

William Cottrell's *The Book of Fire* (2004, http://mountain-press.com/) contains well illustrated and easy-to-read descriptions of the physical science of combustion and wildland fire.

Materials and preparation:

- Locate the *Fire Triangle* poster in the trunk or prepare to draw the figure on the board. But do not display it right away. See Step 4 below.
- Gumdrops (3 or more/student group)
- Toothpicks (3 or more/student group)
- Paper, scissors, tape, pen or pencil

Procedure:

1. Explain: Students will share what they already know about fire and then organize this knowledge to better understand what makes fires burn and what makes them go out.
2. Ask students what is needed to make a fire. List their responses on the board (they may include matches, paper, cardboard etc. as well as wildland fuels). Try to write them in three loose clusters (fuel, heat, and oxygen), which you'll label later.
3. Ask students to come up with a word that describes each category. Guide them to the concepts of fuel, heat, and oxygen, and then label the categories. These are the 3 parts of the Fire Triangle. You may need to explain what oxygen is: an invisible gas, one of several "ingredients" in the air we breathe. It comprises about 21% of air, and we use only about 20% of that in a single breath. If we used all of it, cardiopulmonary respiration (CPR) would not work!
4. Display the Fire Triangle poster and/or label the sides of your drawing. Explain: you can use a triangle to illustrate what makes fires burn and what makes them go out. Triangles are used in constructing buildings and bridges because they are much stronger shapes than squares or other many-sided shapes. (OPTIONAL MATHEMATICAL EXERCISE: Ask students to use their gumdrops and toothpicks to make a triangle, a square, and a pentagon. See which one is most stable and which is easiest to deform.)

5. Ask each student group to:

   a) Build a triangle from gumdrops and toothpicks, make a small label for each leg of the triangle (fuel, heat, oxygen), and attach the label with tape.

   b) Show each other what happens when one leg of a triangle is removed. (The triangle collapses.)

   c) Put the triangle back together and use it to explain to each other what happens to a fire when one component of the Fire Triangle is removed. (The fire goes out, or fire cannot start in the first place.)

6. Ask students to explain how you can put a fire out using the components of the Fire Triangle. Examples:

   - When you throw water (or dirt, or use a household fire extinguisher) on a fire, you cut off oxygen and remove heat.
   - 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, or the gas tank in the car is empty, the fires go out.

7. Ask: Burnable things surround us every day—why are they not on fire? (An external source of heat is needed to ignite the fuels. Once a fire has started, it produces more than enough heat to continue burning.)

Assessment: Demonstrate or show a video of "stop, drop, and roll" (information available at http://burnprevention.org/programs-services/teachers-corner/ as of August 2016). Have students practice this, and then identify (in writing) which part(s) of the Fire Triangle are removed, making the fire go out.

Evaluation:	Excellent	Good	Fair	Poor
"Stop, Drop, and Roll" response	-Identified oxygen and heat as the parts of the Fire Triangle removed.	-Identified oxygen or heat as a part of the Fire Triangle removed.	- Did not identify oxygen or heat as part of the Fire Triangle removed, but showed some understanding of the concept of Fire Triangle.	-Did not identify oxygen or heat as part of the Fire Triangle removed. -Did not show understanding of the concept of Fire Triangle.

Extension: In 2012, the Alan Alda Center for Communicating Science (http://www.centerforcommunicatingscience.org/) sponsored a competition to find an explanation of flames that would be understandable to an 11-year-old. The winning entry was a 7-minute video produced by Austrian scientist Ben Ames. As of August 2016, it is available at http://vimeo.com/40271657. This video cartoon describes the basic chemistry of combustion and the related processes of pyrolysis, oxidation, chemiluminescence, and incandescence. It even contains a theme song that helps viewers learn and pronounce these technical terms.

3. Making Fires Burn or Go Out 2:
Demonstrating the Fire Triangle and Heat Plume

Lesson Overview: This activity contains three demonstrations in which students observe real fires to see how the conceptual model of the Fire Triangle applies to real combustion.

Lesson Goal: Increase students' understanding of combustion. Increase their awareness that use of fire requires safe practices and responsible adult supervision.

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

Duration: One to two half-hour sessions

Group size: Whole class

Setting: Indoors

New FireWorks vocabulary: *heat plume, carbon dioxide*

Objectives:

- Students can use the Fire Triangle to explain why lighted matches go out.
- Students can use the Fire Triangle to explain why it is difficult to light a candle in the presence of a mixture of baking soda and vinegar (or dry ice).

Standards:		1st	2nd	3rd	4th	5th
Common Core ELA	Writing	8	8	8	8	8
	Speaking/Listening	4,6	4,6	4,6	4,6	4,6
	Language Standards	1,2	1,2,3	1,2,3	1,2,3	1,2,3
Common Core Math	Measurement/Data		2.MD-1,2,9	3.MD-4	4.MD-4	5.MD-2
	Geometry					5.G-1,2
NGSS	Structure/Properties of Matter		PS1.A			PS1.A
EEEGL	Strand 1	C,E,G				C,E,G

Teacher Background – initial background is in the previous activity (E02). Further background: The three demonstrations in this activity show how the Fire Triangle model applies to actual combustion. In the first, students observe the shape of a fire's *heat plume.* In the second, they see what happens when heat and fuels come together in different spatial arrangements. In the third, they observe what happens when a fire is deprived of oxygen (O_2). All three demonstrations use fire – burning individual matches or votive candles. Take all safety precautions outlined in the *FireWorks Safety* poster. Explain them to students to increase their awareness of fire safety.

About Demonstration 3: This demonstration shows that oxygen is required for fire. We describe 2 ways to do this; both of them use carbon dioxide. Option 1, which is written into the lesson below, uses carbon dioxide gas produced by mixing baking soda and vinegar; if you use this option, you can explore the chemical reactions between baking soda and vinegar. Option 2, which is described after the "Evaluation" section at the end of the lesson, uses carbon dioxide gas produced from dry ice; if you use this option, you can explore the difference between phase change and chemical change.

Option 1. Here are the 2 equations that describe the chemical changes that produce carbon dioxide gas from vinegar and baking soda:

	vinegar (acetic acid)	+	baking soda (sodium bicarbonate)	→	carbonic acid	sodium acetate
[1]	CH_3COOH	+	$NaHCO_3$	→	$H_2CO_3(aq)$	$NaCH_3COO$ (aq)

Sodium acetate is the goo at the bottom of the container. Carbonic acid looks like water. The carbonic acid immediately breaks down into carbon dioxide gas and water:

[2] $H_2CO_3 \rightarrow CO_2(g) + H_2O$

Carbon dioxide is one of the components of air. It is heavier than oxygen, as you can see from this calculation of the molecular weights of the two compounds:

Element	Atomic weight
Carbon (C)	12 g
Oxygen (O)	16 g

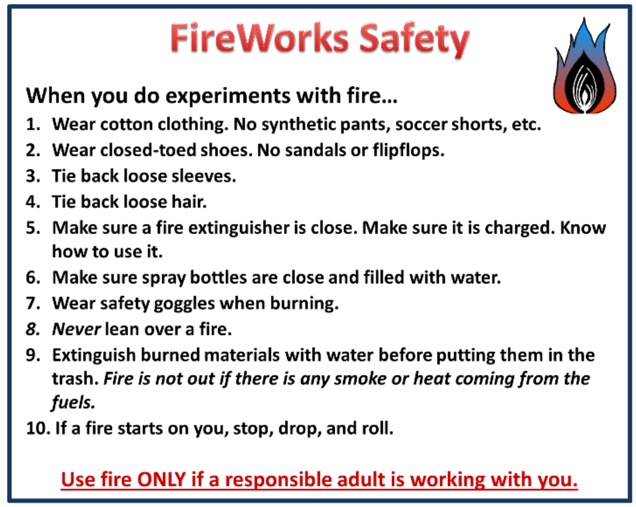
A mole of CO_2 weighs 12 g + 2 * 16 g = 44 g
A mole of O_2 weighs 2 * 16 g = 32 g

Thus, if carbon dioxide and oxygen are placed together in a container with no turbulence, the carbon dioxide will sink to the bottom and oxygen will rise to the top.

Option 2. When you use dry ice for this demonstration, you convert dry ice (frozen carbon dioxide) from the solid phase, at a temperature of −78.5 °C (−109.3 °F) or lower, into its gaseous phase. Note that carbon dioxide does not form a liquid at Earth's atmospheric pressure, so it goes directly from the solid to the gas phase – hence the term "dry" ice. We say that the dry ice "sublimes," and the process is called "sublimation."

Materials and preparation:
We recommend doing this activity as three demonstrations for the whole class. First, choose your location. Demonstrations 1 and 2 can produce flames 10-15 cm long. Can you do this safely in your classroom and without setting off a smoke alarm? Can you take your students to a lab where it will be safer? Do not try to burn outdoors because even the slightest wind will blow out single matches and candles.

Ask individual students to help with various tasks. It is best for a teacher or another adult to light the matches and candles, but explain how to handle matches and fire safely as you do the demonstrations.



FireWorks Safety

When you do experiments with fire…

1. **Wear cotton clothing. No synthetic pants, soccer shorts, etc.**
2. **Wear closed-toed shoes. No sandals or flipflops.**
3. **Tie back loose sleeves.**
4. **Tie back loose hair.**
5. **Make sure a fire extinguisher is close. Make sure it is charged. Know how to use it.**
6. **Make sure spray bottles are close and filled with water.**
7. **Wear safety goggles when burning.**
8. ***Never* lean over a fire.**
9. **Extinguish burned materials with water before putting them in the trash. *Fire is not out if there is any smoke or heat coming from the fuels.***
10. **If a fire starts on you, stop, drop, and roll.**

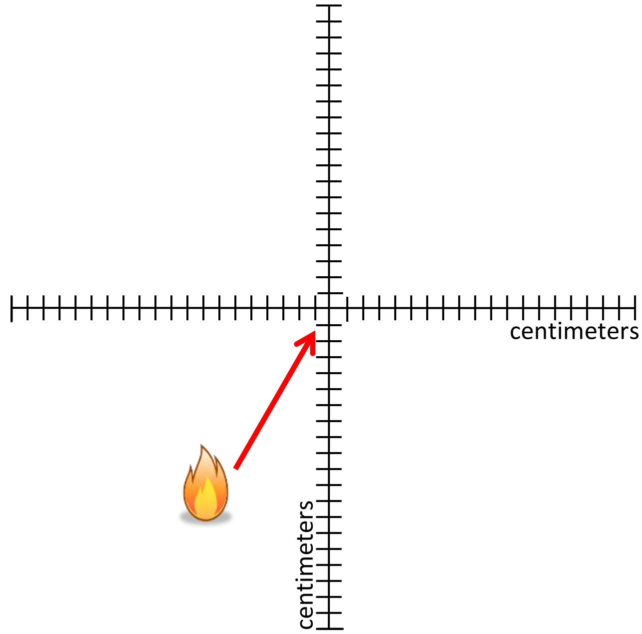
Use fire ONLY if a responsible adult is working with you.

- Display the *FireWorks Safety* poster. Follow safety guidelines about clothing and hair when you prepare for this activity. Have a package of hair bands in your pocket so you can give them out if needed.
- Get a box of wooden kitchen matches. The box need not be full.
- Display the *Fire Triangle* poster or simply draw it on the board.

- Set up your work station with this equipment:
  - Box of wooden matches
  - Fire extinguisher, fully charged
  - Spray bottle, filled with water
  - 1 ruler
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 2 votive candles
  - 2 beakers
  - 1 pair safety goggles
  - 1 oven mitt
  - 1 support stand
  - 1 metal rod with alligator clips at the ends
  - 1 clamp
  - About ½ cup of baking soda
  - About ½ cup of white vinegar
  - a long fireplace match
- Have a *metal* trash can *without a plastic liner* available.

Set up your demonstration table for **Demonstration 1** (see photo at right): Place the support stand in the center of the metal tray. Attach the clamp to the stand. Attach the metal rod with alligator clips so it forms a "+" with the stand. Place a wooden match in one alligator clip, with its tip pointing down.

Draw this illustration on the board (or print/display: *GraphForDescribingHeatPlume*



Procedure, Demonstration 1, "Where does the heat Go?"

1. Explain: According to the Fire Triangle, a fire cannot burn if it does not have all three of these things: heat, fuel, and oxygen. Now we will watch fire burning individual matches to see how the model works. In this activity, the teacher will perform the demonstrations with student assistance.
2. Do a **Safety Briefing** using the *FireWorks Safety* poster.
3. Organize your team:
   - An **Observer** who is dressed safely
   - A **Measurer**, also dressed safely
   - A data **Recorder**
4. Explain:
   - Observer: Your job is to find out how tall and wide the heat plume is from a burning match. You'll start by holding one hand about 40 centimeters to one side of the match. When the match is completely on fire, you'll bring your hand in closer until you can sense a change in temperature. The goal is to sense even a LITTLE warmth – NOT to see how close you can get without getting burned! We'll use as many matches as needed to get observations from two sides of the flame, above it, and below it. When you make the "below" observation, don't put your hand directly under the burning match, in case the tip breaks off and falls. Instead, hold your hand just a little to one side.
   - Measurer: After each match is out, you'll measure the distance from its tip to the observer's hand (in centimeters).
   - Recorder: You'll mark an axis of the graph to show each measurement.
5. Light the first match. As soon as it is completely on fire, obtain a "side" measurement. After it goes out, USE THE OVEN MITT to remove it from the clip, put a fresh one in, and get a measurement from the other "side" … then a "below" measurement… then an "above" measurement. Use as many matches as you need. Dispose of burned matches in the ashtray or on the metal tray.
6. Connect the marks on the four axes, making a roughly oval shape.

7. Discuss: Where did the heat go? (Most of it went upward, but a little went sideways and downward. Some also went into the metal clip and metal rod, which is why you needed the oven mitt.) Have students touch their hands high above their head. This is roughly the shape of the heat plume, so each of them is creating a model of the heat plume.

Procedure, Demonstration 2, "Why Does the Match Go Out?"

8. Organize your team:
   - One student (the **Timer**) should measure the duration of burning (in seconds).
   - One student (the **Measurer,** who is dressed safely) should measure the length of flames.
   - One student (the **Recorder**) should record data.
9. Copy this table onto the board:

Match is pointing…	Down	Up
How long did the flame get (centimeters)?		
How long did the match burn (seconds)?		
Why did the fire go out?		

10. Place a downward-pointing match in one clip and an upward-pointing match in the other. Light a separate match and use it to ignite the **downward-pointing** one. Measure flame lengths and burning times and record measurements on the board. Repeat, if necessary. <u>If you use additional matches, use the oven mitt</u> to handle the alligator clips.

11. Discuss "Why did the fire go out?" with the class. Ask them to use the Fire Triangle to explain. The downward-pointing match probably burned almost completely. (Combustion is complete if you can pulverize any remaining pieces into powdery ash.) The fire went out mainly because it ran out of fuel. If a tiny stub of unburned wood remained in the alligator clip, it didn't burn because the clip absorbed much of the heat and limited the oxygen getting to the fuel.
12. Light a match and use it to ignite the **upward-pointing** match. Take measurements and record them on the board. Repeat, if necessary. Discuss with the class why the upward-pointing match went out. (The match went out before it burned completely, so it was NOT limited by fuel. It was not limited by oxygen either – since everyone in the classroom was

still breathing comfortably. However, most of the heat was moving up, away from the fuel. If any heat was going down, it was not sufficient to keep the wood burning.)

Assessment #1-2: Ask students to use the three components of the Fire Triangle to explain in writing why the upward-pointing match went out.

Procedure, Demonstration 3, "Why Does the Candle Go Out?" <u>Option 1 – using vinegar and baking soda</u>

13. Do safety reminders.
14. Explain: You are using 2 candles – one "in the open" on the metal tray, and the other inside a beaker. The one on the tray is just your source for easily igniting matches. The one inside the beaker is the focus of the experiment. You will change 1 thing at a time in the experiment, so you know what changes are important.
15. Place one votive candle on the metal tray, and light it. Place the other candle in a beaker or other container.
16. Ignite a long fireplace match from the lighted candle, then use it to light the candle in the beaker. (This step simply demonstrates that the candle is indeed able to be lit inside the beaker.) Blow out the candle in the beaker.

17. Spoon 1-2 tablespoons of baking soda around the base of the candle, about enough to coat the bottom of the beaker. Be careful not to get the baking soda on the candle. Alternatively, you can add the baking soda to an empty beaker and then place the candle on top of it.
18. Relight the fireplace match from the candle on the metal tray. Then use it to light the candle in the beaker to demonstrate that the baking soda did not alter its ability to burn. Then blow it out.
19. Pour about ¼ c (60 mL) of vinegar into the baking soda <u>around</u> the candle. <u>Do this slowly</u> so the mixture doesn't foam so enthusiastically that it wets the candle wick.
20. Relight the fireplace match from the candle on the metal tray. Then use it to relight the candle in the beaker. (You probably can't.)
21. You may repeat the experiment and use different techniques to light the candle in the beaker.
22. Discuss with the class: Why was it so hard to light the candle after the vinegar was combined with baking soda? (When baking soda and vinegar are combined, they form CO_2, an invisible gas that is heavier than oxygen. The resulting CO_2 gas crowded the O_2 out of the beaker. Thus there was not enough O_2 available for burning.)

23. **Clean up:** Make sure all burned materials and matches are out before you dispose of them – that is, there is no smoke and no heat being released. Use a metal trash can without a plastic liner. If in doubt, dump them in a bucket of water before putting in trash.

Assessment #3: In writing, have students use the Fire Triangle to explain why it was hard to light the candle after vinegar was combined with baking soda.

Evaluation:

	Excellent	Good	Fair	Poor
Assessment #1-2	-Heat moved up, so it was not reaching the fuel. -Fuel and oxygen were still present.	-Heat moved up, so it did not reach the fuel.	-Heat was removed.	Unclear if student understood.
Assessment #3	-When baking soda and vinegar combined, they produced carbon dioxide, which is heavier than oxygen. The carbon dioxide sank to the bottom and crowded the oxygen out of the beaker. -No oxygen was available for burning.	-Carbon dioxide sank to bottom and crowded oxygen to top. -No oxygen was available for burning.	-No oxygen was available for burning.	-Student did not indicate that they understood the experiment.

Demonstration 3, "Why Does the Candle Go Out?" <u>Option 2 – using dry ice</u>

- Set up your work station with this equipment:
  - Box of wooden matches
  - Fire extinguisher, fully charged
  - Spray bottle, filled with water
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 2 votive candles
  - 2 beakers
  - 1 pair safety goggles
  - 1 oven mitt
  - a long fireplace match
  - tongs for handling dry ice

Procedure:

1. Do a safety briefing. In it, explain that you'll be using "dry ice". This is frozen carbon dioxide (one of the components of air), and it's very cold (-78°C (-109°F))—much colder than ice made from water. Because it is so cold, it should never be handled without tongs or gloves or a thick oven mitt. You will be performing this experiment while the class makes observations.

2. Explain: You are using 2 candles – one "in the open" on the metal tray, and the other inside a beaker. The one on the tray is just your source for easily igniting matches. The one inside the beaker is the focus of the experiment. You will change 1 thing at a time in the experiment, so you know what changes are important.

3. Place one votive candle on the metal tray, and light it. Place the other candle in a beaker or other container.

4. Ignite a long fireplace match from the lighted candle, then use it to light the candle in the beaker. (This step simply demonstrates that the candle is indeed able to be lit inside the beaker.) Blow out the candle in the beaker.

5. Place 3-4 small pieces of dry ice next to the candle in the beaker. <u>Use tongs or a mitt to handle the dry ice.</u>

6. Relight the fireplace match from the candle on the metal tray. Then use it to relight the candle in the beaker. (You probably can't because carbon dioxide has sublimed from the dry ice, crowding out the oxygen.)

7. You may repeat the experiment and use different techniques to try to light the candle in the beaker. You may also pour the invisible carbon dioxide onto the lighted candle, which will extinguish it.

8. Discuss with the class: Why was it so hard to light the candle with dry ice present? (Dry ice was turning from a solid to a gas as it warmed up – a process called sublimation. We say the dry ice is "subliming." The resulting CO_2 gas was crowding the O_2 out of the beaker for two reasons: because CO_2 is heavier than O_2 – based on its molecular weight – and because the CO_2 gas subliming from dry ice is very cold, which makes the gas more dense than it would be at room temperature. Thus there was no O_2 available for burning.)

9. **Clean up:** Make sure all burned materials and matches are out before you dispose of them – that is, there is no smoke and no heat being released. Use a metal trash can without a plastic liner. If in doubt, dump them in a bucket of water before putting in trash.

Unit III.
The Wildland Fire Environment

4. How Wildland Fires Spread 1: Experiment with a Matchstick Forest

Lesson Overview: Students use a physical model to learn how slope and the density of trees (or other kinds of standing fuels) affect fire spread.

Lesson Goal: Increase students' understanding of wildland fire spread in forests and other kinds of standing fuels.

Subjects: Science, Mathematics, Writing, Health and Safety

Duration: One or two half-hour sessions

Group size: Whole class

Setting: Indoor laboratory or outdoors

New FireWorks vocabulary: *crown fire, density, slope, stand (stand density), standing fuels*

Objectives:

- Students can apply their theoretical understanding of the Fire Triangle (from Unit II) to a physical model of a forest stand.
- Students can understand how slope and density of trees (or other standing fuels) affect fire spread.
- Students can illustrate on a diagram how fire is likely to spread and why.

Standards:		1st	2nd	3rd	4th	5th
CCSS--ELA	Writing	1,8	1,8	1,8	1,8	1,8
	Speaking and Listening	1,3,5,6	1,3,5,6	1,3,5,6	1,3,5,6	1,3,5,6
	Language	1,2	1,2	1,2,6	1,2,6	1,2,6
CCSS--Math	Measurement/Data	4				
NGSS	Earth's Systems: Processes that Shape Earth		ESS1.C, ESS2.A, ETS1.C		ETS1.B, ESS3.B	
	Engineering Design		ETS1.C			ETS1.A,B,C
	Weather and Climate			ESS3.B		
EEEGL	Strand 1	A,B,C,E,F,G				A,B,C,E,F,G

Teacher Background: In this activity, students use a physical model called the "matchstick forest" to investigate two of the variables that affect the spread of wildland fire: slope and the density of trees or other standing fuels. The fuels are represented in the model by single matches. For safety's sake, please note that the flames in this experiment can reach more than a foot in height. Plan accordingly. In addition, note that even very light breezes affect the way matches burn in this experiment. If you are working outdoors, the demonstrations may illustrate mainly that fire spread is complex and sometimes unpredictable.

Fires tend to spread upslope, so a fire that starts at the bottom of a hill is likely to spread faster than one that starts on a hilltop (other conditions being equal). This is because:

- the fuels uphill from a fire tend to be dried and warmed by the rising heat plume
- the flames on a fire spreading uphill are quite close to the uphill fuels, while the flames are farther away from the fuels below the fire. Therefore, fuels below the fire are affected very little – at least until burning materials roll downhill and ignite new fires below.

If a fire is burning in dense forest, it may spread from treetop to treetop, that is, it may become a crown fire. In more open forests, fires are more likely to remain in the surface fuels, that is, remaining surface fires. However, surface fires tend to spread more rapidly in open than dense stands because the wind speed is usually greater in open stands.

Table 2 describes three demonstrations that can be used in this activity. We recommend that you start with Demonstration 1, which illustrates fire's tendency to burn uphill, and then use either Demonstration 2A or 2B:

- Demonstration 2A illustrates basic principles as they apply to all kinds of plant communities subject to fire (any kind of forest, woodland, or shrubland, the world over).
- Demonstration 2B illustrates the principles as they apply to forests with different fire histories – long intervals between fires and short intervals.

Table 2. Three demonstrations that use matchstick forest models

Experimental question	Potential hypotheses & explanations	Experimental setup
Demo. 1: How does slope affect fire spread?	Fires moving uphill tend to spread faster and burn more completely than fires moving downhill. **Explanation:** As heat moves uphill, it dries and warms the fuels above. In addition, flames are closer to uphill fuels than to fuels on level ground.	Use 49 matches/board. Lay 1 board flat. Set up 2 tilted boards using two long bolts (1 bolt in each board). Ignite by lighting a full row of matches along the edge of each board: • On flat board, ignite one side. • On one tilted board, ignite the top row. • On other tilted board, ignite the bottom row.
Use EITHER Demonstration 2A or 2B.		
Demo. 2A: How does density of a forest stand (or other standing fuels) affect fire spread?	Fires generally spread faster and combustion is more complete in dense stands than in more open stands. **Explanation:** Heat and flames are more likely to reach fuels that are close together, drying them out and igniting them.	Use long bolts (to create steep slopes) for all models. Use the following matchstick densities/board (see Figure E04-1: Setup of matches for Demonstration 2A) • 49 matches • 25 matches (50%), distributed evenly • 12 matches (25%), distributed evenly • 12 matches (25%) in clusters Ignite all boards from the bottom row.
Demo. 2B: How does tree density resulting from different fire histories affect fire spread?	Fires generally spread faster and combustion is more complete in dense forest stands, such as forests that have not burned in a long time, than in more open forests, such as stands that have been burned frequently. **Explanation:** Heat and flames are more likely to reach fuels that are close together, drying them out and igniting them. Frequent fires tend to reduce stand density by killing small trees and those of fire-sensitive species. Frequent fires also reduce fuels, both horizontally and vertically, so fires are not likely to be severe enough to kill most of the trees.	Use long bolts (to create steep slopes) for all models. A single board represents about 1/40 hectare, an area about 16 meters on a side. Use the following matchstick densities/board: • 49 matches to represent dense stands that have not burned in a century. • 25 matches to represent a forest that has experienced low- and moderate-severity fires, creating a forest with evenly spaced trees. • 5 matches, spaced far apart, to represent open-grown forests that have experienced frequent fires. • 12 matches, distributed in clusters, to represent forests that have experienced patches of both severe fire and low-severity fire. Ignite all boards from the bottom row.

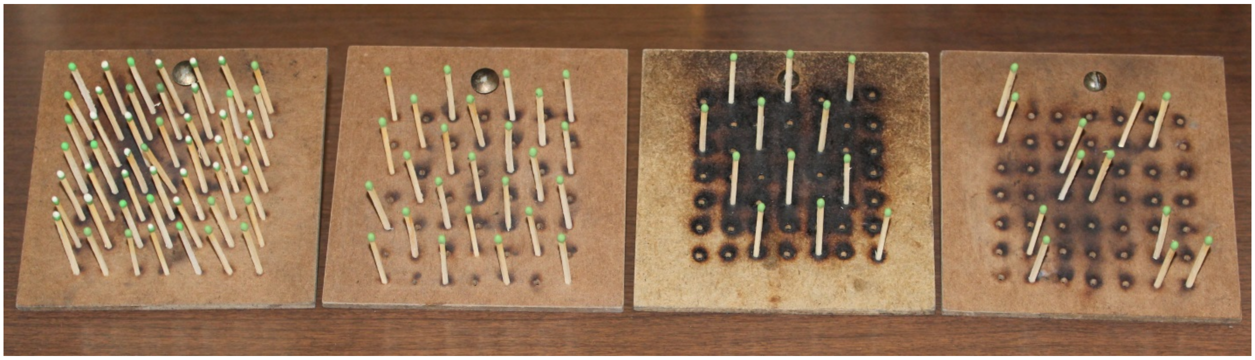


Figure E04-1: Setup of matches for Demonstration 2A.

Materials and preparation:
Do the two experiments as demonstrations. Students can help you set up the boards with the right number of matches. Ignite the matchstick forests one at a time from the bottom row of matches, so all students can observe all fires.

Choose your location carefully. If you burn indoors, be aware that the experiments can produce flames 30-40 centimeters long. Can you do this safely in your classroom and without setting off a smoke alarm? Can you take your students to a lab where it will be safer? If you burn outdoors, be prepared for variable results, since even very subtle breezes will change the fire spread pattern and may overwhelm the effects of slope and matchstick (stand) density.

- Download *E04_Downhill-UphillDiagram.pptx* to use in the assessment.
- Get plenty of wooden kitchen matches (not provided in the trunk). You will need at least 300.
- If you burn outside and it is windy, you may need to ignite with a lighter. It may be helpful to have 4-5 pieces of poster-board that students can hold at a safe distance to protect the flames from wind.
- Have fully-charged fire extinguisher handy.
- Set up your work station with this equipment (available in the trunk):
  - Two spray bottles. Fill them with water.
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 4 masonite ("matchstick forest") boards from the matchstick forest kit
  - Nuts and bolts from the matchstick forest kit
  - 1 pair of safety goggles
  - *FireWorks* safety poster
- Have a *metal* trash can *without a plastic liner* nearby.
- Stop watch or clock with a second hand.

Procedure:

1. Do a **safety checkup** with students using the *FireWorks safety* poster.
2. Explain a *crown fire*: A fire that moves from tree top to tree top.
3. Show students the matchstick forest model (masonite board, nuts and bolts). The board represents the ground surface; each match represents a tree or other standing fuel; the match tips represent tree crowns or other flammable fuels at the top of the standing fuel. Discuss the variables that can be investigated with this model.
4. Discuss experimental design with the class, including the principle of changing only one variable at a time to figure out cause-and-effect. Note that you'll change only slope in Demonstration 1 and only matchstick density in Demonstration 2.

Demonstration 1 (see Table 2 above for set-up and instructions).

5. Explain: A testable prediction or guess is called a hypothesis. Ask students to offer hypotheses – that is, to predict what will happen – when each board is burned. They may have several hypotheses. Write them all on the board.
6. Assign a student to record the start time and end time of each burn. Make sure a clock showing seconds is available or have the timer use a stopwatch. (If you have a stopwatch, you don't need the "Start time" and "End time" columns in the table below.)
7. Copy this table on the board:

Slope	Start time	End time	Duration (seconds)	Matches burned (tree crowns)
1. Flat				
2. Steep – burning downhill				
3. Steep – burning uphill				

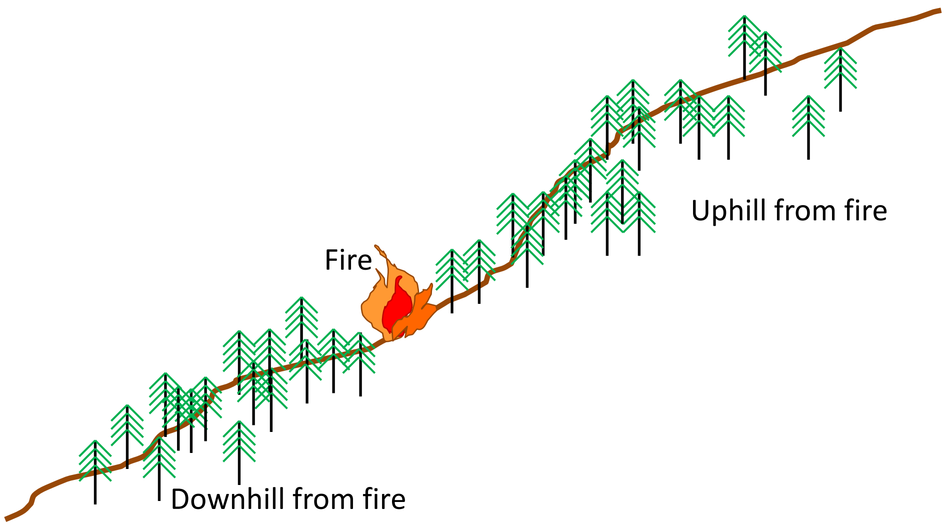
8. Refer to Table 2 for further instructions.
9. Dispose of burned matches in the ashtray or on the metal tray.
10. After all of three matchstick forests have burned, calculate the fire duration for each. Discuss the results. Were their hypotheses correct? Ask students to describe how the fire moved through the "tree crowns" or match heads.

Demonstration 2A or 2B (see Table 2 above for set-up and instructions). 2A focuses on the general concept of matchstick (stand) density, while 2B focuses on tree densities resulting from different fire histories.

11. Ask for hypotheses and write them on the board.

12. Change the first column of the table on the board to reflect the three matchstick densities you will use (Table 2, Demo 2A or 2B).
13. Ignite the matchstick forests one at a time, always by igniting the bottom row of matches.
14. After all boards have burned, calculate the fire duration for each. Discuss how the fire moved through the "tree crowns" (match heads).
15. Discuss the results. Were their hypotheses correct?
16. **Clean up:** Use a metal trash can without a plastic liner. If in doubt whether fire is out, dump materials in a bucket of water before putting them in the trash.

Assessment: Project *E04_Downhill-UphillDiagram.pptx* or sketch something like it on the board. Have students explain in writing or by drawing what direction the fire would be most likely to spread and what part of the forest would be most likely to have crown fire. Have them use complete sentences to explain why.



Evaluation:
Full Credit: Student indicated that the fire is more likely to spread uphill and crown on the hillside above the flames than on flat land or below the flames. Student indicated in complete sentence(s) that trees on the slope are dried and heated by the rising heat plume, and/or fuels are closer to the flames, and/or trees are most dense on the steep section above the flame. If the student suggested that cross-slope or down-slope winds could overwhelm the effects of slope or that embers rolling downhill could start a fast-moving fire below, those answers are also valid.
Partial Credit: Student indicated that fire is likely to crown uphill from the flames.
Less than Partial Credit: Student indicated that the fire is likely to spread faster on a flat area or downhill, and/or student did not indicate understanding of how slope affects fire spread and potential for crowning.

5. Fuel Properties: The Campfire Challenge

Lesson Overview: In this activity, students explore how different properties of fuels affect fire behavior – especially how hard it is to ignite fuels and how long they are likely to burn. Students consider various combinations of fuels (“fuel recipes”), predict how they will burn, then test their hypotheses.

Lesson Goal: Increase students’ understanding of fuel properties and how they affect fire spread and fire duration.

Subjects: Science, Reading, Writing, Speaking and Listening, Health and Safety

Duration: One half-hour session

Group size: Teams of 3-4

Setting: Outdoors or laboratory with good ventilation

New FireWorks vocabulary: *fuel moisture, ladder fuels*

Objectives:

- Students can select and arrange fuels to build a small campfire that will be easy to ignite and burn a relatively long time.
- Students can explain how fuel properties affect fire spread and fire duration.

Standards:		1st	2nd	3rd	4th	5th
CCSS	Reading: Informational Texts	10	10	10	10	10
	Reading: Foundational Skills	4	4	4	4	4
	Writing	1,8	1,8	1,8,10	1,8,10	1,8,10
	Speaking and Listening	2,3,6	2,3,4,6	3,4,6	3,4,6	3,4,6
	Language	1,2	1,2,3	1,2,3	1,2,3	1,2,3
NGSS	Structures and Property of Matter		PS1.B		ETS1.B	ETS1.A,B,C
EEEGL	Strand 1	A,B,C,D				A,B,C,D

Teacher Background: Anyone who has built a campfire knows that you have to choose your fuels wisely and arrange them carefully. Four fuel properties influence fire behavior: amount, size, moisture content, and spatial arrangement. These properties determine how flames heat the fuels and how much oxygen is in contact with them, and thus how quickly they will ignite and how long they will burn:

- All other conditions being equal, larger amounts of fuel will produce the most heat. Whether they burn quickly or slowly, however, depends on their moisture, size and arrangement.
- Small particles tend to ignite more easily than large particles because they have more surface area (per volume) exposed to heat and oxygen. (Interesting exceptions to this guideline are explored in the High School curriculum, Activity H07.) Large fuels, once ignited, usually burn longer than small ones.

- It is more difficult to ignite moist fuels than dry ones; they also burn more slowly, make more smoke, and tend to burn less completely.
- Spatial arrangement of fuels is complex: If they are packed so tightly that oxygen isn't available, they won't ignite; if they are so far apart that heat from one particle can't reach the next, they won't ignite.

In this activity, students are assigned specific recipes for the fuels for a campfire. Some of the recipes will be very hard to ignite, some easier; some have the potential to burn for a long time; some will burn out quickly. They also get 7 matches, which can be put into the fuel mixture if they wish – but they must keep at least 1 for lighting the campfire. The students will make hypotheses about how their fuel recipes will burn. Then they will arrange the fuels to burn as well as they can, and then they will test their fuel arrangements – and thus their hypotheses.

Materials and preparation:
This activity is best done outdoors because it can be messy and smoky. However, do not do it outdoors on a windy day. Select a place far from dry grass, bark chips, and other fuels. Have a bucket of water and a hose available, with the water turned on. The student teams will be using matches, although your or another adult will actually light the fires. For safety's sake, ask a parent or other volunteer(s) to help.

If you do this activity indoors, use a laboratory with good ventilation.

- At least two days ahead of time, obtain enough of these dead fuels to do the activity—that is, about a dozen "handfuls" of each:
  - dead conifer needles
  - small twigs (less than 0.5 centimeter in diameter)
  - large sticks (about 2-3 centimeters in diameter)

  Spread them out in a dry place so they are uniformly dry by the time you use them.
- The day before you do the activity, remind students to dress appropriately for burning. Post and refer to the FireWorks Safety poster.

FireWorks Safety

When you do experiments with fire…

1. **Wear cotton clothing. No synthetic pants, soccer shorts, etc.**
2. **Wear closed-toed shoes. No sandals or flipflops.**
3. **Tie back loose sleeves.**
4. **Tie back loose hair.**
5. **Make sure a fire extinguisher is close. Make sure it is charged. Know how to use it.**
6. **Make sure spray bottles are close and filled with water.**
7. **Wear safety goggles when burning.**
8. ***Never* lean over a fire.**
9. **Extinguish burned materials with water before putting them in the trash. *Fire is not out if there is any smoke or heat coming from the fuels.***
10. **If a fire starts on you, stop, drop, and roll.**

Use fire ONLY if a responsible adult is working with you.

- The day before you do the activity, collect enough green conifer needles to do the activity.

- Copy the ingredients for the fuel recipes onto the board (or a poster, if you plan to do the activity outdoors).

Recipe	Ingredients
1	Small twigs Big sticks
2	Big sticks Green conifer needles
3	Dead, dry conifer needles Big sticks
4	Dead, dry conifer needles Small twigs

- Set up your teacher area with:
  - The Fuel Recipe box. Be sure to select the recipes labeled "E" for Elementary students.
  - 4 grocery bags or boxes containing fuels (dead, dry conifer needles; small twigs (<0.5 cm); big sticks (2-3 cm); green needles). Label the bags. You can use the tie-on labels in the trunk. If there's a label for "duff," ignore it.
  - Fire extinguisher
  - 2 spray bottles, filled with water
  - Other water (bucket, charged hose, etc.) to ensure you can easily put a fire out
- Set up student work stations. Four work stations work well (1 station/recipe), but you can have more stations and repeat recipes. Each station needs:
  - One 9" diameter aluminum pie tin with tilted edges
  - 1 metal tray (i.e., cookie sheet) can be used beneath the pie tin, if desired
  - 1 match box with **7 matches** (not in trunk)
  - 1 ashtray
  - 1 pair of safety goggles
  - 1 oven mitt
- Have a *metal* trash can *without a plastic liner* available.
  - Decide whether you will project *E05_ Photos_FuelProperties.pptx* for the assessment or provide a copy for each student. Make copies if necessary.

Procedures:

1. Explain: Students will work in teams to build small "campfires," but they don't get to choose their own fuels. They will use specific combinations of fuels. The experimental questions are:
   - What kinds of fuels are easiest to start on fire ("ignite")?
   - What kinds of fuels burn longest?
2. Using the recipes listed on the board, ask students to "vote" on:
   - which will be <u>easiest</u> to start on fire
   - which will be <u>hardest</u> to start on fire
3. Then have them vote on:
   - which will burn out in the <u>shortest</u> time
   - which will burn <u>longest</u>

   Record their votes on the board. Explain: These are their hypotheses.
4. Do a **safety checkup** with students using the *FireWorks Safety* poster. Remind students of the item on the poster that says they should <u>never lean over a burning fire</u>.
5. Group students into teams (4 teams works well).
6. Explain the procedure. <u>The whole team is responsible for safety. If any student is hurt, the team must alert the teacher and use water to put out their campfire immediately.</u> Each team will:
   a. Draw a recipe from the Recipe Box.
   b. Collect the two ingredients on their recipe from the labeled ingredient bags. Fuels are "measured" by the "handful," which is subjective, but the point is to use about the same amount of each fuel in a campfire.
   c. Discuss and work together to arrange the fuels. The goal is to make the fuels ignite as easily as possible and burn as completely as possible. The fuels must fit inside the pie tin; they may not spill over the sides. The 7 matches may be used within the fuels or to ignite them. Obviously, at least 1 match will be needed for ignition.
   d. Have a teacher or other adult verify that they have met the requirements. Answer any questions. Explain that, after ignition, the team <u>may not</u> rearrange the fuels, but they <u>may</u> blow on the fire.
7. Have yourself or another adult light the match(es) for each team. If you have 1 adult per team, all teams can ignite at the same time. If not, ignite the fires one at a time so you can supervise. After ignition, monitor progress and watch for safe practices. Dispose of burned matches in the ashtray or on the metal tray.

8. After all teams have either burned all their fuels or used all their matches, have each team explain to the class their strategy for arranging fuels and how they might do it differently the next time. Note that some campfires may still be burning.

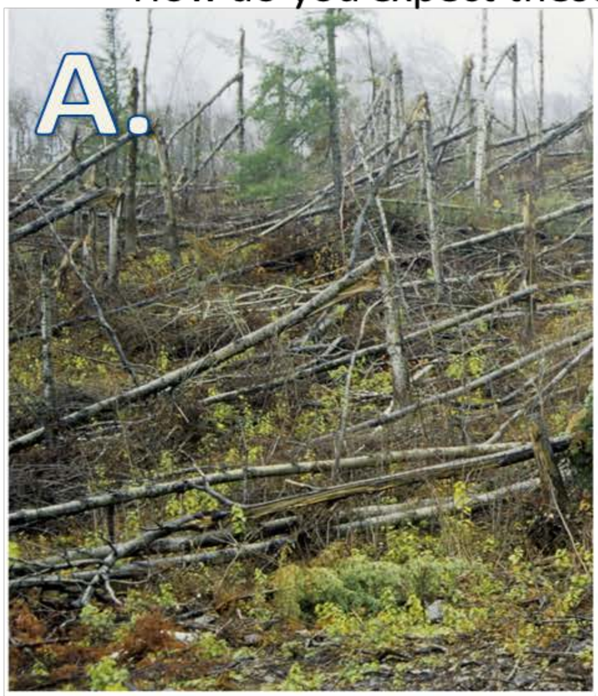
9. Discuss the four hypotheses with the class. Which ones were verified by the experimental campfires? Include these concepts in the discussion: heat transfer, the Fire Triangle, and the four fuel properties that influence fire behavior (amount, size, moisture content, and spatial arrangement).

    - *How much fuel is there*? The more fuel, the longer your fire can burn and the more heat it can produce… if you can get the fuels to ignite.
    - *Fuel particle size. Fine fuels* – that is, small pieces – are usually easiest to ignite (if they are dry, of course), because even a small heat plume can surround them and heat them up fast. But because they are small, they burn up quickly. *Large fuels* tend to burn slowly because it takes time for the outside surface to burn away, exposing new layers to oxygen and heat.
    - *Moisture* makes fuels hard to ignite and also makes them burn slowly. This is because the moisture must be removed before a particle can be heated to ignition temperature.
    - *Spatial arrangement*
        - The *fluffiness* of fuels determines how easily heat and oxygen can reach the fuels. An important skill in building a campfire is to get the spatial arrangement of fuels "just right" so lots of heat and oxygen are available to the unburned fuels. Fuels have to be sort of <u>near each other</u> for fire to spread from one piece to another. For example, if you crumple up 20 pieces of newspaper and scatter them across a large room, a fire cannot spread from one piece to another. But the pieces can also be <u>too tightly</u> packed for heat and oxygen to disperse among them. For example, a tightly piled stack of newspapers will be hard to start on fire. (Once started, however, that pile of newspapers could smolder for a long time.)
        - *Vertical arrangement:* A clever campfire builder takes advantage of heat's tendency to rise by putting easily-ignitable fuels beneath those that are hard to ignite. That is, we place small ("fine") fuels, which we call kindling, near the bottom of the fuel bed and then place layers of large ("coarse") fuels directly above. This principle also applies in forests: If the gaps between surface fuels and tree crowns are large, a fire cannot get from the surface fuels into the tree crowns. If the gaps are small – if the surface litter and grass are connected with shrubs and saplings, and these are connected with the lowest branches of the trees – then fire can climb up these *ladder fuels* and reach the crowns.

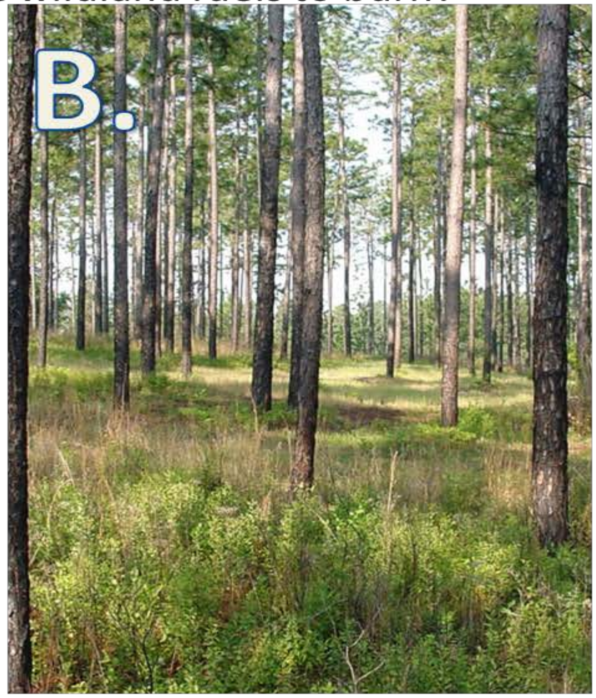
10. **Clean up:** Make sure all burned materials and matches are out before you dispose of them – that is, there is no smoke and no heat being released. Use oven mitts if the pie tins are still hot. Use an empty metal trash can without a plastic liner. If in doubt, dump fuels into a bucket of water before putting them in the trash.

Assessment: Project *E05_ Photos_FuelProperties.pptx* or provide a copy to each student:

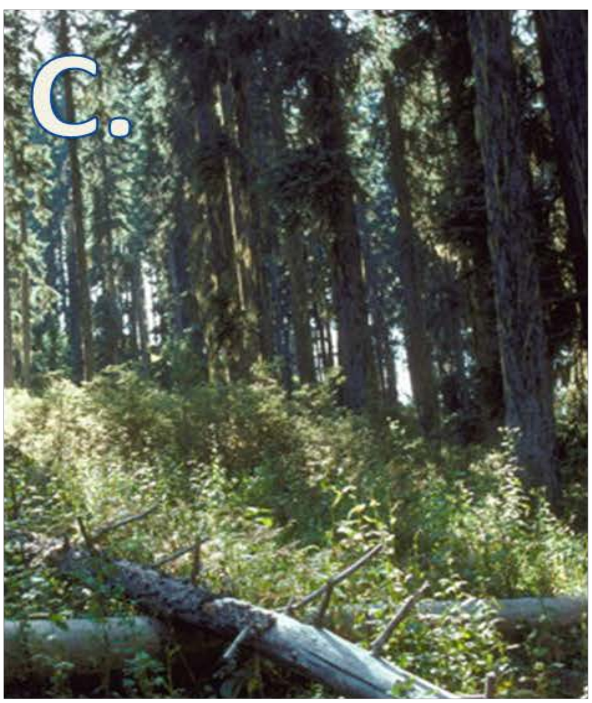
How do you expect these wildland fuels to burn?



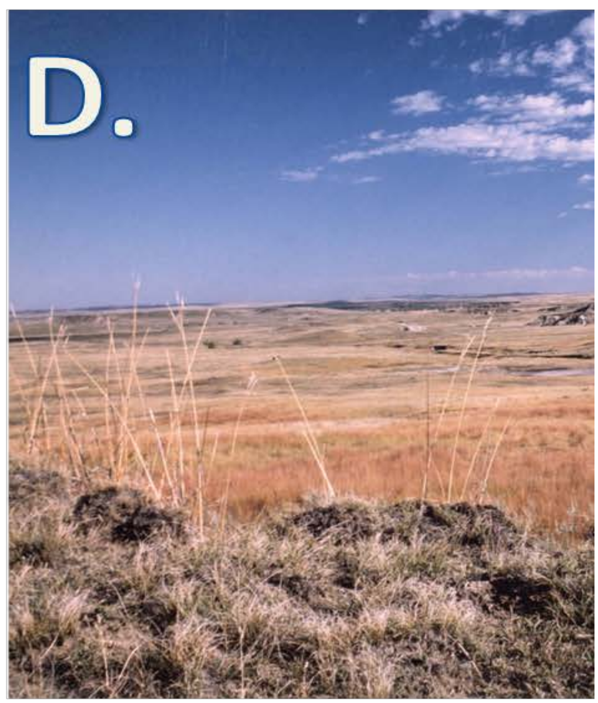
Fallen trees after a wind storm, Superior National Forest, MN. USDA Forest Service photo by Joseph O'Brien, Bugwood.org.



Longleaf pine forest, Georgia. Photo by Chuck Bargeron, University of Georgia, Bugwood.org.



Forest of grand fir and other species, Idaho. USDA Forest Service photo by Dave Powell, Bugwood.org.



Medora Landscape, Dakota Prairie Grasslands. USDA Forest Service photo.

Explain: Each of these wildland sites has different kinds of fuels (amount, moisture, size, and fluffiness). Discuss the questions below as a class. Then have students either answer the questions in writing or answer/explain together in pairs:

1. Which place will start on fire most easily? Use at least one fuel property to explain why.
2. If the weather has been hot and dry for a long time, which place will burn longest? Use at least one fuel property to explain why.
3. **Optional challenge question**: If it gets dry enough for a surface fire to spread under the trees in photos B and C, which site is most likely to have a crown fire?

Evaluation:	**Full Credit**	**Partial Credit**	**Less than Partial Credit**
Question #1	”D” will ignite most easily because it has a lot of fine fuels. It is also the only site that has a lot of dry fuels.	”D” will ignite most easily. Explanation addresses only one fuel property.	“D” is not mentioned. Response does not indicate student understands how fuel properties affect ignition.
Question #2	”A” or “C” will burn longest. (Either answer is valid.) Both of these have a lot of large fuels. Fuel moisture does not apply to this question because it states “If the weather has been hot and dry for a long time…”	”A” or “C” will burn longest. Explanation addresses the amount or size of fuels.	Neither “A” nor “C” is mentioned. Response does not indicate student understands how fuel properties affect fire duration.
Question #3. Optional challenge question	“C” is more likely to have crown fire because the surface fuels are more continuous from ground to crowns – that is, there are more ladder fuels.	“C” is more likely to have crown fire, but continuous vertical fuels/ladder fuels are not mentioned.	“C” is not mentioned. Response does not indicate student understands how fuel properties affect potential for crown fire.

Extension: Ask each student to write down his or her favorite three ingredients for a successful campfire. In another class period, have students select a handful of each of their favorite ingredients and build a campfire that ignites easily and burns long.

6. Effect of Wind: How Wildland Fires Spread

Lesson Overview: In this activity, students participate in a human model that shows how wind affects fire spread.

Lesson Goal: Increase students' understanding of wildland fire spread as affected by weather.

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

Duration: One half-hour session

Group size: Whole class

Setting: Indoors or outdoors

New FireWorks vocabulary: *backing fire, downwind, head fire*

Objectives:

- Students can participate in a physical model of a forest (or other standing fuels).
- Students can use the Fire Triangle to explain how wind affects fire spread.

Standards:		1st	2nd	3rd	4th	5th
CCSS--ELA	Writing	7,8	7,8	7,8,10	7,8,10	7,8,10
	Speaking and Listening	2,6	2,6	4,6	4,6	4,6
	Language	1,2	1,2	1,2	1,2	1,2
EEEGL	Strand 1	A,B,C,E,F,G				A,B,C,E,F,G
NGSS	Weather and Climate			ESS2.D, ESS3.B		
	Earth's Systems: Processes that Shape the Earth				ESS3.B	

Teacher Background: Weather has a profound influence on wildland fire. Air temperature, the amount of moisture in the air (measured as relative humidity), short- and long-term precipitation, and wind are all important. Wind is the most difficult of these to predict and the one most likely to change erratically during a fire. In this activity, students create a physical model that shows how wind affects fire spread.

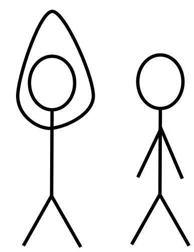
Students learned in Activity 3 that most of the heat from a fire tends to go upward. They called this the *heat plume.* Hot gases rise because they are less dense than the surrounding air, and air at the ground is usually denser than that above it due to gravity. A gust of wind is like a bubble of dense air. It bends the heat plume so it is no longer vertical but instead leans over - toward whatever fuels lie downwind. Wind also bends flames so they are more likely to touch the downwind fuels. For these reasons, fires tend to spread more rapidly <u>with</u> the wind than <u>against</u> it or <u>in still air</u>.

When the wind is blowing uphill, it adds to the effect of slope and accelerates fire spread. When the wind is blowing crosswise or downhill, its effects are harder to predict. A fire burning uphill or with the wind is called a *head fire*; a fire burning against these influences is a *backing fire*. Of course, even if slope and wind favor a fast-spreading head fire, the fuels may be too far apart to sustain combustion, as the students observed in Activity 4 (“matchstick forest”), when they observed boards with 49 matches vs. boards with only 12 matches on them.

Materials and preparation:
None

Procedure:

1. Show students that each of them can “model” the heat plume. If you pretend that your head is a match tip – or the crown of a tree or other standing fuel, then you can show the shape of a heat plume by clasping your hands together high above your head. Your shoulders, arms, and hands represent the outside of the heat plume. A little heat is going down and to the sides, while a lot of it is going up. Ask the students to imitate you – so each of them becomes a model of a heat plume. When standing with their hands at their sides, they can be models of trees (or other standing fuels); their heads represent the tree crowns.



2. Have students line up side by side in a straight line with their arms at their sides, about half an arm’s length apart. Have the “tree” at the far end of the line stand 2-3 arms’ lengths away from its nearest neighbor. Select 2-3 students from the near end of the line to help you in the next step. Explain: The students in the line are modeling a dense forest stand. It is not on fire, so they should keep their hands at their sides.

3. Have the class make the sounds for a crash of lightning and a loud rumble of thunder. Tell the “tree” at the near end of the line that he or she has been struck by lightning and fire has run up the trunk into the tree crown. Ask: How does that look? (The student should now model a heat plume – hands clasped above his/her head.) Point out that the heat plume does not reach the next student in line, so the fire is not spreading.

4. Now have your helper students act out a gust of wind coming up to the “burning tree” at the near end of the line. Include sound effects, waving arms, etc.

5. Have the “burning tree” show that the wind bends its heat plume over so it reaches the next “tree” – which is ignited. The wind stays strong, so the next and the next are ignited too. It is an active crown fire (a term that they learned about in Activity 4). Continue this pattern until the “fire” ignites the second-last tree. Can that tree bend its heat plume enough to ignite the last one? If not, this part of the forest is too open for crown fire to spread, and the fire stops.

6. Ask: Use the Fire Triangle to explain how the wind in this forest model changed the fire behavior. The wind pushed the heat from a burning tree toward its neighbor tree, making it hot enough to ignite. A gust of wind is like a big bubble of dense air, so the wind also increased the amount of oxygen reaching the fuels.

7. Ask: Do you think the effects of wind on fire are similar to the effects of slope, which we looked at with the matchstick forests in Activity 4? Wind and slope both put the flames closer to fuels on one side (uphill/downwind), so they heat up faster and ignite more easily than fuels on the other side. If there is no fuel on that uphill/downwind side, of course, the fire cannot spread in that direction.

Assessment: Ask students to write answers to these 2 questions:

1. Why do you blow on a campfire to make it burn better? Use 2 parts of the Fire Triangle to explain. You blow on a campfire to push the heat and flames into the unburned fuels.
2. Why do you blow on a candle to put the flame out? Use 2 parts of the Fire Triangle to explain. You blow on a candle to push the heat away from the fuel (melted wax in the candle wick).

   If the student uses oxygen in his/her explanation, evaluation is more complicated; he/she should receive credit for identifying any part of this explanation:

   - Because your breath is denser than the air around you, it might be increasing the oxygen available to the fire.
   - However, your exhaled breath contains only about 2/3 as much oxygen as the air around you, so you might not be increasing the oxygen available after all.
   - Furthermore, your breath is probably moister than the surrounding air, so you would be increasing the humidity around the fire, and – since the moisture absorbs some of the heat - that would make the fuels harder to burn.

Evaluation:	**Full Credit**	**Partial Credit**	**Less than Partial Credit**
	Uses 2 components of Fire Triangle correctly.	Uses 1 component of Fire Triangle correctly.	Uses 0 components of Fire Triangle correctly.

Unit IV.
Fire Effects on the Environment

Unit IV brings students' attention to the effects of wildland fires on non-living parts of the ecosystem. The Elementary curriculum covers fire effects on air quality and human health. If you want to address fire effects on soil and water, consider using **Activity 10 in the Middle School** curriculum or **Activity 12 in the High School** curriculum.

2010 Eagle Trail Fire, Tok, AK, by Larry Walsh (inciweb.nwcg.gov)

7. Smoke from Wildland Fire: Just Hanging Around?

Lesson Overview: In this activity, students learn that smoke from wildland fires can either disperse readily or stick around, reducing visibility on the earth's surface and making it difficult to breathe. Then they apply health guidelines regarding smoke to a very important question: Can Physical Education (PE) Class proceed with the scheduled 1-km run, or do we need to change plans?

Lesson Goal: Increase students' understanding of smoke from wildland fires and its potential effects on human health.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Social Studies, Health Enhancement

Duration: One half-hour session

Group size: Entire class

Setting: Classroom

New FireWorks vocabulary: *particulate matter, smoke, visibility*

Objectives:

- Students can use information about air quality and visibility to recommend measures for protecting their own respiratory health and that of others.

Standards:		1st	2nd	3rd	4th	5th
CCSS	Speaking and Listening	1,2,3,4,6	1,2,3,4,6	1,2,3,4,6	1,2,3,4,6	1,2,3,4,6
	Language	1,2,6	1,2,6	1,2,6	1,2,6	1,2,6
NGSS	Weather and Climate			ESS3.B, ESS2.D		
	Earth's Systems: Processes that Shape Earth				ESS3.B	ESS3.C
EEEGL	Strand 1	E,F,G				E,F,G

Teacher Background: There's no wildland fire without smoke, but the amount of smoke produced and the ways in which it disperses differ from one fire to another and even from one time to another on a single fire. If the smoke disperses upward rapidly, high-altitude winds will scatter it downwind, and the only noticeable result may be the beautiful, orange-tinged sunrise and sunset colors produced by particles in the air. However, if the smoke is trapped near the fire (by an inversion), it can make the air difficult to breathe and even difficult to see through. Smoke then becomes a health hazard, especially for anyone who has asthma or other respiratory illness, and for anyone engaging in strenuous exercise.

In this activity, students learn that smoke can disperse readily or be trapped by an inversion and why this matters. Then they use data on visibility to decide if smoke from a wildland fire may be hazardous to their health.

On most summer days, sunlight warms the earth's surface each morning, and the air lying on the earth's surface is heated too. This warming, expanding air rises, and its temperature decreases due to the expansion. If the air is dry, the temperature falls about 1°C for every 100-meter rise in altitude. As a result of this natural cooling, mountain tops tend to remain much cooler than valleys even on hot summer days. Because the air is constantly moving and mixing under these circumstances, we call it unstable.

Sometimes the sun doesn't warm the earth's surface very much during the day. Perhaps the earth is covered with snow that reflects the sunlight instead of absorbing its energy. Perhaps the cloud cover or the smoke layer from a fire is too dense to let sunlight through. When this happens, a warm layer of air rests on top of the cold air. The warm air traps the cold air on the earth's surface. This is called an inversion because the normal daytime pattern (warm air on the bottom, cool air on top) is upside-down. The blanket of warm air lying on top of the cold air is called the inversion layer. During an inversion, the cold surface air is very stable. It cannot be dislodged until it is heated or stirred up by wind.

During an inversion, dust and other particulates in the air are trapped in the cold air at the earth's surface. Inversions during wildland fires trap smoke. Sometimes it is so dense that you can't see very far and the streetlights come on in the middle of the day. This much smoke interferes with breathing and is actually dangerous for babies and anyone with asthma or other respiratory illnesses. It is a good idea to limit aerobic activities and even to stay indoors until the air quality improves.

NOTE: This activity does not discuss inversions and how they form. If you are interested in presenting that information and demonstrating an inversion, see **Middle School Lesson M09.**

Materials and preparation:

- Download *E07_smoke_slides.pptx*
- Print 1 copy/student of **Handout E07-1:WhatWillWeDoWithPEClass?**

Procedures:

1. Ask students: What is smoke? Smoke consists of water, gases, and tiny particles of unburned and partially burned fuels. These are called *particulates* or *particulate matter*. The particulates are light enough to circulate in the atmosphere instead of settling immediately to earth, as larger particles do.
2. Project *E07_smoke_slides.pptx.* Use the handout and narrative shown at the end of this activity.
    - Slides 1-4 illustrate where smoke goes and how it can hang around for days or even weeks.

- Slides 5-10 illustrate the effect of smoke on visibility. They show a single viewpoint with different amounts of smoke.
    - Slide 5 explains the metric used to measure air quality: micrograms/cubic meter ($\mu g/m^3$), the weight of smoke particulates of a certain size (and smaller) in a specific volume of air. PM10 is the weight of particulates 10 micrometers across and smaller. PM2.5 is the weight of particulates 2.5 micrometers across and smaller.
    - Slide 10 is a summary of slides 5-9. It shows the changes in visibility with 5 vs. 90 $\mu g/m^3$ of PM10.

3. Ask: How does smoke affect us? Smoke reduces visibility, as the photos showed. Smoke also makes it harder to breathe as the particles get stuck inside our lungs. The particles interfere with our ability to absorb oxygen and release carbon dioxide.
4. Explain: Medical experts have provided guidelines for outdoor recreation to help us protect our lungs from smoke. Give each student a copy of **Handout E07-1: What Will We Do with PE Class?**
5. Go back to Slides 7-9. For each photo, use the handout to decide together what to do with PE class: Are these conditions OK for a soccer match? for a 1-km run? for a basketball game? How about volleyball – indoors or outdoors? If a student has asthma, should he/she have additional restrictions?

Assessment: Instruct the students:

1. Pair off. One of you be the school nurse, the other be the Physical Education (PE) teacher. There have been some large fires in your area recently. You look out the window, and you see that the air is smoky. You can just barely see the top of a hill 4 miles away. You had planned to have your PE class do a timed 1-km run today, but now you are not sure you should do that. Talk the situation over, use the handout, and decide what to do about PE class. Make sure your plan will take care of 3 students who have asthma.
2. Together, report to the class. Answer these questions:
    - What kinds of activities does the handout recommend for the amount of smoke in the air today?
    - What will you do in PE class today and why? If you are not going to do the scheduled 1-km run, what activities will you do instead?
    - Do you have special instructions for the students who have asthma?

Evaluation:

Full Credit	Partial Credit	Less than Partial Credit
-The student pair used information on handout to explain that visibility of four miles fits in the **unhealthy** health effect category. -The pair decided to postpone or cancel the 1-km run because it is a high-exertion activity. -The pair chose an appropriate alternative activity* -If they chose an outdoor activity, they provided an indoor alternative for students who have asthma.	The student pair makes one or two of the following errors: -used the wrong health effect category or did not show understanding of health effects of smoke. -chose inappropriate activity for the health effect category chosen -If the pair chose an outdoor activity, they did not provide an indoor alternative for students with asthma.	-The student pair did not use recommendations from handout or did not show understanding of health effects of smoke. -The pair did not choose an appropriate activity. -If they chose an outdoor activity, they did not choose an appropriate activity for asthmatic students.

*Appropriate activities:

- If outdoors, the activities should be low-exertion and possibly short in duration. This might be an opportunity to practice kicks and footwork in soccer, pitching/batting in softball, etc. It is difficult to assess what the handout means by “prolonged periods of time,” but a 40- to 60-minute PE class is probably acceptable. However, asthmatic students cannot participate outdoors.
- If indoors, can be high-exertion and use the whole class period, and asthmatic students can participate. However, it might be good to err on the side of caution, since indoor air can become quite polluted when outdoor smoke concentrations are high.
- A classroom lesson or activity, perhaps something related to health or diet, might be a good alternative – especially if the gym is not available.

Handout E07-1: What Will We Do with PE Class?

Decision making recommendations during wildfire season for

Outdoor Sporting Events

based on visibility and air quality

Health Effect Category*	Visibility*	Recommendation
Good	13.4 miles and up	Hold outdoor sporting events as usual. Athletes with asthma should keep rescue inhalers at hand. Athletes with other smoke related sensitivities should take precautions as symptoms dictate.
Moderate/ Unhealthy for Sensitive Groups	5.1 to 13.3 miles	Hold outdoor sporting events as usual. Athletes with asthma should have rescue inhalers readily available and pretreat before exercise as directed by their healthcare provider. All athletes with respiratory illness should limit outdoor activity, monitor symptoms and reduce/cease activity if symptoms arise.
Unhealthy	2.2 to 5.0 miles	Consider postponing/delaying outdoor sporting events, especially high exertion activities like soccer and track and field. If possible, move athletic practices indoors. If event/practice is held, athletes with asthma or other respiratory illnesses are advised not to participate. All athletes should limit their outdoor activity for prolonged periods of time.
Very Unhealthy	1.3 to 2.1 miles	Consider postponing/delaying all outdoor sporting events. Move all athletic practices indoors. All athletes with asthma and other respiratory illnesses are advised to stay indoors. All others should avoid prolonged exertion outdoors.
Hazardous	1.3 miles or less	Cancel all outdoor sporting events or relocate to an indoor location. Move all athletic practices indoors.
At all times, athletes experiencing respiratory symptoms should consult their personal healthcare provider		

*Visibility: How far can you see? To figure this out:

1. Face away from the sun.
2. Look for landmarks at a known distance from you.
3. If you can't see a landmark, then you know that visibility is less than that distance.

Source: http://www.missoulacounty.us/home/showdocument?id=5543

Slides and notes for *E07_smoke_slides.pptx*

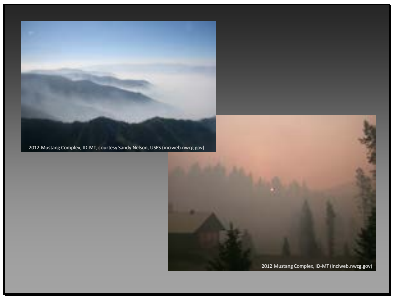
Slide 1

We’ve measured the shape of the heat plume from small fires, and we’ve watched the smoke from our classroom experimental fires. Here are photos of smoke from wildland fires. Where does the smoke usually go? (Up, and then in the same direction as the wind. It also stays around the base of the fire where it is being produced.)

Slide 2

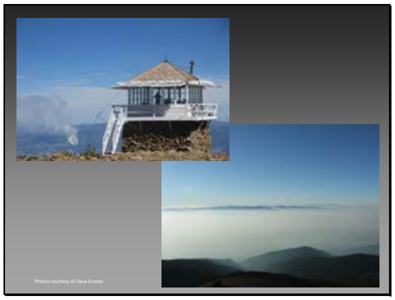
Smoke doesn’t just disappear into the air. Satellite photos show that it can travel a long way. Discussion: Use the 25-km scale on the left photo to figure out how wide the smoke plume is (50-75 km) and how far it has traveled (at least 300 km). Think of some towns or other landmarks that are that far away.

Slide 3



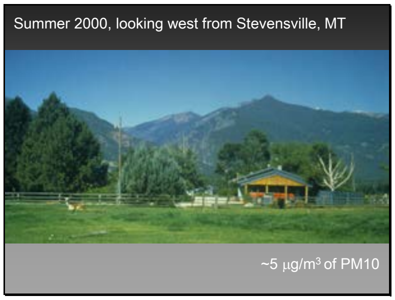
Smoke sometimes settles down near the ground and stays there for days or even weeks. This might be smoke from a fire nearby, or it could be smoke from fires hundreds of miles away.

Slide 4



Here are two contrasting views, looking eastward from St. Mary Lookout, Bitterroot National Forest, MT. Top: Summer 2013. Smoke disperses upward from a fire in the valley, then drifts northward. Bottom: Smoke has settled into the valley overnight. Now it keeps sunlight from reaching the valley floor, so the air above the smoke layer is warmer than in the valley. The smoke is trapped in the cold, heavy, dense valley air.

Slide 5



In the next few pictures, you can see what smoke does to visibility.

OPTIONAL INFO: What is that number at the bottom of the slide? It is a way of measuring the concentration of particulates in the air. It is read "micrograms per cubic meter of particles less than 10 micrometers in diameter."

Slide 6

Slide 7

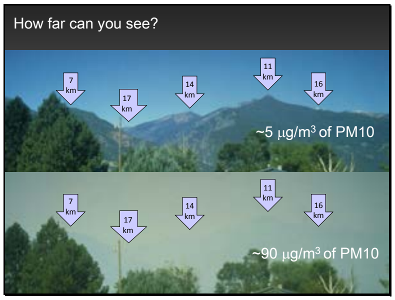
Slide 8

The farthest mountains have nearly disappeared.

Slide 9

Now the far mountains have completely disappeared, and the near ones are very hard to see.

Slide 10



The arrows show how far away the mountains and ridges are in clean air and unhealthy air.

Unit V. Fire's Relationship with Organisms and Communities

Having studied Units I-IV, students are now well informed about combustion, wildland fire behavior, fuels, and fire effects on nonliving parts of the ecosystem. In this unit, they will integrate their knowledge of fire with knowledge about living things, that is, specific organisms that live in montane ecosystems of the Sierra Nevada. They will learn about specific plants, animals, and fungi and the characteristics that help them survive fire or reproduce successfully after fire. They will learn to identify several tree species in the Sierra Nevada. And they will observe a demonstration of how fire can open the cones of a conifer species so it can release its seeds.

8. Who Lives Here?
Adopting a Plant, Animal, or Fungus

Overview: This activity introduces a suite of organisms that live in forests and shrublands (*chaparral*) of the Sierra Nevada. Each student "adopts" an organism, learns about its characteristics and its relationship to fire, and gives a 1- to 2-minute presentation on it to the class – complete with a mask, costume, or puppet (alternative ways to present the information: poster, computer presentation, written abstract).

Goal: Increase students' understanding of ecological communities and *biodiversity* by learning about some of the plants, animals, and fungi that live in forests and shrublands of the Sierra Nevada.

Subjects: Science, Reading, Speaking and Listening, Art

Duration: 1-2 class periods for student preparation, 1-2 minutes each for presentations

Group size: Whole class

Setting: Classroom

New FireWorks vocabulary: *biodiversity, chaparral, community, herb, kingdom, organism*

Objectives:

- Students can prepare a mask, costume, or puppet (or use other media) and then give a 1- to 2-minute presentation to the class that describes the biology of their "character" and its relationship to fire.
- Students can recognize several characteristics of organisms: their kingdom, family or life-form, way(s) of obtaining energy, and typical responses to fire.

ABOUT SCHEDULING PRESENTATIONS: It may be helpful to spread the student presentations over several class periods, 2-3 at a time. Make sure they are done by the time you start **Activity E14**, in which students learn about community dynamics and succession in a Sierra Nevada forest burned by wildland fire.

You may want to schedule the presentation on Baker cypress right before you do **Activity E11. Recipe for a Baker cypress grove**.

You may want to schedule the presentations about herbs, shrubs, and quaking aspen right before you do **Activity E12. Buried Treasure: Underground Parts that Help Plants Survive Fire**.

Standards:		1st	2nd	3rd	4th	5th
CCSS	Speaking/Listening	1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,6	1,4	1,4
	Reading	2,7	2,7	2,4,7	2,4,7	2,4,7
NGSS	Interdependent Relationships Ecosystems		LS2.A	LS2.C,D		
	Matter and Energy in Organisms and Ecosystems			LS4.D		LS2.A
EEEGL	Strand 1	E,F				E,F
	Strand 2.2	A, C,D				A, C, D

Teacher background: Different kinds of plants and animals have different needs. Some plants grow well only in sunny openings, for example, while some grow well in shade and others require special soil conditions or large amounts of water. Different species that live in the Sierra Nevada have different ways to live, grow, reproduce, survive fires, and thrive after fires. The traits ("adaptations") that help them persist in habitats that burn are sometimes specific to a certain kind of fire, so changes in the kinds of fire or the frequency of fire may make life difficult for the organism.
In this activity, students teach each other about some of the species that live in Sierra Nevada lower and upper montane forests and shrublands. Each student "adopts" a plant, animal, or fungus, prepares a mask, puppet, or costume, and presents his or her organism to the class (alternative ways to present the information: poster, computer presentation, written abstract). Students use the short essays in the Elementary-level *FireWorks Encyclopedia* to learn about their organisms. Each student presentation should address the organism's habitat, its sources of energy, and its ways to survive and/or thrive after fire.

Additional information is in the Middle School FireWorks Curriculum (**FireWorks Encyclopedia_Older grades.pdf**). Technical background is also available in the literature syntheses of the Fire Effects Information System (https://www.feis-crs.org/feis/).

Materials and Preparation:

- Decide how to assign species to students, one per student. You can let them choose or decide yourself ahead of time.
- Print 1 copy of **Table E08-1: Species assignments from the FireWorks Encyclopedia**. Use this list to record the species assigned to each student. The table contains 40 species; if you do not need that many, we suggest you start with those shown in bold print, because these are used in **Activity E14 – Story Time**, the story of succession and fire in Sierra Nevada montane communities.
- Elementary-level *FireWorks Encyclopedia* (**FireWorks Encyclopedia_Younger grades.pdf**) – either the looseleaf binder in the trunk, or electronic copies of pages for students to use
- Art supplies for masks, puppets, or costumes

Procedure:

1. Provide background by leading discussion:

   - A *community* is a group of living things that share something. We talk about being "members of a community." What communities are we members of? (Our family, our class, our school, our town, our county; perhaps a neighborhood, sports team, club, or church)

   - Not all of members of these communities are people. What other *organisms* (plants, animals, fungi, micro-organisms) live in our communities? (Pets, farm animals, house plants, garden and farm plants, insects, spiders, earthworms, "germs"…) There's a lot of *biodiversity* (variety of species) in human communities!

   - Wildlands have communities too – all the living things that live in a certain kind of habitat. Can you think of some *organisms* that live in the wildland communities of our mountains, the Sierra Nevada?

   - We're going to learn about some members of the Sierra Nevada communities and their relationships with fire. We'll only learn about a few of them though. There's a lot of *biodiversity* in our wildlands. In all of California, there are about 6,000 species of plants, 200 species of mammals, and 540 species of birds. And that doesn't even include insects, fungi, or micro-organisms!

2. Explain the assignment: Each student will "adopt" an organism that lives in forests or shrublands of the Sierra Nevada. He or she will:

   - Learn about the organism from the essay in the elementary-level *FireWorks Encyclopedia.*

   - Prepare a mask, costume, or puppet to use in a short presentation to teach the class about the organism (alternative ways to present the information: poster, computer presentation, written abstract).

   - Give a 1- to 2-minute presentation on the organism that includes a basic description of the organism and its needs, what its habitat is like, the kind(s) of fire that occur there, and how it deals with fire.

Assessment: Have students give their 1-2 minute presentations to the class. After all presentations, have students remain "in character" with their mask, costume, or puppet for the **"Walk Your Talk**" **activity** (below). Solutions for each prompt in the activity are listed in **Table E08-02** below.

Explain to students: We'll review all of our organisms using a **"Walk Your Talk"** activity. I'll ask you to move to a special place or step forward, depending the answers to my prompts.

Walk Your talk – what kingdom are you in?

1. Explain: Living things are grouped according to their *kingdoms.* We have been studying organisms in three kingdoms – plants, animals, and fungi. (Designate a space in the classroom for each kingdom.) Everyone, go to your kingdom!

Walk your talk - what kind of organism are you? (After each prompt below, go through the following types of organisms. Have each "organism" announce his/her species name, and have the rest of the class repeat it out loud. When all have finished, have those organisms step back.)

2. Mammals, take 2 steps forward[1].
3. Birds, take 2 steps forward.
4. Insects, take 2 steps forward.
5. Amphibians, take 2 steps forward.
6. Trees, take 2 steps forward.
7. Shrubs, take 2 steps forward.
8. Explain: Grasses, sedges, and wildflowers are all called *herbs* (pronounced "ERBS"). Herbs, take 2 steps forward.

Walk your talk – how do you earn your living? (After each prompt, go through the organisms one by one. Have each "organism" be *introduced by the organism on his/her right*, and have the rest of the class repeat it out loud. After all have finished, have those organisms step back.)

9. If you get your energy from sunlight, take 2 steps forward.
10. If you get your energy from plant tissues, take 2 steps forward.
11. If you get your energy from animal tissues, take 2 steps forward.

Walk your talk – how do you deal with fire? (After each prompt, go through the organisms one by one. Have each "organism" be *introduced by the organism on his/her left*, and have the rest of the class repeat it out loud. After all have finished, have those organisms step back.)

12. If you can survive a fire by moving away or moving underground, take 2 steps forward.
13. If you can survive a fire by staying right where you are, take 2 steps forward.
14. If your top is killed by fire but your underground parts survive, take 2 steps forward.

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[1] You can vary the "stepping forward" part by adding a different motion each time, such as turning around, raising their arms, walking backwards, jumping, etc.

15. If you might die in a fire but your offspring will thrive afterward, take 2 steps forward.
16. If you do not do well after fire and stay away from burned areas, take 2 steps forward.
17. If you don't know how fire affects you, take 2 steps forward.
18. If you like crown fires better than surface fires, take 2 steps forward. (Be flexible in responses to this one, since many organisms have very effective ways to respond to both surface and crown fires. The organisms that definitely should respond to this prompt are listed in the answer key (Table E08-2).
19. If you like surface fires better than crown fires, take 2 steps forward. (Be flexible on this one too. See the answer key.)
20. If the forest, shrubland, or grassland in your home has ever experienced a wildland fire, take 2 steps forward. (This should include everyone! At this point, go around the circle and have the whole class say the name of each organism.)

Evaluation:	Excellent	Fair	Needs Improvement
Presentation	-Presentation was 1-2 minutes in length. -Student prepared a visual component using considerable effort and creativity. -Student provided a basic and accurate description of organism and its needs, community type where it lives, the kind(s) of fire that occur there, and how it deals with fire.	-Presentation was over or under 1-2 minutes. -Student prepared visual component. -Student's basic descriptions of organism, community type, and fires were inaccurate or missing important information.	-Presentation was greatly over or under 1-2 minutes. -Student did not prepare visual component or put minimal effort into preparing it. -Basic information was missing or largely inaccurate.
Classification exercise	Student gave correct information in exercise.	Student gave mostly correct information in exercise.	Student gave mostly incorrect information or did not participate in exercise.

Table E08-1: Species assignments from the *FireWorks Encyclopedia*

Organism	Student Name	Organism	Student Name
American black bear[2]		Sierra gooseberry	
Annosum root rot		**Sierra lodgepole pine**	
Baker cypress		**Sticky whiteleaf manzanita**	
Bark beetles		**Sugar pine**	
Black fire beetle		**Wavyleaf soap plant**	
Black-backed woodpecker		**Webber's milkvetch**	
Bracken fern		**Western gray squirrel**	
California black oak[3]		Western wood-pewee	
California red fir[4]		**White fir**[3]	
California spotted owl		White pine blister rust	
Canyon live oak[2]		Yellow star thistle	
Cheatgrass			
Deer brush			
Deer mouse			
Douglas-fir[3]			
Dusky-footed woodrat			
Fisher			
Fox sparrow			
Incense-cedar			
Jeffrey pine			
Mariposa lily			
Mountain lion			
Mountain whitethorn			
Mountain yellow-legged frogs			
Mule deer			
Northern goshawk			
Ponderosa pine			
Quaking aspen			
Ross's sedge			

[2] Bold-face print indicates species that are used in **Activity E14 - Story Time**. If you do not need all 40 species listed here, give priority to these species so students can relate to them when they hear the story of fire and succession in Sierra Nevada montane communities.
[3] California black oak and Canyon live oak could be combined, as they are in **Story Time.**
[4] Douglas-fir, California red fir, and white fir could be combined, as they are in **Story Time.**

Table E08-2: Teacher's Key to "Walk your Talk" Activity

Organism	Kingdom	Group	Energy source	Response to fire	Fire type
American black bear	Animal	Mammal	Animals, Plants	Move	
Annosum root rot	Fungus	Fungus	Plants	Stay or Don't know	
Baker cypress	Plant	Tree	Sunlight	Reproduce	Crown
Bark beetles	Animal	Insect	Plants	Reproduce	
Black fire beetle	Animal	Insect	Plants	Reproduce	Crown
Black-backed woodpecker	Animal	Bird	Animals	Move	Crown
Bracken fern	Plant	Herb	Sunlight	Sprout	
California black oak	Plant	Tree	Sunlight	Stay, Sprout	Surface
California red fir	Plant	Tree	Sunlight	Stay	Surface
California spotted owl	Animal	bird	Animals	Move	Surface
Canyon live oak	Plant	Tree	Sunlight	Sprout	
Cheatgrass	Plant	Herb	Sunlight	Reproduce	
Deer brush	Plant	Shrub	Sunlight	Sprout, Reproduce	
Deer mouse	Animal	Mammal	Plants	Stay	
Douglas-fir	Plant	Tree	Sunlight	Stay	Surface
Dusky-footed woodrat	Animal	Mammal	Plants	Move	
Fisher	Animal	Mammal	Animals	Move	
Fox sparrow	Animal	Bird	Plants	Move	
Incense-cedar	Plant	Tree	Sunlight	Stay	Surface
Jeffrey pine	Plant	Tree	Sunlight	Stay	Surface
Mariposa lily	Plant	Herb	Sunlight	Sprout, Reproduce	
Mountain lion	Animal	Mammal	Animals	Move	
Mountain whitethorn	Plant	Shrub	Sunlight	Sprout, Reproduce	
Mountain yellow-legged frogs	Animal	Amphibian	Animals, Plants	Don't know	
Mule deer	Animal	Mammal	Plants	Move	
Northern goshawk	Animal	Bird	Animals	Move	Surface
Ponderosa pine	Plant	Tree	Sunlight	Stay	Surface
Quaking aspen	Plant	Tree	Sunlight	Sprout	
Ross's sedge	Plant	Herb	Sunlight	Sprout	
Sierra gooseberry	Plant	Shrub	Sunlight	Sprout, Reproduce	
Sierra lodgepole pine	Plant	Tree	Sunlight	Reproduce, Stay	
Sticky whiteleaf manzanita	Plant	Shrub	Sunlight	Reproduce	
Sugar pine	Plant	Tree	Sunlight	Stay	Surface
Wavyleaf soap plant	Plant	Herb	Sunlight	Sprout, Reproduce	
Webber's milkvetch	Plant	Herb	Sunlight	Don't know	
Western gray squirrel	Animal	Mammal	Plants	Move	
Western wood-pewee	Animal	Bird	Plants	Move	
White fir	Plant	Tree	Sunlight	Stay	Surface
White pine blister rust	Fungus	Fungus	Plants	Reproduce	
Yellow star thistle	Plant	Herb	Sunlight	Reproduce	

9. Tree Parts and Fire: The Class Models a Living Tree

Lesson Overview: In this activity, students learn to name the parts of a tree, describe their functions, and explain how some trees can survive fire or reproduce well after fire.

Lesson Goal: Increase students' understanding of how trees function, how they may be affected by heat from wildland fires, and how they may be able to survive or reproduce well after fire.

Subjects: Science, Writing, Speaking and Listening
Duration: One half-hour session
Group size: Whole class
Setting: Classroom or outdoors
FireWorks vocabulary: *bark, branch, cambium, cone, ground fire, inner wood ("heartwood"), leaf, phloem, photosynthesis, root, seed, surface fire, xylem ("sapwood")*

Objectives:

- Students will participate in an exercise where they build a living model of a tree.
- Students can identify 10 parts of a tree on a diagram.
- Students can describe how tree parts help trees survive fire or reproduce well after fire.

<table>
<tr><th>Standards</th><th></th><th>1st</th><th>2nd</th><th>3rd</th><th>4th</th><th>5th</th></tr>
<tr><td rowspan="2">CCSS</td><td>Speaking and Listening</td><td>3,6</td><td>3,4,6</td><td>2,3,4,6</td><td>2,4,6</td><td>2,4,6</td></tr>
<tr><td>Language</td><td>1,2,4,5,6</td><td>1,2,4,5,6</td><td>1,2,4,5,6</td><td>1,2,4,5,6</td><td>1,2,4,5,6</td></tr>
<tr><td rowspan="4">NGSS</td><td>Structure, Function, Information Processing</td><td>LS1.A, LS1.B, LS1.D</td><td></td><td></td><td>LS1.A</td><td></td></tr>
<tr><td>Interdependent Relationships Ecosystems</td><td></td><td>LS2.A</td><td>LS4.A</td><td></td><td></td></tr>
<tr><td>Inheritance/Variation of Traits</td><td></td><td></td><td>LS1.B</td><td></td><td></td></tr>
<tr><td>Matter and Energy in Organisms and Ecosystems</td><td></td><td></td><td></td><td></td><td>LS2.A,B, LS1.C</td></tr>
<tr><td rowspan="2">EEEGL</td><td>Strand 1</td><td colspan="4">A,C,E,F,G</td><td>A,C,E,F,G</td></tr>
<tr><td>Strand 2</td><td colspan="4">C</td><td></td></tr>
</table>

Teacher Background: In this unit, students are learning how trees can survive wildland fire and grow or regenerate after fire. To do this, they need to know a few terms. In this activity, they work together as a class to create a model of a functioning tree – complete with actions and sounds. During this activity, they describe how some tree parts help it survive fire or reproduce after fire.

Different characteristics enable trees (and other plants) to survive specific kinds of fire:

- Thick bark can protect a tree's sensitive phloem and cambium from the heat of surface fires. However, it provides no protection from crown fires.
- If a tree tends to shed its low branches, surface fires are less likely to climb into the tree crowns than if the tree's branches are continuous from ground to crown.
- If young trees of a species can grow really fast, getting their leaves and branches high above the ground, they may be able to survive surface fires even when young.
- Roots that grow deep in the mineral soil are protected from the heat of surface and ground fires. However, they don't prevent damage to the cambium from surface fires or damage to the leaves and seeds from crown fires.
- If a tree can protect its seeds from fire, new trees can become established afterwards. Tightly sealed cones or capsules protect the seeds of some trees from crown fire. Burial underground protects seeds from all kinds of fire – unless they are in duff or organic soil, which may burn.
- If a tree can sprout from the roots, the base of the trunk, or other underground parts after its top is killed, it can survive both surface fire and crown fire. Its ability to survive ground fire depends on how well its underground parts are protected.

Materials and preparation:

- Obtain a few small packages of nuts or seeds. If you have students with nut allergies, select something that will be safe for them.
- You'll need a large, open space for the living tree model. It's great to do this outdoors. If you're in the classroom, you need a space at least 10 feet across. The directions here are written for a class of about 25. Try to adjust the numbers so everyone can participate.
- Print 1 copy/student: **Handout E09-1: Living Tree Diagram**

Procedure:

1. Explain: The class will make a living model of a tree. This will help us learn about how trees work and how they might survive fire.
2. Ask two tall students to stand back-to-back, with their arms stretched high and reaching slightly outward. Their bodies are the *inner wood ("heartwood")* of the tree trunk, which provides support for the tree but does not take an active part in the tree's life functions. Their arms are the tree's *branches,* and their fingers are its *leaves*, which gather energy from sunlight and turn it into nutrients that all living cells in the tree can use (*photosynthesis*). Ask them to pantomime photosynthesis by wiggling their fingers. Give them a few packages of seeds to "hold" in their branches. Have them create and practice a sound that represents this process. **With this role and those that follow, after the students**

have prepared, let them stay in place but pay attention as you "construct" the rest of the model tree.

3. Ask: How can leaves and branches be protected from fire? Branches and leaves are safe from fire only if they are high up on the tree. Low branches and leaves are vulnerable to *surface fires,* and they serve as ladder fuels that make the tree more likely to support a crown fire.
4. Ask: How can seeds be protected from fire? (1) Bury them underground to keep them safe from surface and crown fires. This may not protect them from *ground* fires if the heat penetrates the soil. (2) Keep them sealed tight inside their cones in the crown until after fire has passed.
5. Ask 4-6 students to stand in a circle around the inner wood, with their right shoulders to the inside and their left shoulders to the outside. They are the *xylem cells ("sapwood")* of the tree. These cells pump water and dissolved minerals from the roots up to the leaves. Have the students create a motion and a sound to represent this process.
6. Ask 4-6 more students to stand shoulder-to-shoulder in a circle around the xylem, facing out. They represent the *cambium* layer – the living cells that create new xylem (to the inside) and *phloem* (to the outside, a thin layer right under the bark). Have the students create a motion and a sound to represent this process.
7. Ask 4-6 more students to stand outside the cambium holding hands. They are the phloem cells. Their job is to carry nutrients throughout the tree—from leaves to branches or stem or and roots, wherever they are needed. Have the students create a motion and a sound.
8. Review these layers of cells: xylem, cambium, phloem. The tree needs all 3 of these layers to live. Which is most important? Cambium is most important, because it produces new xylem and phloem. If they are destroyed, they cannot produce new cells. Ask: What does the tree need to protect its cambium from the heat of fires? Bark! The thicker the better!
9. Ask 5 more students to stand shoulder-to-shoulder outside the phloem, facing out and looking very strong. They represent the tree's *bark*, which contains mostly dead cells and air, and protects the inner layers from injury. Have the students create a motion and a sound.
10. Ask the remaining students to lie on the floor—feet at the base of the tree, heads and arms spread out along the ground. They are the *roots*, with their tips and tiny hairs (called "root hairs") growing out, searching for water. Have the students create a motion and sound. Give them some seed packages.
11. Ask: How can roots and buried seeds be protected from fire? Soil protects them. The deeper they are, the better. Roots are only vulnerable to fire if the soil gets very hot or if they are living in soil that contains a lot of dead plant material, which can burn in a *ground fire*.

12. Review the action and sound for each group of students, one at a time. Then ask them to all do their work at once. They will see that a living tree is a very busy, hard-working kind of organism!
13. When you've had enough bedlam, **review:** Have the students disassemble the tree but stay in groups of similar tree parts. Ask each group to describe how they can be protected from fire. Supplement their ideas with these:
    - **Innerwood**: Grow thick xylem and bark. **Branches, leaves, and seeds in the crown**: Grow tall really fast to get the leaves and seeds away from surface fires. Shed low branches so surface fires can't climb into the tree's crown. Pack seeds into thick, tightly sealed cones or capsules so they won't be killed by crown fire.
    - **Xylem**: Fill up with lots of water so you can't be easily overheated. Make sure you have thick bark.
    - **Cambium and phloem**: Get very thick bark for insulation from surface fire.
    - **Bark**: Grow thick.
    - **Roots and fallen seeds**: Grow roots deep so you can survive even if the litter and duff on the surface are burned. Be able to sprout new growth if the tree parts above ground are killed. Store seeds deep in soil, too.

Assessment: Give each student a copy of **Handout E09-1: Living Tree Diagram**. Ask students to follow the directions at the top of the handout – that is:

1. Use the word bank to label the parts of the tree.
2. At the bottom, list two things that help a tree survive fire or grow well after fire.

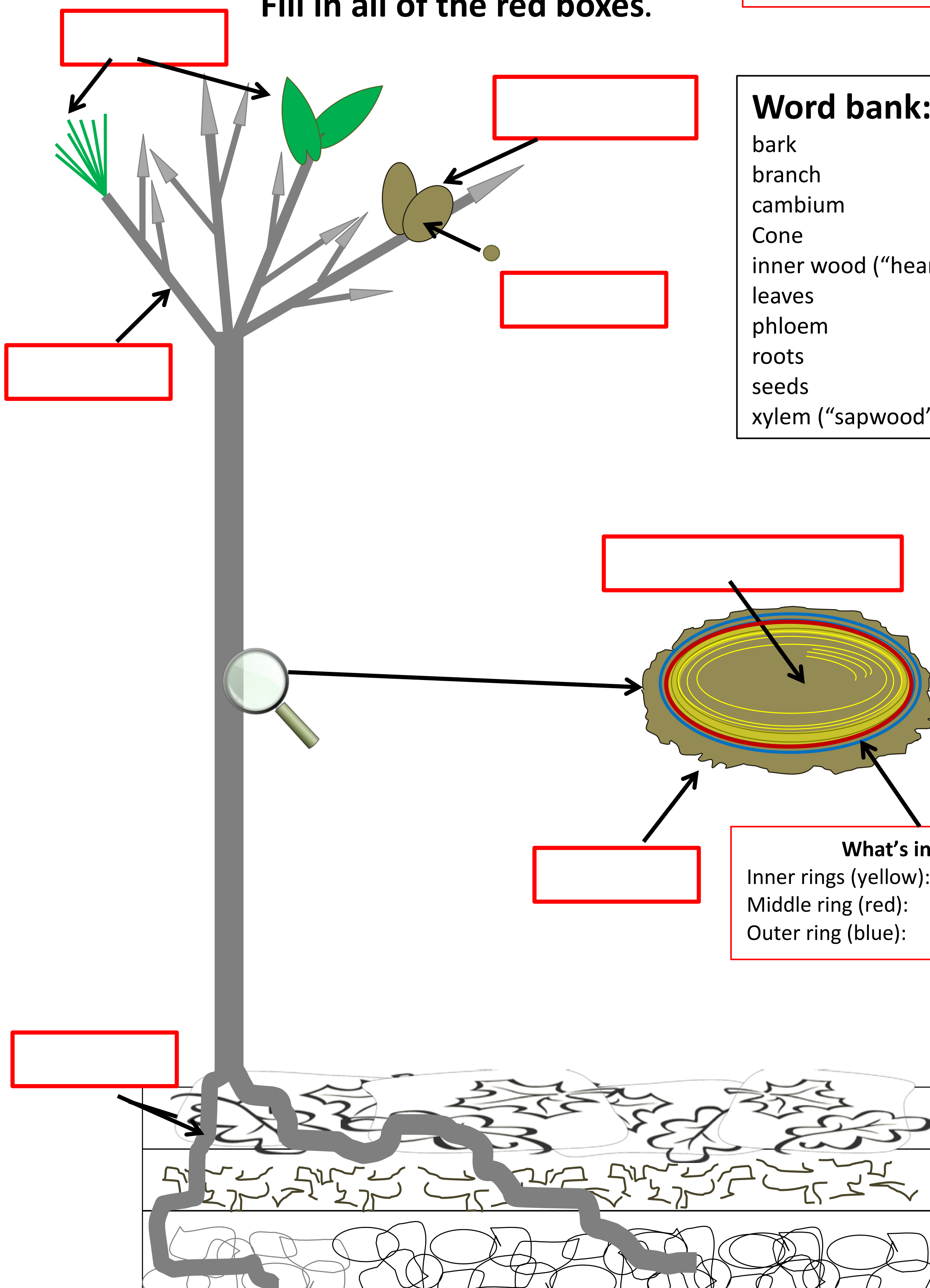
Evaluation: Refer to **Answer Key for Handout E09-1: Living Tree Diagram** (below).

Evaluation:	Full Credit	Partial Credit	Needs Improvement
Labeling component	8-10 correct labels	5-7 correct labels	0-4 correct labels
Writing component	Correctly listed two things that help a tree survive fire or grow well after fire.	Correctly listed one thing that helps a tree survive fire or grow well after fire.	Did not list anything that helps a tree survive fire or grow well after fire.

Handout E09-1: Living Tree Diagram

Name: ________________

Fill in all of the red boxes.



Word bank:

- bark
- branch
- cambium
- Cone
- inner wood (“heartwood”)
- leaves
- phloem
- roots
- seeds
- xylem (“sapwood”)

What’s in there?

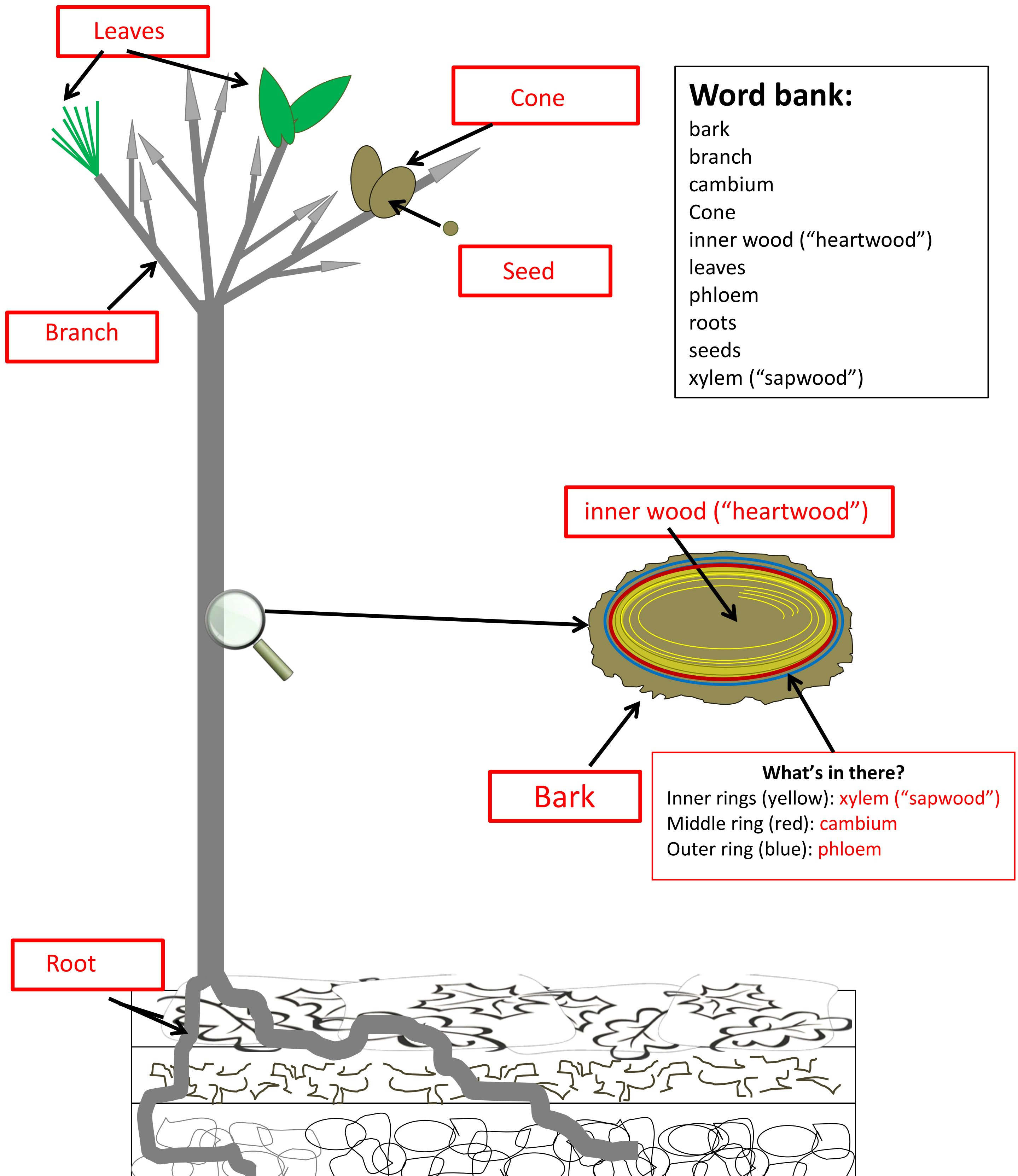
Inner rings (yellow):

Middle ring (red):

Outer ring (blue):

List 2 things that help a tree survive fire or grow well after fire:

Answer Key for Handout E09-1: Living Tree



List 2 things that help a tree survive fire or grow well after fire: Has thick bark, sheds low branches, grows fast, has deep roots, buries seeds in soil, stores seeds in sealed cones, is able to sprout after top is killed…

10. Tree Identification: Using a Key to Identify "Mystery Trees"

Lesson Overview: In this activity, students examine botanical specimens of tree species and learn to use a dichotomous key to identify them.

Lesson Goal: Students will understand that tree species are diverse and one can identify trees by looking at them carefully.

Objectives:

- Students can use a key to determine the tree species from a collection of images and specimens.

Subjects: Science, Mathematics (logic), Writing, Speaking and Listening

Duration: One half-hour session

Group size: Whole class, possibly working in teams of 2-3

Setting: Classroom

New FireWorks vocabulary: *bundle, key*

Standards:		1st	2nd	3rd	4th	5th
Common Core ELA	Reading: Informational Texts	4	4	4	4	4
	Writing	8	8	7,8	7,8	7,8
	Speaking/Listening	3,6	3,4,6	2,3,4,6	2,4,6	2,4,6
	Language Standards	1,2,4,5,6	1,2,4,5,6	1,2,4,5,6	1,2,4,5,6	1,2,4,5,6
NGSS	Structure, Function, and Information Processing	LS1.A, LS1.D			LS1.A	
	Inheritance/Variation of Traits			LS1.B, LS3.B		
	Matter and Energy in Organisms and Ecosystems					PS3.D
	Interdependent Relationships in Ecosystems		LS4.D	LS4.C		
EEEGL	Strand 1	A,C,E,F,G				A,C,E,F,G
	Strand 2	C				

Teacher Background: A wildland ecosystem is characterized by diversity, and the diversity of tree species is an important characteristic of forests. To understand the complexity of fire's role in forests, students must be able to distinguish among tree species. In this activity, they learn how to use a dichotomous key to identify 12 of the important trees in Sierra Nevada montane forests. You will work together as a class to identify 1 species from photos and botanical specimens provided in the trunk. Then the students will visit 11 stations, each with specimens from 1 species, and use the key to identify them.

This activity requires reading skill. For early elementary students, do the activity together as a class using student teams:

- Project **Handout E10-1: Identify 12 Trees**.
- Provide a set of specimens (tree bark/trunk, cone or flower, foliage, photo collection) to each student team.
- Read the questions on the key together as a class.
- Have student teams examine the specimens, raise their hands when they can answer "yes" to a question for their species, and thus move through the key together and determine the correct species.

Code letters for the tree species:

Baker cypress	A
California black oak	C
California red fir	S
Canyon live oak	P
Douglas-fir	E
Incense-cedar	J
Jeffrey pine	K
Ponderosa pine	Q
Quaking aspen	B
Sierra lodgepole pine	M
Sugar pine	T
White fir	X

The dichotomous key in **Handout E10-1: Identify 12 Trees** can also be used in the field, so this activity can prepare students for a field trip. If you want to test their knowledge in the field, find an area with several of these tree species represented, label the trees with the letter codes here, and have students fill in the handout as they move from tree to tree. In preparing the students, let them know that they are not likely to find EVERY species in the key living in one place, and they are likely to find species that are NOT in the key.

NOTE: This key will not work well in winter because some trees will lose their leaves.

Materials and preparation:

- Print 1 copy/student of **Handout E10-1: Identify 12 Trees** (two pages – print 2-sided, if possible).
- Project **Handout E10-1: Identify 12 Trees**.

- Find the following materials for species Q (ponderosa pine) and place them at your desk. All of these materials are in the trunk.

  Tree bark/trunk specimen
  Cone or flower specimen
  Foliage specimen
  Photo collection for the species (e-copy available: E10_TreePhotoPacket.pdf)

- Assemble 11 stations in the classroom, each containing all of the materials for one species.

Procedure:

1. Ask: Can you name any tree species that live in the Sierra Nevada? When you see this tree in the woods or on a mountainside, how do you know what kind it is – that is, how can you identify it? Open-ended discussion. You could note species names & 1-2 characteristics on the board.

2. Explain: Today we'll add to what you already know by learning how to use a *key* to identify tree species. By the end of class, you'll be able to identify 12 species that live in Sierra Nevada forests. This key is not just useful for identifying dead tree parts in the classroom. Once you know how to use the key, you can take it into the forest and identify trees in the field. We'll identify one species together, and then you will do the 11 others at stations.

3. Give each student a copy of **Handout E10-1: Identify 12 Trees**

4. Project **Handout E10-1**. Starting at the left side of the key, work with the students to identify tree "Q," ponderosa pine. As you do this together, students will see how to identify a tree based on characteristics of the leaves, bark, cones, flowers, etc. Make these points:

   - When you're using the key, you always have to start at the left box; you can't start identifying a species in the middle of the key.

   - Once you think you've made an identification, you must check your specimen against the species description on the back of the handout. Why? This key has only 12 species, but there are many more in the field. You'll need the extra clues to make sure you've got the species right.

   - When you've made and confirmed an identification, enter the letter of the specimen in the box with the species name.

Assessment:
Have students circulate from one station to another (order doesn't matter), identify the tree species at each station, and enter the correct code letter for each species in the handout.

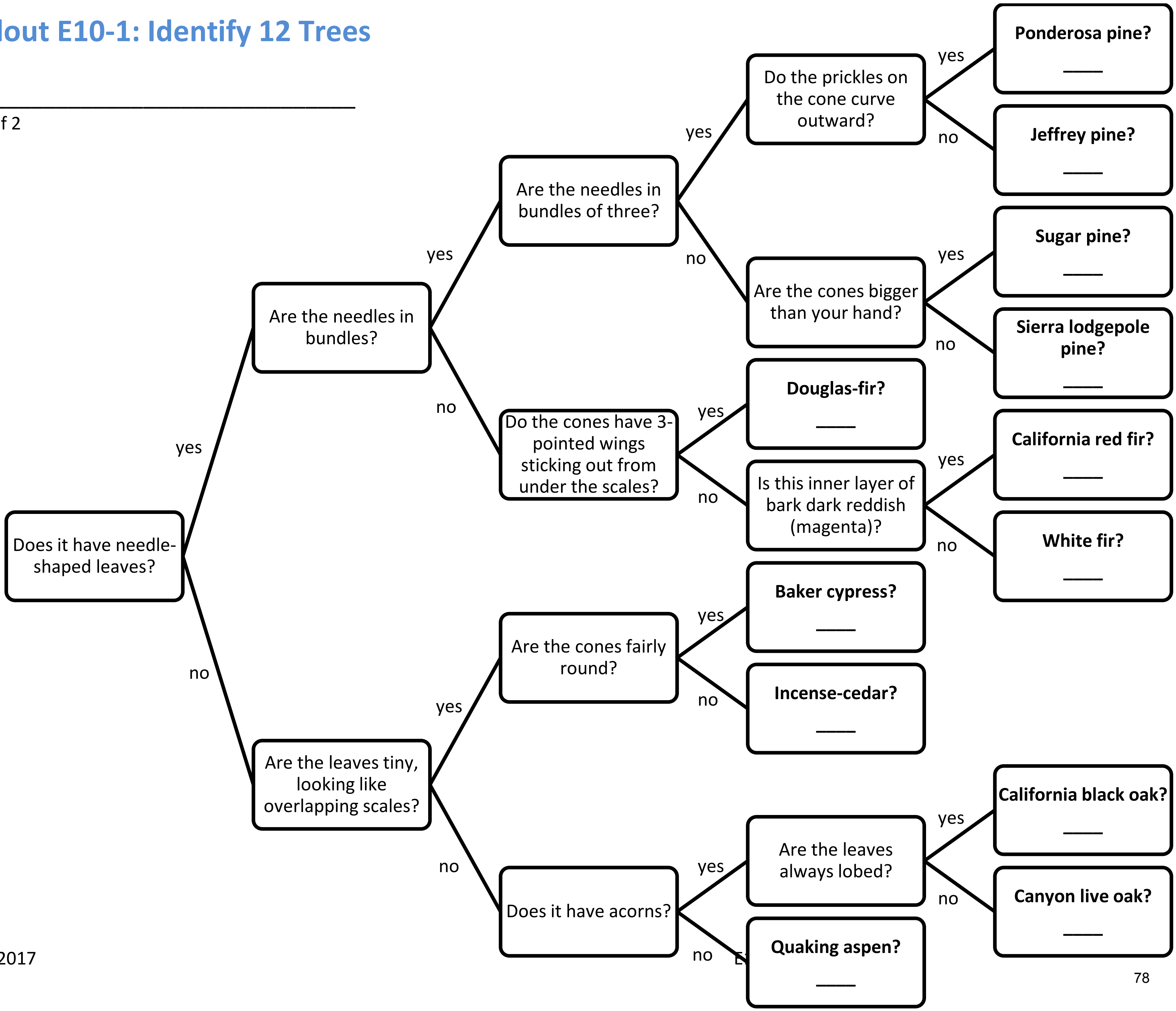
Evaluation:

Full Credit	Partial Credit	Less than Partial Credit
-Student correctly identified 8-12 species	-Student correctly identified 4-7 species	-Student correctly identified less than 4 species

Handout E10-1: Identify 12 Trees

Name_______________________________

Page 1 of 2

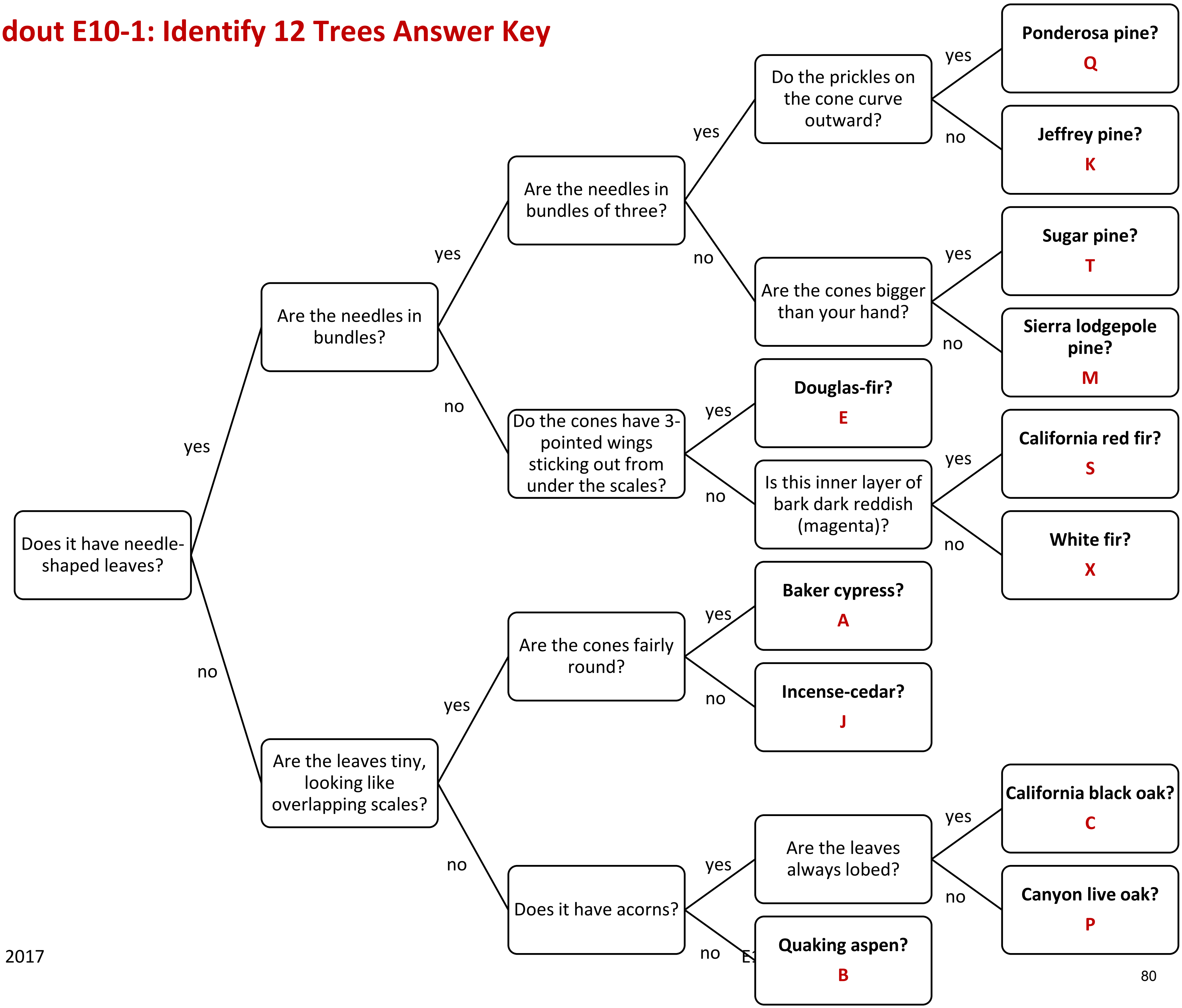


1. **Baker cypresses** have tiny leaves that look like overlapping scales. The trees' bark is thin and reddish-brown. The cones are round and are sealed closed by a hard, waxy coating.
2. **California black oaks** have leaves with "lobed" (curvy) edges. The leaves fall off each winter. Adult trees have thick, rough bark. California black oak trees produce acorns.
3. **California red firs** have short needles and brown, furrowed bark. If you break off a chunk of bark, you will see a deep red color. The cones are on the top of the tree, and they stick straight up. The cones fall apart easily, so you rarely see whole cones on the ground. California red fir needles are typically shorter than those of white fir.
4. **Canyon live oak** leaves are often oblong and have smooth edges, but they can also have pointy teeth along their edges. The leaves are evergreen, so they do not fall off in the winter. The trees' bark is thin and flaky. Like all oaks, canyon live oak trees produce acorns.
5. **Douglas-firs** have short, flat needles and brown, furrowed bark. The buds at the ends of their twigs are pointy. Their cones have little, 3-pointed "wings" that stick out from under the cone scales. It looks like tiny mice are trying to burrow in, but they can't hide completely!
6. **Incense-cedar** leaves look like overlapping scales, and their twigs look a little like fern fronds. Adult trees have thick, reddish-brown bark with deep furrows. Narrow strips hang loose from the trunk. Small, male cones form at the tips of the leaves. Female cones look like stiff brown flowers when they open at the end of the summer.
7. **Jeffrey pines** have long needles that usually grow from the twig in *bundles* of 3. Their cones are big. The cones have prickles that point inward. The trees' bark is yellowish or brown, sometimes even orange. It falls off in pieces that look like they belong in a jigsaw puzzle. Jeffrey pines produce a vanilla-like smell, especially in the springtime. Jeffrey pine needles and cones are typically bigger than those of ponderosa pine.
8. **Ponderosa pines** have long needles that usually grow from the twig in bundles of 3. Their cones are big. The cones have prickles that point outward. The trees' bark is yellowish or brown, sometimes even orange. It falls off in pieces that look like they belong in a jigsaw puzzle. Ponderosa pines produce a vanilla-like smell, especially in the springtime.

"Gentle Jeffrey, prickly ponderosa."

9. **Quaking aspens** have roundish leaves with a pointed tip. Their leaves move almost constantly because they are very sensitive to wind. The leaves turn yellow and fall off in the fall. The trees' bark is mostly grayish-white and smooth, although old trees can have furrowed bark down near the ground. Aspen seeds are packaged with cottony fluff that helps them float long distances on wind and water.
10. **Sierra lodgepole pines** have needles that grow from the twig in bundles of two. They have fairly thin, rough bark. The cones are about as long as the needles, and they open when their seeds are ripe. Sierra lodgepole pines grow high in the mountains.
11. **Sugar pines** have needles that grow from the twig in bundles of five. They grow tall and have thick, furrowed, reddish-brown bark. Their cones are very long, often longer than a 30 centimeters. Their branches spread wide from the trunk.
12. **White firs** have short needles. The bark on young trees is gray and smooth. The bark on old trees is gray with deep furrows that have orange streaks inside. If you break off a chunk, you will see a yellowish or orange color. Cones are on the top of the tree, and they stick straight up. The cones fall apart easily, so you rarely see whole cones on the ground. White fir needles are typically longer than those of California red fir.

Handout E10-1: Identify 12 Trees Answer Key



11. Recipe for a Baker cypress grove: Serotinous Cones

Lesson Overview: In this activity, students extract seeds from *serotinous* cones, count them, and estimate the number of seeds that might fall in an area after a large, severe fire.

Lesson Goal: Students will understand that Baker cypress and knobcone pine cones are *serotinous* and need wildland fire to open their cones and release their seeds. Thus they can establish a new forest after fire.

> **Subjects:** Science, Mathematics, Writing, Speaking and Listening
>
> **Duration:** two half hour sessions
>
> **Group size:** Whole class, possibly working in teams
>
> **Setting:** Classroom
>
> **New FireWorks Vocabulary:** *embryo, filled seed, seed wing, serotiny/serotinous*

Objectives:

- Students can identify filled vs. empty seeds.
- Students can explain the importance of fire and serotiny for regeneration of knobcone pine and Baker cypress.

> **ABOUT STUDENT PRESENTATIONS:** If you assigned Baker cypress to a student in **Activity E08. Who Lives Here? Adopting a Plant, Animal, or Fungus**, this would be a great time for that presentation. If you did not do that activity or did not assign Baker cypress, we recommend that you either
>
> - have students read the essay on Baker cypress in the *FireWorks Encyclopedia* (pp. 5-6 in either **FireWorksEncyclopedia_YoungerGrades.pdf** or **FireWorksEncyclopedia_OlderGrades.pdf**) or
> - teach some of the information provided in the **Teacher Background** below.

Standards:		1st	2nd	3rd	4th	5th
Common Core Math	Operations/Algebraic Thinking	1,2,3,7	1,2,3	1,3,5,8		
	Number and Operations Base Ten	1,2	1,2,3,4,5,6,7,8	1,3		
	Measurement and Data	1				
	Represent and Interpret Data		10	3		
NGSS	Structure, Function, and Information Processing	LS1.A, B				
	Interdependent Relationships in Ecosystems		LS2.A	LS2.C, LS4.C		
EEEGL	Strand 1	C,E,F,G				C,E,F,G

Teacher Background:
Children, as well as adults, often assume that fire is a catastrophe for all living things. Throughout Unit V of FireWorks, students learn that many native species in the Sierra Nevada can survive fire and/or reproduce well afterward. This activity demonstrates that 2 tree species in California – knobcone pine and Baker cypress – actually NEED fire to reproduce well, and the hotter the fire, the better.

In this activity, boiling water is used to open the cone of a knobcone pine. These cones are *serotinous* – that is, remaining closed on the tree with seed dissemination delayed (from the Latin *sero,* meaning “late). Students will observe the cone gradually opening and then count the number of *filled seeds* that fall out. Filled seeds are those that contain an *embryo*; they are larger and more solid than unfilled seeds, which have not matured (possibly because they were not pollinated) and cannot produce a new plant. Filled knobcone pine seeds are about a half centimeter across.

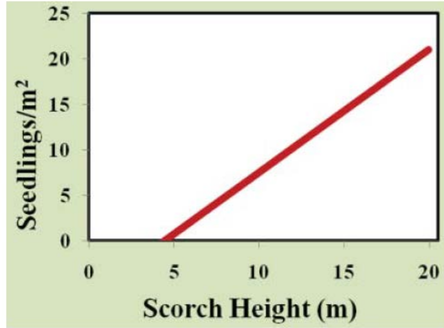
While this activity uses knobcone pine cones to demonstrate serotiny, knobcone pines are a foothills species rather than a montane species, so they are not included in the rest of this curriculum. We use them to demonstrate serotiny because the serotinous species that does occur in montane forests of the Sierra Nevada – the Baker cypress – is very rare and its seeds are too precious to be collected for classroom demonstrations.

About Baker cypress: Baker cypress stands are only found in 11 locations northern California and southern Oregon. They grow in dry places on mountains from about 1,000 to 2,200 meters.

Baker cypress trees evolved to burn; that is, they are adapted to fire, and they depend on fire. Baker cypress cones are *serotinous*. That means that the cones remain sealed shut until the heat from a fire melts the cones’ resinous coating. Once the coating is melted, cones open and release their seeds. The seeds fall to the ground in perfect conditions for establishing a new grove: lots of sunlight, few overstory trees, and lots of nutrition in the soil for at least a few years.

Not just any fire is hot enough to melt the resinous coating on Baker cypress cones. Intense crown fires kill the mature trees, but they are exactly what Baker cypresses need to release their seeds. In fact, crown fires are more likely to occur in Baker cypress groves than in many Sierra forests because the trees grow in dense thickets and retain their dead lower branches – perfect ladder fuels for a crown fire.

In recent years, land managers have noticed that Baker cypress trees are dying and groves are not regenerating. Although Baker cypress is adapted to wildland fire, fire has been excluded from their groves for almost a century. Wildland fires, such as the 2007 Moonlight Fire in the Plumas National Forest, may help these old groves regenerate. After the Moonlight Fire, scientists found that Baker cypress seedling density was highest in areas where the fire was most severe (as indicated by the height of scorch on trees).[1]



Materials (<u>not provided</u> in FireWorks trunks)

- One or two knobcone pine cones
- Boiling water
- Jar that is large enough to fit 1 or more knobcone pine cones and cover them with water

Procedure: This activity has two parts (Day 1 and Following Days). In Day 1, teachers place the cone(s) in a transparent jar of boiling water, and students observe sights, sounds, and smells of the resin melting and possibly of cones beginning to open. In the following days, students witness the cone(s) opening and seeds falling out.

Procedure - Day 1:

1. Pass around the knobcone pine cone(s) for students to examine. Ask: These cones have lots of seeds inside. How can they get out? Have the students observe that the cones are closed up tight, and it seems there is no way to get the seeds out. They may try pounding or picking at the cone scales… don't let them hurt themselves!

2. Ask: Is that a problem for the tree? Discussion – If the tree is ever going to reproduce, the seeds have to get out somehow.

3. Ask: How might the tree solve this problem? Welcome any ideas from the students. Fire is likely to be mentioned. That would be great.

4. Explain: This kind of tree and a few others have unusual cones. They are sealed tight by a resin, which is like hardened glue. This property is called *serotiny.* If we heat the cones, the resin will melt and the seeds will fall out. Another kind of tree with serotinous cones is Baker cypress, but we will not use them in this lesson because Baker cypress groves are rare and precious, so we don't want to take any of their cones.

5. Explain: Let's use boiling water to melt the resin and open the cones in our jar. **Tell students to be very quiet and to listen and look** for signs of the resin melting. Poor boiling or very hot water into the cone-filled jar.

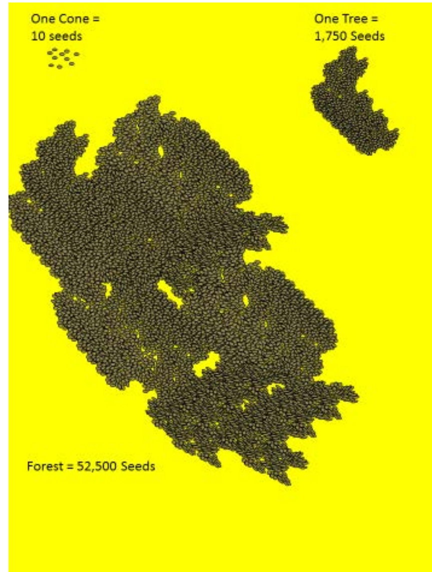
[1] https://www.firescience.gov/projects/briefs/06-2-1-17_FSBrief126.pdf

6. After a minute, ask for observations. They may include seeing little bubble of gas coming from between the cones scales as the resin melts and the air inside expands and escapes; seeing the melted resin as an oily or waxy layer on top of the water; hearing the bubbles hiss as they come out of the cones; smelling the resin as it melts. **NOTE:** It may take several days for the cones to dry out and open. You can dry them more quickly by heating them. If you do this, seeds will begin to fall out the next day.
   - Microwave: 1 minute on high. If the cones do not open well with this much heat, try another minute. Let them cool before handling them.
   - Oven: Place the cone on foil on a cookie sheet and heat them in a conventional oven at 300º F for about 30 minutes.
7. Hang the cones upside-down from somewhere in your classroom where they will not be disturbed for a few days. Place a white cloth or large sheet of paper below them to catch the seeds.

Procedure - Following Days … after the cones are dry and open:

8. Observe any seeds that have fallen out.
9. Shake the cones over your sheet/paper to get any remaining seeds out.
10. Have the students examine the seeds.
11. Explain: Each seed has two parts – a long papery *wing* and the actual seed. Seeds that have *embryos* inside (baby trees) will be 5-7 mm long; these are called *filled seeds*. Seeds that are much smaller are empty (containing no embryo), and students should not count them.
12. Have students count the filled seeds.
13. Explain: We can use our data to estimate how many seeds a whole tree produces in a year and how many seeds might be stored in a whole tree, ready for the next fire to open the cones.
    a. Suppose the tree that produced these seeds makes 175 cones its lifetime. How many filled seeds is it likely to produce? Multiply the filled seed count from your demonstration by 175. If you opened more than 1 cone, use the average seed count from all of them.
    b. Suppose our tree is in a forest about the size of a football field with 30 knobcone pines in it. How many seeds might be in the seed bank for that whole forest? Multiply the answer from (a) by 30.
    14. Have a couple of students make a poster containing all of this information. Glue the seeds to the poster or put them in a bag nearby. Display the poster and seeds next to

the cone. (In case you would like to show them an example, this graphic – using 10 seeds/cone - is available in the FireWorks files, entitled **Lotsa_seeds)**



Assessment:
Have each student write a short paragraph that answers this question: **What would happen to knobcone pine and Baker cypress forests if fires never visited their homes?**

Evaluation: Answers should include this information:

- Knobcone pines and Baker cypress trees are serotinous, which means that their cones will not open without heat.
- If fires do not burn these trees, very few of their cones will open up – perhaps none will open. So they will not be able to release their seeds, and no baby knobcone pine or Baker cypress trees will grow.
- Without fire, the old trees will eventually die, and new young trees will not take their place.

12. Buried Treasure: Underground Parts that Help Plants Survive Fire

Lesson Overview: Students look at specimens of 9 plant species – grasses, wildflowers, shrubs, and trees – and examine their underground parts. They learn how these parts enable the plants to survive and/or thrive after fire.

Lesson Goal: To increase students' understanding that many plants have underground parts that enable them to survive wildland fire and/or reproduce successfully after fire.

Subjects: Science, Reading, Writing, Art
Duration: One to two half-hour sessions
Group size: Whole class, possibly working in teams
Setting: Classroom
New FireWorks vocabulary: *buried treasure, fire-dependent, sprout, top-kill*

Objective: Given an opportunity to study, draw, and discuss the underground parts of botanical specimens:

- Students can draw an imaginary plant that contains at least two kinds of underground parts that enable it to survive wildland fire and/or reproduce afterward.
- Students can explain how the underground parts of their imaginary plants allow them to survive fire or reproduce afterward.

ABOUT STUDENT PRESENTATIONS: If you did **Activity E08. Who Lives Here? Adopting a Plant, Animal, or Fungus**, this would be a great time for student presentations on all of the herb and shrub species – and possibly also on quaking aspen. That way they can connect the concept of "buried treasures" to the underground parts of particular species that they've been studying.

Standards:		1st	2nd	3rd	4th	5th
Common Core ELA	Speaking/Listening	1,2,3,4,5	1,2,3,4,5	1,2	1,2	1,2
NGSS	Structure, Function, and Information Processing	LS1.A,B,D			LS1.A	
	Interdependent Relationships in Ecosystems		ETS1.B	LS2.C, LS4.C,D		
	Inheritance/Variation of Traits			LS1.B, LS3.B		
	Engineering Design		ETS1.B			ETS1.C
EEEGL	Strand 1	A,C,E,G				A,C,E,G

Teacher Background: Most children are familiar with the above-ground appearance of plants. But they are not usually familiar with the plants' underground parts, and yet these *buried treasures* are the features that enable some native trees and most grasses, shrubs, and wildflowers to survive wildland fire and thrive afterward. There are many kinds of buried treasures; this activity covers only a few, but enough to demonstrate the variety in plants that are native to the Sierra Nevada and are well adapted to fire.

Most kinds of buried treasure enable plants to sprout new growth after their above-ground parts are removed. Buried roots, stems, bulbs, corms, root crowns, and rhizomes account for the ability of perennial plants to survive cold winters, grazing, fire, and other forces that kill off their aboveground parts. (This is called *top-kill*.)

Seeds are also buried treasures, if they are stored deep enough in the soil to be protected from the heat of fires. Of course, they must be buried in soil that will not burn; seeds buried in duff or peat are vulnerable to fire if these materials dry out and begin to burn.

Some plants produce seeds that <u>cannot</u> germinate until they are heated, so they disappear within a few years after a fire and then show up by the thousands the year after the next fire. This is typical of Plant #9 in the FireWorks collection, sticky whiteleaf manzanita. When a species <u>requires</u> fire to survive or regenerate, we call it *fire dependent* because it <u>depends on</u> fire.

Buried treasures are plant adaptations to fire and other disturbances, such as animal grazing and the cold of winter. Another plant adaptation to fire in the Sierra Nevada is the thick bark of mature ponderosa pines, Jeffrey pines, sugar pines, and firs, which students observed if they did **Activity E10, Tree Identification: Using a Key to Identify "Mystery Trees."** Another adaptation to fire is cone serotiny, which they observed if they did **Activity E11: Recipe for a Baker cypress grove: Serotinous Cones.**

Materials and preparation:

- Find the 9 plant specimens in the trunk. The list below shows their buried treasures next to their names.
  1. quaking aspen (spreading roots)
  2. Sierran gooseberry (root crown)
  3. deer brush (root crown)
  4. mountain whitethorn (lignotuber)
  5. Ross's sedge (root crown/some short rhizomes)
  6. mariposa lily (bulb)
  7. wavyleaf soap plant (bulb)
  8. bracken fern (rhizomes)
  9. sticky whiteleaf manzanita (seeds only)

  Keep #9 at your desk to use when you begin the activity. Set the others aside.

- Make 1/student: **Handout E12-1: Buried Treasures**.

Real specimens from the field would be better for this activity than the specimens in the trunk. If possible, bring to the class real, fresh samples of some of the species listed below. (This could also be done on a class field trip.) If you do this, however, be sure to explain ethical collecting to the students and model it in the field: Collect only with permission from the land owner; collect only from a location that has abundant specimens of that species (20 or more is a rule of thumb); replace the disturbed soil carefully; collect only as much as you need; if collection is high-quality, preserve it for future use by pressing and laminating it.

- **OPTIONAL:** Bag of roasted peanuts. See Step 3 below.

Procedure:

1. Explain: In this activity, we'll learn about the *buried treasures* of plants – the underground parts that enable them to survive fire, reproduce after fire, or both. Seed, of course, is a way for plants to reproduce after fire. Seeds do not burn up if they are buried deep enough to be protected from the fire's heat.
2. Ask/explain: What does a seed need to make a new plant? A seed contains an embryo (baby plant), plus the nutrition needed to grow up to the top of the soil and start photosynthesizing, plus some kind of protection from rotting or being eaten before the plant can start to grow.
3. **OPTIONAL:** In most seeds, the embryos are very tiny, so they can't be identified without a microscope. But peanut embryos are big enough to see with the naked eye. **If no one in your class is allergic to peanuts**, get a bag of roasted peanuts and give one to each student. Have the students remove the shell and papery seed coat and break the peanut in half. Then they can see the tiny embryo with two cotyledons and a small root wad, surrounded by nutritious, fatty tissue that can support the baby plant until its leaves emerge into sunlight and can begin photosynthesizing. And then they can eat the peanut!
4. Ask: How can seeds get buried in nature? Layers of duff pile up over them, burrowing animals carry them underground, birds carry them and bury them, animals eat them and then release them in their scat. Some grasses and herbs have little "drills" attached to their seeds. These change shape as they respond to moisture, actually pulling the seed into the soil! OPTIONAL, watch a short video of an *Erodium* seed drilling itself into the soil: https://www.youtube.com/watch?v=TOJG5mF6OLs
5. Show them **plant #9, sticky whiteleaf manzanita**. Explain: This plant produces seeds that can be buried underground for many years without rotting. The seeds don't just survive fires; they need the heat from fire to grow a new plant. The seeds accumulate in the soil for years, "waiting" for a fire to occur. We say this plant is *fire dependent* because it depends on fire to reproduce. We say the plant's seeds are buried in the soil's seed bank, just as the seeds of Baker cypress and knobcone pine (in their serotinous cones) are stored in a seed bank on the tree itself (see **Activity E11: Recipe for a Baker Cypress grove: Serotinous Cones**).
6. Explain: Many plants have another kind of buried treasure: underground parts that can *sprout* new tops if their above-ground parts are removed. They can sprout after deer eat off their tops, after winter freezes them, and after fire kills all of their above-ground parts. Even though these plants may look dead after a fire, we know that they are probably still alive underground. We don't say they are killed; we say they are *top-killed.* Let's look at some of these.
7. Break the class into 8 groups. Place plant specimens 1-8 on tables or desks throughout the room. Give each student a copy of **Handout E12-1: Buried Treasures**.

8. Instruct them:
    - sketch the plant's buried treasure in the box below the photo, then
    - move on to the next plant and sketch its buried treasure… until you've done them all.
9. When everyone has finished, discuss: What similarities and differences did you see among the buried treasures? Use guiding questions such as: Which plants have stringy-looking treasures? Which ones look like radishes or potatoes? Which ones look like wood?
10. **Review:** Point to a few of the specimens and remind students: Buried treasures all contain some cells that can grow whole new plants and some cells that contain nutrition to support the growing cells until they get up to the surface and make their own nutrition by photosynthesizing.
11. **OPTIONAL:** If you want students to learn the technical names for the plants' buried treasures (root, rhizome, lignotuber, bulb, etc.), you can teach them using the list above under **Materials and Preparation…** or have them refer to the students who adopted these species in **Activity E08: Who Lives Here?...** or have them read about these species in the *FireWorks Encyclopedia,* especially the version for older students (**FireWorks Encyclopedia_OlderGrades.pdf**).

Assessment: Explain: Now you get the chance to invent a new plant. Design a brand-new plant species that can survive fire because it has two or more buried treasures.

1. Draw the plant.
2. Give it a name.
3. Explain (in writing or verbally to the class) how your plant's underground parts help it survive fire or reproduce afterward.

OPTIONAL: You could use this assessment to teach about scientific names.

Scientific names use the Latin language, and every scientific name has two parts. The first part identifies the genus (or general group). You could agree as a class to call all of your made-up plants something like *Pyrophilus* – meaning "fire lover."

The second part of a scientific name distinguishes the individual species from similar ones. Sometimes the species name refers to a special feature of the plant. For example, the species name for quaking aspen is *Populus tremuloides,* because its leaves "tremble" all the time. Sometimes the species name refers to the person who first described it (to Europeans). For example, the species name for Douglas-fir is *Pseudotsuga Douglasii,* in honor of David Douglas, a Scottish botanist who lived and explored in the 1800s.

Evaluation:	**Fully successful**	**Partly successful**	**Unsuccessful**
New Plant	-Student created a plant that has 2 buried treasures. (These can be similar to those in the specimens, or totally new and imaginative.) -Student gave logical explanation of how the 2 buried treasures enable the plant to survive and/or reproduce after fire.	-Student created a plant that has 1 buried treasure. -Student gave logical explanation of how the buried treasure enables the plant to survive and/or reproduce after fire.	-Student created a plant without buried treasures OR -Student did not give logical explanation of how the buried treasure(s) enable the plant to survive and/or reproduce after fire.

Handout E12-1: Buried Treasures

Name:_______________

Plant 1.
Quaking aspen
(by Terry Spivey, USDA Forest Service, Bugwood.org)

Plant 2.
Sierra gooseberry
(by Becky Howard)

Plant 3.
Deerbrush
(by Ilana Abrahamson)

Plant 4.
Mountain whitethorn
(by Ilana Abrahamson)

Plant 5. Ross's sedge (by Paul Slitcher).

Plant 6. Mariposa lily (by Jane S. Richardson).

Plant 7. Wavy leaf soap plant (by Becky Howard).

Plant 8. Bracken fern (by Robert Vidéki, Doronicum Kft., Bugwood.org)

Unit VI. Fire History and Succession

13-1. My Tree Autobiography: Seeing History through Trees' Growth Rings

Lesson Overview: In this activity, students examine a fire-scarred tree cross section (sometimes called a "tree cookie") and a display that shows tree growth rings. Then they record their own personal histories using growth rings as a metaphor.

Lesson Goal: Students will understand how growth rings form and how they record a tree's history.

Subjects: Science, Mathematics (counting), Writing
Duration: One half-hour session
Group size: Whole class
Setting: Classroom
New FireWorks vocabulary:
autobiography, earlywood, estimate, growth ring, latewood

Objective:

- Students understand how tree growth rings are formed well enough to sketch their own histories using personal "growth rings" – one ring for each year of their lives.

Standards:		1st	2nd	3rd	4th	5th
CCSS--ELA	Speaking and Listening	2,5,6	2,5,6	2,5,6	2,5,6	2,5,6
EEEGL	Strand 1	A,B,C,E,F,G				A,B,C,E, F,G
NGSS	Structure, Function, and Informational Processing	LS1.B				
	Earth's Systems: Processes that Shape Earth		ESS1.C		ESS1.C	
	Inheritance and Variation of traits: Life Cycles and Traits			LS1.B	ESS3.B	

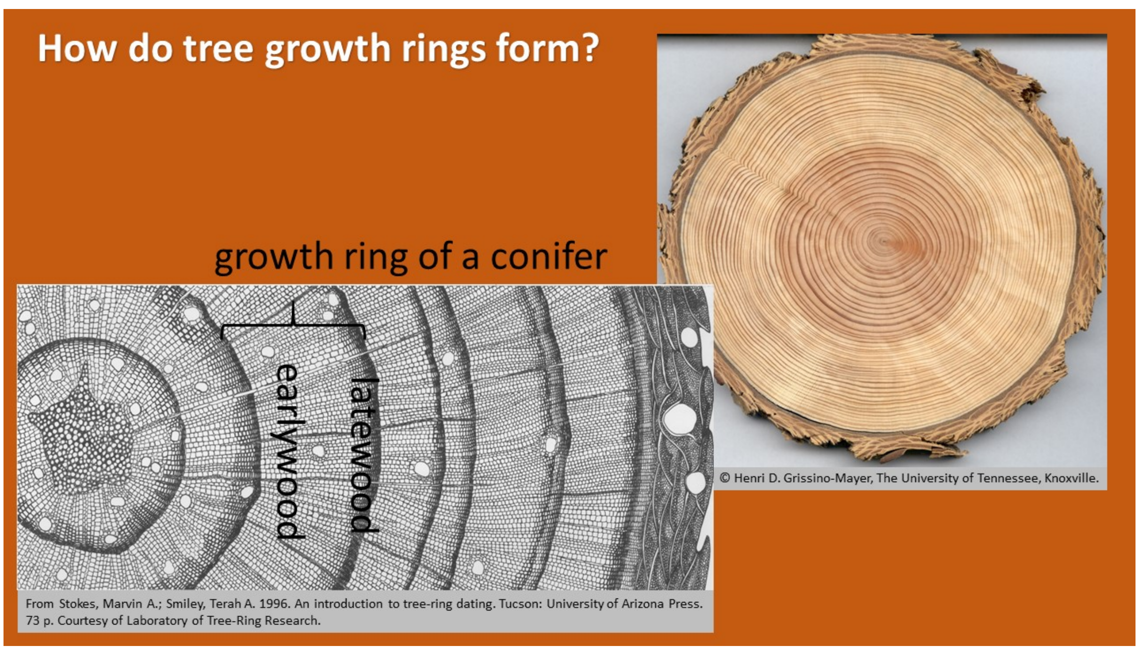
Teacher Background: In temperate ecosystems, tree growth rates vary throughout the year: In winter, trees are dormant and don't produce any new xylem cells. In spring and early summer, when trees have plenty of moisture, they usually grow rapidly and produce very large xylem cells with thin walls. These large cells form a light-colored band in the wood, which is called *earlywood.* Trees usually grow more slowly in late summer and fall, when they have less moisture, so they produce much smaller xylem cells. These cells form a dark-colored band called *latewood.* With a microscope, you can see the relative sizes of the earlywood and latewood cells. Without a microscope, you can still see the bands of wood. The combination of a light-colored band and a dark-colored band is a *growth ring,* and it represents one year's growth – usually. We will make that assumption in this activity.

However, you should know that trees are not entirely reliable at recording their history in one growth ring per year. Stress can affect their growth and hence the development of rings. In a stressful year, a tree might not produce a growth ring at all, or the ring might not go all the way around the tree's circumference. If summer growth slows down due to stress and then accelerates again, the tree might produce a "false ring." We will not address any of those possibilities in this activity, but it may be helpful for you to know about them.

Even if a tree has produced false rings or has had some years without growth rings, scientists can determine exactly what year a growth ring was formed using *dendrochronology.* Lots of information about dendrochronology is available at http://ltrr.arizona.edu/about/treerings. If you would like to delve into this field and teach dendrochronology in your classroom, look for materials at http://ltrr.arizona.edu/educators.

Materials and preparation:

- **Decide** how much detail to ask for in the students' autobiographies (see **Assessment** below.) If you want much detail, you could introduce the project a day or two ahead and have students talk to their families about when various things happened in their lives.
- Download and project ***GrowthRingsForm.pptx***.



- If you have a FireWorks trunk, get out all tree cross-sections so students can examine them in detail. If you don't have a trunk, you might be able to obtain a few cross-sections locally.

Procedure:

1. Explain: In this activity, we're going to learn how trees grow and compare that to the ways in which we humans grow.
2. Ask: How is your body different now from when you were a baby? When the students describe obvious changes (taller, heavier, more hair, teeth…), try to get them to

describe how those things happened. For example, how did your legs get longer? My bones grew longer & I put more muscle on them…. How did your head get bigger? My skull grew and I kept filling it with new brain cells.

3. Ask: Trees get taller and heavier too as they grow up. They also get wider and grow more branches. Do they do it just like we humans do, by growing longer bones and adding muscle cells, brain cells, etc? No, trees grow mainly by producing new rings of wood every year and adding length to their top, branches and roots. Refer to ***GrowthRingsForm.pptx*** and any real tree cookies that you can pass around. Explain: Scientists Chris Baisan and Rex Adams obtained the "tree cookie" that's shown in this photo from a Douglas-fir tree in New Mexico. They used it to learn about how old the tree was and how it grew. How do you think they did that? They counted its growth rings to estimate the tree's age.
4. Can you see growth rings in the tree cookie? Explain, referring to the microscope photograph shown in the ***GrowthRingsForm*** display***.*** In spring and early summer, when trees have plenty of moisture, they usually grow rapidly and produce very large xylem cells. These large cells form a light-colored band in the wood, which is called *earlywood.* In late summer and fall, trees usually grow more slowly because they have less moisture, so they produce much smaller xylem cells. These small cells form a dark-colored band called *latewood.* The combination of a light band and a dark band is a *growth ring,* and it represents one year's growth.
5. Ask: In the cookie shown in ***GrowthRingsForm.pptx,*** what is the brown ring on the outside? Bark – which protects the tree but doesn't get counted as an annual ring because it stays outside the tree's growing wood as it produces new rings from year to year. Bark is a little bit like our skin, which stays on our outside as bones and organs on the inside get bigger. Like our skin, a tree's bark fits perfectly around its insides.
6. Review with students: We can count growth rings to estimate the age of a tree and learn other things about its history, like when the tree had an especially good or difficult year. Ask: How do you think the ring from a very dry, stressful year might look? Probably narrow. What would the ring from a perfect year look like – plenty of water, plenty of sunshine, plenty of space and nutrients? Probably wide.
7. **OPTIONAL:** Explain that COUNTING growth rings can only give us an *estimate* of a tree's age, because sometimes trees grow in unusual ways. Once in awhile, they grow two rings in one year, or a partial ring, or no ring at all! For now, we will assume that every ring represents one year of growth.
8. We're going to use some imagination now. We'll pretend that we have growth rings, just as trees do, and we'll use these growth rings to show our *autobiography.* Explain: You must know the year of your birth to do the activity. (Help them figure that out if they don't know.)
9. Give each student a sheet of drawing paper. Have them write their names and "My Tree Autobiography" at the top. Have them fold their paper in half the "short way," then unfold it. Explain: The left side is for drawing their growth rings, and the right side is for writing an autobiography. (See the example below. Note that it was prepared with PowerPoint though. Don't expect your students to all draw tidy circles!)

Assessment: Have students begin together as you demonstrate the first few steps. Then have them complete the activity individually:

- In the center of the left half of the page, draw a small star, since you ARE the star of this story. Draw a small circle around it. Write your birth year inside the circle.
- On the right half of the page, near the top, write your birth year and add, "I was born!"
- Draw another circle around the first one. Write the next year in the circle. On the right half of the page, write that year under the first. Add "I had my first birthday."
- Draw and label another circle and write the date on the right.
- Continue to draw circles and list dates until you get to the current year. If you remember an especially good year for you, make the ring wide. If you remember that as a hard year, make it narrow. On the right half of the paper, write the current year and "This year I am in third (or fourth or whatever) grade." Then draw a ragged circle around all of the circles to represent the tree's bark.
- Take your diagram home OR work with the teacher to find out something important about at least 5 of the years during your lifetime. Write each of these facts on the right half of the page next to the year when it happened. Use a complete sentence for each fact. You might include the birth of a brother or sister, the year you started school, or when you went on a special vacation or moved to a new home. You could include the arrival or loss of a pet, or an illness or death or other crisis.

TEACHERS, it might be fun to post the students' autobiographies, but be cautious about this too. Some may not want to share their histories, or they may record sensitive, personal events that should not be shared.

Evaluation:	**Full credit**	**Partial credit**	**No credit**
Drawing	Student drew a reasonable likeness of a tree cookie, with 1 growth ring for every year of his/her life.	Student drew a reasonable likeness of a tree cookie, with several growth rings.	Student's diagram did not resemble a tree cookie.
Writing	Student listed all the years of his/her life and used a complete sentence to identify something special about at least 5 years.	Student listed most of the years of his/her life and identified something special about at 3-5 years.	Student listed only a few years of his/her life and identified something special about fewer than 3 years.

Example Tree Autobiography

2007 - I was born.

2008 – In this year, I had my first birthday.

2009 – My sister was born.

2010 – We went to the ocean. I found seashells.

2011 –

2012 – My dog Sadie was born.

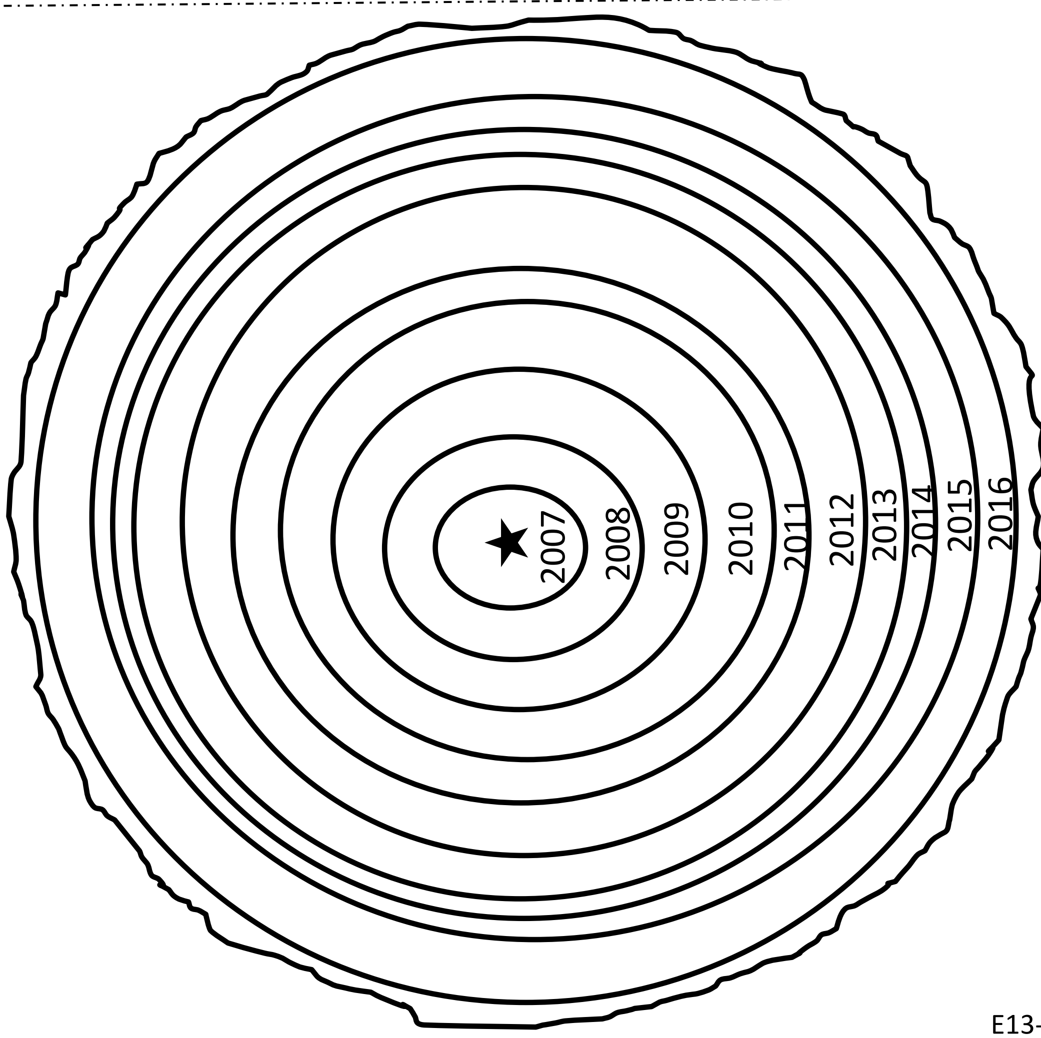
2013 – I started Kindergarten.

2014 – My cousin stayed at our house.

2015 –

2016 – This year I am in 3rd grade.

Fold paper in middle.



13-2. Story of a Fire-scarred Tree

Lesson Overview: Students will create a human model demonstrating how fire scars are formed on a tree trunk. Then they will examine a cross section from a fire-scarred tree that is provided in the trunk and describe its fire history.

Lesson Goal: To increase students' understanding of how trees can survive fires, how fire scars are formed, and how some trees have survived frequent fires.

Subjects: Science, Mathematics, Reading, Writing

Duration: Two half-hour sessions

Group size: Whole class

Setting: Classroom. Second part of activity will be at a station where students work 1-2 at a time.

New FireWorks vocabulary: *catface, fire scar*

Objectives:

- Students can calculate the years between fires from a sample.
- Students can find the longest, shortest, and average intervals between fires.
- Students can write a report that summarizes the fire history of the tree.

Standards:		1st	2nd	3rd	4th	5th
CCSS--ELA	Speaking and Listening	2,5,6	2,5,6	2,5,6	2,5,6	2,5,6
	Reading Informational Texts	4,10	4,10	4,10	4,10	4,10
EEEGL	Strand 1	A,B,C,E,F,G				A,B,C,E, F,G
NGSS	Structure, Function, and Informational Processing	LS1.B				
	Earth's Systems: Processes that Shape the Earth		ESS1.C		ESS1.C	
	Inheritance and Variation of traits: Life Cycles and Traits			LS1.B		

Teacher Background: Fire has been a part of the history of most forests in North America for thousands of years. Tree *growth rings* and *fire scars* (scars made by fires on tree trunks) tell about a forest's fire history. In this activity, students participate in a short drama that helps them visualize how fire can scar a tree without killing it. Then they make observations, record data, and use it to imagine and tell the history of a single tree that has survived several fires during its lifetime. Note that **each trunk has its own, unique fire-scarred tree cookie** and a completed version of the handout for that cookie. The handout key shown below is just an example.

Fire scientists use many specialized terms to describe fires and their effects. For this grade level, we simplify a bit. We use surface fire – a term that students learned when they modeled the parts of a living tree (**Activity E09**) – to mean fires that burn underneath the large trees in a forest without killing them. However, surface fires actually can kill even very large trees by killing their cambium or roots. At this grade level, we might refer to that kind of fire as a "very hot" surface fire. At higher grade levels, we use more precise technical terms: *low-severity* fire for fires that kill few or none of the mature trees, and *stand-replacing fire* for fires that kill most of the mature trees (because a new generation of trees must develop to *replace* the ones killed by fire).

We also simplify for this grade level by assuming that a tree produces one (and only one) growth ring each year. That is not always true, as student learned in **Activity 13-1. My Tree Autobiography: Seeing History through Trees' Growth Rings**.

Materials and preparation:

- Find a small whisk broom (or fold orange construction paper into a fan) and a piece of black plastic or cloth about 25 cm inches wide and 0.5-1.0 m long.
- Make 1 copy/student of **Handout E13-2-01. A Tree's Story**.
- View the video at www.youtube.com/watch?v=MyFBYQh_S_M to see how the human model of fire scar formation works. The model is also described in Step 3 below.
- Download and project ***E13_2_FireScars.pptx***.
- Display the long poster that shows a fire-scarred tree trunk (**LifesizeFireScar.pptx**). Hang it so its bottom reaches the floor. NOTE that this poster is about 50% of actual size.
- Display the fire-scarred tree cookie from the FireWorks trunk. You will examine it with the class, so try to stand it up against the board or a wall. Later, students will study it 1-2 at a time to complete the handout. At that point, lay it down on a table so they can examine it closely. **Note: Every FireWorks trunk contains a different specimen.** Your trunk contains a copy of Handout E13-2-01 with the data from your specimen. The answer key at the end of this lesson just one example, showing data from tree 51-25-03[1].

Procedure:

1. Start by examining the long poster of the fire-scarred tree trunk with the class. (If you do not have the poster, you can project the PowerPoint **LifesizeFireScar.pptx.** Have students ever seen a scar like this on a tree trunk? It is called a *catface.* What caused the scar? Anything that scrapes away the tree's bark and kills part of its cambium can create a catface. Fire-scarred catfaces usually start from the ground, are triangular, and have vertical creases in them. Have a few students stand in front of the scar. Have them reach up as high

[1] Moody, Tadashi J.; Fites-Kaufman, JoAnn; Stephens, Scott L. 2006. Fire history and climate influences from forests in the northern Sierra Nevada, USA. Fire Ecology. 2(1): 115-141.

as they can. Can they reach the top of the scar? Explain that the photo is only about half the size of the actual tree, so the scar would actually reach much higher than is shown here.

2. Give each student a copy of **Handout E13-2-01. A Tree's Story**. Discuss the close-up photo on the handout: Where do the dark vertical creases come from – the ones that the red arrows point to? Each crease shows where the tree grew new wood after a fire, from the undamaged cambium at the edge of the damaged wood. The creases are *fire scars.*

3. We are going to do an activity together, as a class, to learn more about how fire scars form.

   a) One student stands up and holds his/her arms out in a circle, forming a ring that represents the tree's cambium – the layer under the bark that is essential for continued growth.

   b) One student acts as a surface fire. He/she uses the whisk broom to "burn" from one side of the tree around to the other side and then continues on away from the tree. Explain: This is a surface fire. It might kill a few trees, but it is not "hot" enough to kill very many, like a crown fire would.

   c) Interview the "tree." Ask how he/she felt during the fire. Point out that the tree is still alive, since it is talking!

   d) Explain: The tree is alive, but the fire was hot enough to kill a little of the cambium, the area where the student's hands are. Drape your piece of black cloth or plastic over the "killed" section to remind the class that these cells are dead and cannot produce a new growth ring the next year.

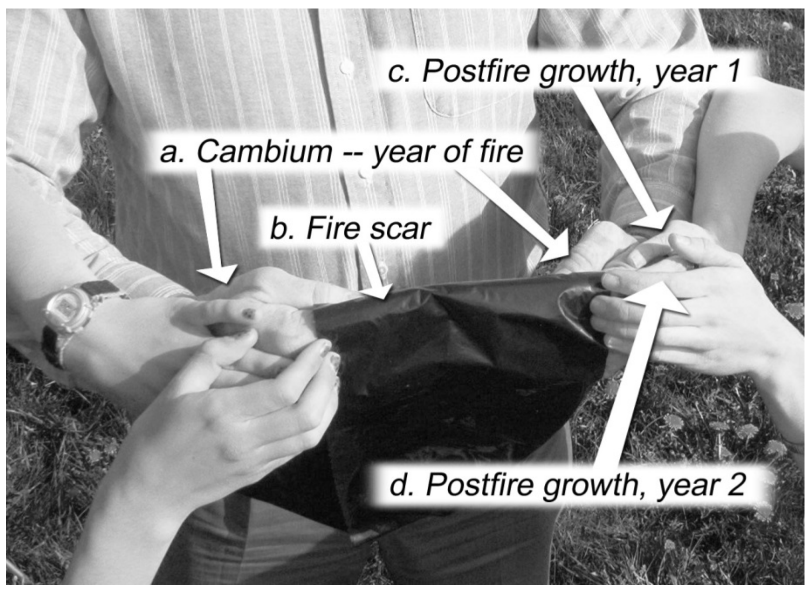


Figure E13-2-01. Students build a living model of tree cambium and fire scar with their hands.

   e) Explain: A year has gone by. Get two more students to help, one standing on each side of the "tree." They are the next year's growth ring. Each places a hand against the arm of the "tree," right at the edge of the area killed by fire (which is covered in black). They can't cover the black area because those cells are dead, unable to divide anymore.

   f) Get two more students to represent the tree's growth in the second year after fire. They place their hands on top of those of the last two students. Their hands can overlap the black cloth a little, curling around the fingertips that represent last year's growth. This shows that the cells at the edges of the scar divide both outward and laterally, so wood is beginning to grow over the scar. This is how the "bubble" of growth forms at each side of a fire scar.

g) Use more pairs of students to represent more years of growth after fire so they can see how the new wood curls over the old scar.

h) Point out that fire created two vertical creases in the wood – one on each side of the catface.

i) If you wish, have another surface fire and form two more bubbles of postfire growth, one on each side of the catface.

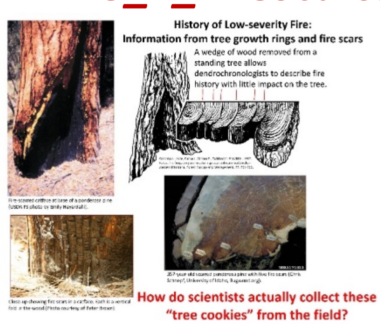
j) Explain: Sometimes the growing wood from the two sides of the fire scar comes together from both sides. Do you see how that could happen? Then the bark covering the live wood also comes together. Eventually, the bark hides the scar from anyone who doesn't know about fire scars. To those "in the know," like this class, a sort of caved-in look suggests that the tree has survived many surface fires and has had a long time to heal.

4. With the class, examine the fire-scarred tree cross section from the trunk. Explain: Scientists cut this specimen from a tree or stump on the Plumas National Forest so they could learn about the forest's fire history. To learn how scientists can get a specimen without cutting down a live tree, go through the presentation ***E13_2_FireScars.pptx***. (The 6 slides are shown below.)

5. Discuss the fire-scarred tree specimen in the trunk. Can they see the vertical creases of some fire scars? Can they see how bubbles of wood grew part-way over the scar after each fire? Some of the bubbles may have lost their rounded edges because later fires burned the outer wood away.

Slides from *E13_2_FireScars.pptx*

Slide 1



Slide 2

A wedge was cut from this standing dead tree.

Photo courtesy of Dr. Emily Heyerdahl, USDA Forest Service, Missoula Fire Sciences Laboratory, Missoula, MT

Slide 3

Top and bottom cuts have been made.

After top and bottom cuts, 2 vertical cuts free the wedge.

Photos courtesy of Dr. Emily Heyerdahl, USDA Forest Service, Missoula Fire Sciences Laboratory, Missoula, MT

Slide 4

Fallen dead trees provide a lot of information on fire history.

Photo courtesy of Dr. Emily Heyerdahl, USDA Forest Service, Missoula Fire Sciences Laboratory, Missoula, MT

The sawyer wears protective clothing to work safely.

Side 5

The wedge from this old log had many fire scars.

Photo courtesy of Dr. Emily Heyerdahl, USDA Forest Service, Missoula Fire Sciences Laboratory, Missoula, MT

Slide 6

Assessment:

1. Explain to students: You will use words and mathematics to describe the fire history of the tree specimen from the trunk. You will work on the handout at an activity station, individually or 2 at a time.
2. Work with the students as a class to answer Question 1 and start on Question 2. See the **Sample answer key to Handout E13-2-01** below for an example.
3. If the students have not done division yet, skip Question 6 and the corresponding part of their report.
4. The final question on the handout requires some outside research on human history. It is not essential to understanding the science of fire history, but it will help give students some sense of the age of the tree cookie and the length of time during which surface fires visited regularly.

Evaluation: See the **answer key to Handout E13-2-01** for the specific fire-scarred tree cookie in your trunk.

Handout E13-2-01. A Tree’s Story

Name: ______________________

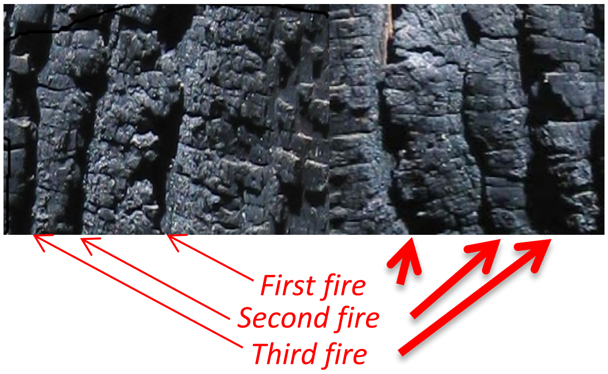
This is a close-up picture of a *catface*. It shows scars from three fires. Three arrows show where the fires scarred the <u>left side</u> of the catface.

1. Draw 3 more arrows above to show where the fires scarred the <u>right side</u> of the catface.
2. Look at the fire-scarred tree cookie in your classroom. In the table on the right, under “Fire year,” write the date of every fire scar on the tree cookie. Write the dates in order, from the most recent to the oldest. You might not need all the lines.
3. Figure out how many years occurred between fire years. To do that, subtract each date from the date above it and write the answer under “Years between fires.”
4. What is the longest time between fires? ________ years
5. What is the shortest time between fires? ________ years
6. What is the average time between fires? That is the total of the “Years between fires” column divided by the number of entries in that column. _____
7. Write a report of your results. Give it a title, author (you), and date. Write at least 1 paragraph. Use complete sentences. Tell the reader how many fires the tree experienced, the longest and shortest time between fires, and the average number of years between fires. Tell the reader if the average is shorter or longer than your lifetime. Tell the reader at least 1 fact from human history that occurred during the tree’s lifetime.

Fire year	Years between fires

Sample answer key to Handout E13-2-01 - for Tree 51-25-03[2]

Actual answers will depend on which tree cookie is in your trunk.



Fire year	Years between fires
1840	
	11
1829	
	7
1822	
	10
1812	
	7
1805	
	6
1799	
	5
1794	
	6
1788	
	22
1766	
	18
1748	

1. Draw 3 more arrows above to show where the fires scarred the right side of the catface.
2. Look at the big fire-scarred tree cookie in your classroom. In this table, under "Fire year," write the date of every fire scar marked on the tree cookie. Write the dates in order, from the most recent to the oldest. You might not need all the lines.
3. Back at your desk, figure out how many years occurred between fire years. To do that, subtract each date from the date above it and write the answer under "Years between fires."
4. What is the longest time between fires? 22 years
5. What is the shortest time between fires? 5 years
6. What is the average time between fires? That is the total of the "Years between fires" column divided by the number of entries in that column. 10.2 years
7. Write a report of your results. **Evaluation:** Does the report have these items?
    - title
    - author's name
    - date
    - 1 paragraph or more
    - complete sentences
    - how many fires the tree experienced
    - the longest and shortest time between fires
    - the average number of years between fires
    - Statement: whether the average is shorter or longer than the author's lifetime
    - 1 fact from human history – will require some outside research by the student

[2] Sampled for the following study: Moody, Tadashi J.; Fites-Kaufman, JoAnn; Stephens, Scott L. 2006. Fire history and climate influences from forests in the northern Sierra Nevada, USA. Fire Ecology. 2(1):116-141.

14. Story Time: Fire and Succession

Subjects: Science, Reading, Speaking and Listening
Duration: Several 30-minute class sessions
Group Size: Whole class
New FireWorks terms: refer to the *Storrie Fire Story* narrative for a list of potentially new terms

Overview: Students view an animated, narrated presentation of the *The Storrie Story*. They participate in the presentation by contributing sound effects on cues. *The Storrie Story* describes the Storrie Fire of 2000 in the Plumas and Lassen National Forests and succession after fire. It covers forest communities and wildlife that occur in Sierra Nevada lower and upper montane forests.

Note: *The Storrie Story* has 5 chapters. You may want to spread the activity out over several days, presenting 1-2 chapters each day.

Goal: Increase student understanding of the many kinds of changes that occur in forest communities over time – with and without fire.

Objectives:

- Students can listen to and learn about how fires affect the plants and animals that live in Sierra Nevada forests, and about how forests change over time.
- Students can participate in a listening activity by providing appropriate sound effects on cue.
- Students can write about or illustrate different types of fire and the responses of various organisms to fire.

ABOUT STUDENT PRESENTATIONS: If you did **Activity E08. Who Lives Here? Adopting a Plant, Animal, or Fungus**, make sure all student presentations are completed before you do this activity.

Standards:		1st	2nd	3rd	4th	5th
Common Core ELA	Writing Standards	2,3,5,6	2,3,7,8	3,7,8	3,7,8	3,8
	Speaking and Listening	2,4,5,6	2,4,5,6	2,4,6	2,4,6	2,4,6
NGSS	Interdependent Relationships in Ecosystems		LS2.A, LS4.D	LS2.C, LS2.D,LS4.C		
	Weather and Climate					ESS2.D
	Matter and Energy in Organisms and Ecosystems					LS2.A
	Structure, Function, and Information Processing	LS1.A, LS2.B			LS1.A	
	Inheritance and Variation of Traits			LS1.B		
EEEGL	Strand 1	C,E,F,G				C,E,F,G

Teacher Background: Forests change over time in the process called *succession*. Fire is a dramatic force for change, but change occurs without fire, too. Some plants need sunny openings to grow well, so they thrive in the first years after fire, and some animals thrive on these plants. 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.

The Storrie Fire Story is a cartoon-illustrated narrative that describes succession through time in montane ecosystems of the Sierra Nevada and tells the story of a real wildland fire, the Storrie Fire that occurred in 2000 on the Plumas and Lassen National Forests. The story has 5 chapters:

1. **Who's at Home Here?** introduces the plants and animals that have lived in the lower and upper montane forests of the Sierra Nevada for many centuries. This chapter sets the scene for the story of historical fire and succession, and changes that have occurred in the past 150-200 years.
2. **Surface Fire Visits the Canyon** illustrates a low-severity fire spreading through the lower montane ecosystem and shows how the native plants and animals respond to this kind of fire.
3. **Rollercoaster Fires** illustrates a mixed-severity fire spreading through the upper montane ecosystem. It shows the fire becoming very severe as it spreads through a Baker cypress stand. It shows how the native plants and animals respond.
4. **Changing times** describes changes in montane forests over the past 100 years or so, as fire was excluded from montane forests of the Sierra Nevada.
5. **The Storrie Fire** illustrates what happened in August of 2000, when a human-caused fire burned thousands of acres in the Plumas and Lassen National Forests. Then it describes how the landscape and the people responded to the fire.

After the class has heard the whole story of the Storrie Fire, students create their own artistic or written comparison/contrast of 2 chapters in the story.

Materials and Preparation:

- Download 5 PowerPoint Presentations: ***StoryTime_Chapter1.pptx****, and* ***Chapters 2, 3, 4*** *and* ***5****.*
- In the trunk, find the poster with the key to the Story Time characters (***CharactersKey.pptx***) and display it in your classroom.
- In the trunk, find the color printout of the narrative for *The Storrie Fire Story* (**TheStorrieFireStory.docx**) - or arrange to read it on a computer. If you intend to use the Internet links for sound effects, you will need to open the file on a computer. Review the first page of this document for instructions.
- Decide how you want students to prepare for sound effects. For animal sounds, you can have groups of students rehearse ahead of time by listening to the Internet links provided with the narrative. Or you can go to those links as you tell the story, having the whole class learn the bird call or animal sound together.

Procedure for each of the 5 chapters:

1. Gather the students, perhaps in a circle, and prepare them for a story about a forest community. Explain: They should listen carefully to the story so they can see what fire does over many years, and so they are ready to create sound effects when you give them a cue.
2. Ask students to watch for a few special things in the stories:
    - Things that cause habitat changes over the years
    - Plants and animals that especially like just-burned forests
    - Plants and animals that especially like old, unburned forests
3. Read the story (**TheStorrieFireStory.docx**) along with the slides (***StoryTime_Chapter1.pptx****, and* ***Chapters 2, 3, 4*** *and* ***5***). Use lots of sound effects, even where the script does not call for them.

Assessment: You may want to make the printed narrative of *The Storrie Fire Story* from the trunk available so students can refer to it.

1. Explain: Think about the five chapters in *The Storrie Fire Story*. In every chapter except Chapter 1, we saw how forests change over time. We learned how forests change if fire occurs and also if it does not occur.
2. Review what happened in each chapter:
    - Chapter 1. Who's at Home Here? (setting the stage)
    - Chapter 2. Surface Fire Visits the Canyon (low-severity fire)
    - Chapter 3. Rollercoaster Fires (mixed-severity fire, including stand-replacing fire in a Baker cypress stand)

- Chapter 4. Changing times (a century or more without fire)
- Chapter 5. The Storrie Fire (a big, severe fire that occurred in 2000)

3. Explain: You will create a comic strip/drawing or write 2 paragraphs that compare/ contrast 2 of the chapters. Your project should include these things:
    - Plants that live there (if drawing, label them)
    - Animals that live there (if drawing, then label them)
    - Kind of fire that that occurred (if any)
    - What changes occurred during the chapter

Evaluation:	**Complete**	**Incomplete**
Comic strip/Drawing Option	-Student addressed all four items listed above.	-Student addressed less than four items.
Writing Option	-Student wrote two complete paragraphs in which they addressed the four items listed above.	-Student did not write 2 complete paragraphs or -Student addressed less than four items.

Unit VII. People in Fire's Homeland

15. Homes in the Forest: An Introduction to "Firewise" Practices

Subjects: Science, Reading, Writing, Speaking and Listening, Health
Duration: one class period
Group Size: Whole class
Setting: Indoors
New Fireworks Vocabulary: *firewise*

Overview: Students use their knowledge about vegetation, fuels, and fire behavior to develop some rules that can help people protect their homes from wildland fire. Then they apply their rules by assessing photos of wildland homes, asking how "firewise" they are, make recommendations to the home owners, and justify their recommendations.

Goal: Based on an understanding of wildland fire, students can assess how well homes are protected from fire and recommend ways to improve their protection.

Objectives: Given a list and/or images of things that homeowners can do to protect their homes from wildfire:

- Students can assess the hazards on and around homes in wildland settings.
- Students can recommend steps to improve their protection from wildland fire.
- Students can give reasons for their recommendations.

<table>
<tr><th>Standards:</th><th></th><th>1st</th><th>2nd</th><th>3rd</th><th>4th</th><th>5th</th></tr>
<tr><td rowspan="2">Common Core ELA</td><td>Writing Standards</td><td>1,2,3</td><td>1,2,3</td><td>1,8</td><td>1,10</td><td>1,10</td></tr>
<tr><td>Speaking and Listening</td><td>1,2,3,6</td><td>1,2,6</td><td>1,3,4,6</td><td>1,4</td><td>1,4</td></tr>
<tr><td rowspan="4">NGSS</td><td>Engineering Design</td><td></td><td>ETS.1A,B,C</td><td></td><td></td><td>ETS1.A,B,C</td></tr>
<tr><td>Interdependent Relationships in Ecosystems</td><td></td><td>ETS1.B</td><td>LS4.D</td><td></td><td></td></tr>
<tr><td>Weather and Climate</td><td></td><td></td><td>ESS3.D, ESS3.B</td><td></td><td></td></tr>
<tr><td>Earth's Systems: Processes that Shape the Earth</td><td></td><td></td><td></td><td>ESS3.B, ETS1.B</td><td>ESS3.C</td></tr>
<tr><td rowspan="3">EEEGL</td><td>Strand 1</td><td colspan="4">A,C,G</td><td>A,C,G</td></tr>
<tr><td>Strand 2.4</td><td colspan="4">A</td><td>A</td></tr>
<tr><td>Strand 4</td><td colspan="4">B,D</td><td>B,D</td></tr>
</table>

Teacher background: All photos in this activity were provided on the homepage of Firewise, a product of the National Fire Protection Association:
http://www.firewise.org/wildfire-preparedness/teaching-tools/photo-library.aspx
This activity is meant to challenge the students to apply their knowledge about fire science to a real-world problem. It is no substitute for a thorough assessment of a home's protection from wildland fire. The Firewise website provides excellent materials for that purpose.

Here are the main Firewise questions and associated fire behavior principles for the photos used in this activity:

- Are there any ways that a surface fire could spread from the edge of the forest right up to the home? Why does it matter? (Surface fires need continuous fuels and spread especially well in dead, dry fuels.)
- Are there any places where an ember blown on the wind could land on or under something burnable and then start the home on fire? Why does it matter? (Fires need fuels… heat rises, so a smoldering ember under a deck or eave is dangerous.)
- Are there ladder fuels at the base of trees near the house? Why does it matter? (Surface fires can use ladder fuels to climb into tree crowns, and embers can fly from a burning tree crown)
- Do you think the road is wide enough and good enough for a fire engine to get to the house? (Not likely to emerge from their study of fire science, but worth bringing out in discussion)

Materials and Preparation

- Download and project ***E15-1_FirewiseHomes.pptx***. OPTIONAL: If you want to go through additional photos with the class, download ***E15-2_MoreFirewiseHomes.pptx*****,** which has another 8 photos.
- Make copies of **Handout E15-1: Work to do on this home**, for half of the class, and make copies of **Handout E15-2: Work to do on this home**, for the other half.

Procedure

1. Write on the left side of the board: "Ecosystems of the Sierra Nevada need wildland fire." Write on the right side: "Wildland fire can hurt people and destroy homes."
2. Ask: If you think the statement on the left is true (point to it!), stand up. Regardless of how many students stand up, have some discussion on this point. Ask for specific examples of organisms that need fire. Then have students sit down.
3. Ask: If you think the statement on the right is true, stand up. Have a short discussion about this point, if needed. Then have students sit down.
4. Explain: These two things may both be true, but they also create a problem about what to do with fire. Do we want it or not? There are no easy solutions to this problem. What do you suggest? Discussion. Have students explain why various approaches might work, based

on their understanding of fire and fuels. Try to get to the idea that people can take action to reduce the risk of injury or damage to their homes from wildland fire.

5. Let's list some ways to protect a house and property from wildland fire. These are called *firewise* practices. In the middle of the board, write "Firewise Rules." For each suggestion, get an explanation of why it should reduce risk. If the suggested rule is valid, list it on the board. You can use the table below to draw out some rules.

What to do:	**Why it works!**
Screen in the porch and under the deck.	An ember could blow on the wind and land on or under the porch or deck, which is dangerous because fires need fuels…heat rises, so a smoldering ember could start the deck or porch on fire.
Safe driveway	The driveway needs to be wide and good enough for a fire engine to get to the house.
Limited surface fuels (vegetation)	Vegetation near the house create a greater opportunity for embers to catch and fire to spread.
No Trees overhanging house	Trees that overhand the house can easily spread fire to the house.
Green lawn	Green lawns are less likely to catch and spread fire.

6. Explain: Now let's apply our rules and maybe add to them or change them. We'll look at pictures of homes and decide what makes them firewise and what could be improved.

7. Replace the statements to left and right of your rules on the board with: "Good job!" and "Needs work."

8. Explain: For each photo, we'll list firewise practices under "Good job!" and things that the home owner should work on under "Needs work."

9. Go through **E15-1_FirewiseHomes.pptx.** With each photo, ask students to apply their rules to decide firewise the home is. List their thoughts under "Good job!" and "Needs work":

Slides and notes from *E15-1_FirewiseHomes.pptx*

Slide 1

Slide 2

Good job! -- Screened in porch is good, screening under the deck might be good to keep embers out if it was metal screening (although this should not be done with wooden lattice. Also some experts now recommend NOT doing this because the screening can trap embers), wide driveway is good, green grass is good.
Needs work: Clean the roof, get the duff out from base of trees, remove some trees from back of house, make sure area under steps is free of burnables.

Slide 3

Good job! Roof looks clean, there's little vegetation next to house, only a little surface fuels, there are no trees overhanging the house.
Needs work: Replace wood shake roof, rake needles from under trees

Slide 4

Good job! House has a clean roof, there's little vegetation next to house, there are no trees overhanging house, there's a green lawn.
Needs work: Water the lawn a little more. Could remove some of the trees behind the house.

Slide 5

Good job! House has a clean roof and a green lawn, there's no vegetation close to house, house has shingle roof **Needs work:** Get rid of the wood latticework below deck. Make sure there's no flammable stuff under there. Replace bark chips below deck with rocks.

10. If you want to evaluate more photos, use **E15-2_MoreFirewiseHomes.pptx**. The slides and notes are listed at the end of this activity.
11. Ask: Now that we've looked at some real homes, can you think of anything that should be changed in our list of firewise rules or added to it. Discussion.
12. Work with the class to make a simple "Firewise checklist" – 5 or more questions that anyone can use to evaluate a home's protection from wildland fire. Example questions:
    - Is the roof clean?
    - Is there a strip of un-burnable material separating vegetation from the house?
    - Are trees and shrubs close to the house? If so, are they short and far apart?
    - Are there low branches or other "ladder fuels" under the trees?
    - Is the lawn green?
    - Is there a screen or unburnable barrier to keep embers from landing under the deck and steps?
    - Is there a road wide enough for a fire engine to get in while people are getting out?

Assessment:

1. Give each student either **Handout E15-1: Work to do on this home** or **E15-2: Work to do on this home**.

2. Have them complete their individual handouts.
3. Then have them team up with someone who completed the other version, trade handouts, and try to improve both.

Evaluation:
Here are some points that the students should make about the two photos:

	Good Job!	Needs Work.
Handout E15-1	Clean roof Wide gravel driveway No vegetation right next to house Woods near house are open, airy	Screen under the deck
Handout E15-2	Clean roof Woods near house are open Some barriers to keep embers from under deck	Screen more under the steps and deck Mow grass near house Water grass

Handout E15-1: Work to do on this home?

Name: _______________

1. Good job!

2. Needs work:

3. This will help because…

Handout E15-2: Work to do on this home?

Name: _______________

1. Good job!

2. Needs work:

3. This will help because…

Slides and notes for *E15-2_MoreFirewiseHomes.pptx*

Slide 1

Slide 2

Good job! Asphalt shingles – nonflammable.
Needs work: Clean the roof! Prune the limbs of trees that hang over the roof.

Slide 3

Good job! It's difficult to see positives from this distance and at this angle.
Needs work: Clear out shrubs and trees close to the house! Make sure there's a fuel separation between house and vegetation – rock or green lawn.

Slide 4

Good job! Asphalt shingles – nonflammable.
Needs work: Clean the roof! Trees seem to be hanging over the house, and limbs surround the chimney. Clear the branches away.

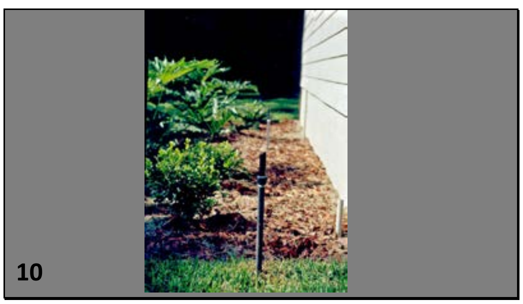
Slide 5

Good job! Trees in the area around the house have been thinned. The house looks free of clutter such as wood piles. The roof is clean.
Needs work: Get rid of logging slash. Prune lower branches from trees. Now that the area close to the house has been opened up, don't let it get brushy or dry out. Establish and maintain green lawn.

Slide 6

Good job! Clever the way rocks have been used to landscape around the foundation It looks like there's green lawn on the other side of the sidewalk It looks like trees in the background are spaced far apart**.**
Needs work: Can't think of anything other than maintenance.

Slide 7



Good job! It looks like there's some green lawn in the foreground.
Needs work: Are those bark chips next to the foundation? That's not a good idea. Keep the landscaping shrubs watered and moist.

Slide 8

Good job! The landscaping here obviously protected the home from a severe fire. The shrubs in the margin between forest and house are dead, but the rocks under them and the green lawn kept the fire from reaching the house. It looks like the roof is asphalt shingle (fire resistant). It is likely that the home owner keeps the outside of the house clear of debris that could ignite from firebrands.
Needs work: Hard to find anything to suggest.

Slide 9

Good job! Rock foundation for deck is a good idea. The forest is very open around the house. The house is built on a flat spot rather than on the hillside. It looks like there's a green lawn around the house.
Needs work: There seems to be a lot of vegetation around the deck. Reduce it or make sure it's plants that are difficult to ignite.

16. Revisiting Wildland Fire in the Sierra Nevada

> **Subjects:** Science, Writing, Speaking and Listening, Arts, Environmental Education
>
> **Duration:** one half-hour session
>
> **Group size:** Whole class
>
> **Setting:** Indoors
>
> **New FireWorks vocabulary**: *fire manager*

This activity works only if you used **Activity E01. Visiting Wildland Fire in the Sierra Nevada**.

Lesson Overview: Students view the same photo presentation they saw in Activity 1 (***E01_M01_VisitingWildlandFire.pptx***), which shows wildland fires and some of the plants and animals that they learned about in the curriculum. This time, they narrate the presentation themselves. Afterward, they discuss their feelings about wildland fire and whether they have changed from the feelings recorded in **Activity E01**. Finally, in the Assessment, they consider whether a fire manager's job is easy or hard.

Lesson Goals: Reinforce students' understanding that wildland fire is a complicated process that can benefit ecosystems but can also harm people and homes so it must be carefully managed. Demonstrate to students how much they have learned.

Objectives: Given a series of photos…

- Students can describe different organisms and their relationships with fire.
- Students can articulate feelings about fire and compare/contrast them with feelings when they began the curriculum.
- Students can imagine the job of a fire manager and describe its difficulty.

<table>
<tr><th>Standards:</th><th></th><th>1st</th><th>2nd</th><th>3rd</th><th>4th</th><th>5th</th></tr>
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<tr><td>NGSS</td><td>Structure and Property of Matter</td><td></td><td>PS1.B</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Interdependent Relationships in Ecosystems</td><td></td><td>ETS1.B</td><td>LS2.C, LS4.C, LS4.D</td><td></td><td></td></tr>
<tr><td></td><td>Weather and Climate</td><td></td><td></td><td>ESS3.B</td><td></td><td></td></tr>
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<tr><td>EEEGL</td><td>Strand 1</td><td colspan="4">E,G</td><td>E,G</td></tr>
<tr><td></td><td>Strand 2.2</td><td colspan="4">A,C</td><td>A,C</td></tr>
</table>

Materials and preparation:

- Download ***E01_M01_VisitingWildlandFire.pptx*** for presentation to class.
- Find the flipchart with questions that students asked about fire in **Activity E01. Visiting Wildland Fire in the Sierra Nevada**. Post it in the classroom.
- Find the flipchart with students' feelings recorded at the end of **Activity E01**. Don't post it yet.
- Optional: Print the assessment questions on **Handout E16-1** (1/student).

Procedure:

1. Explain: For our final activity in the FireWorks curriculum, we're going to go back to the first activity we did to discover what we have learned about fire and our feelings about it.
2. Go through the questions that came up in **Activity E01.** Ask students to answer them. If they can't, suggest that they consult a local expert or do some research to find answers.
3. Explain: Now we will watch the same presentation that we saw at the start of our study of wildland fire. Last time, we had a short narrative about each photo. This time, you will explain what's going on in each photo, as you were explaining about wildland fire to a friend or family member.
4. Go through the presentation ***E01_M01_VisitingWildlandFire.pptx***. Ask students to provide information about each slide. (The original slides and narrative are provided below.) When you get to the fire behavior slides, ask them what kind of fire each one shows. Slide 1: surface fire or low-severity fire; slide 8: severe or crown fire; slide 14: mixture of fire types or mixed-severity fire; slide 21: smoldering and possibly ground fire.
5. Ask: Do you want to add any answers to the flipchart questions? Do you have more questions? Record these and suggest a way to answer any new questions.
6. Display the flipchart on which you recorded their feelings about fire in **Activity E01**. Remind them that people's feelings often differ without being "right" or "wrong," so all of the feelings from class members in the past are valid and deserve respect, and if they have new or changed feelings, those also deserve respect. Ask if they want to add to the list or discuss changes in their feelings.

Assessment: Ask the students to answer these 5 questions on a sheet of paper or use **Handout E16-1.**

1. What is one new thing that you have learned about how spread in wildlands?
2. What is one new thing that you have learned about how wildland fires affect plants, animals, or fungi in ecosystems?
3. What are two words that describe your feelings about wildland fire?
4. Do you think your feelings about fire have changed? Explain.
5. A fire manager has to make sure plants and animals have enough fire to stay healthy but also keep fire from hurting people and their homes. Do you think this job is hard or easy? Explain.

Evaluation:

Question	Successful	Unsuccessful
1	Provides 1 correct fact about fire spread in wildlands.	“Fact” is incorrect or missing.
2	Provides 1 correct fact about fire effects on an organism.	“Fact” is incorrect or missing.
3	Provides 2 “feeling” words.	Provides 0-1 “feeling” words.
4	Answers question and gives explanation.	Does not answer question or does not give explanation.
5	Answers question and gives logical explanation.	Does not answer question or does not give logical explanation.

Slides and Narrative for *E01_M01_VisitingWildlandFire.pptx*

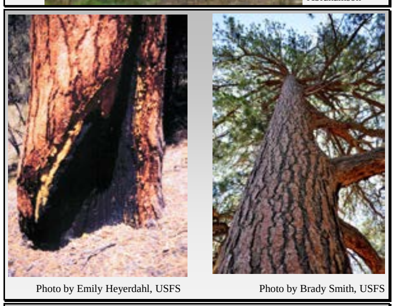
Slide 1

Here is a fire burning in a forest of the Sierra Nevada.

Slide 2

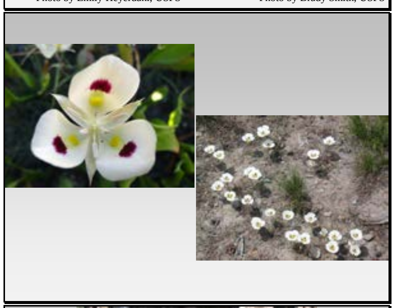
This is what the land looks like after that kind of fire.

Slide 3



Here are some plants that live in the forest after fire:
… A ponderosa pine tree that has survived many fires

Slide 4

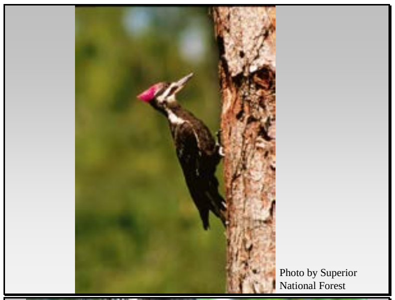


… Mariposa lily, a wildflower that survives fire and then grows really well.

Slide 5

… A California black oak that sprouts after fire.

Slide 6



Here are some animals that live in the forest after fire:
… Pileated woodpecker, which loves big, old trees that have survived fires long ago.

Slide 7

… Western gray squirrels that eat the seeds of trees that have survived the fire.

Slide 8

Here is another kind of fire in the Sierra Nevada.

Slide 9

This is what the land looks like after that kind of fire.

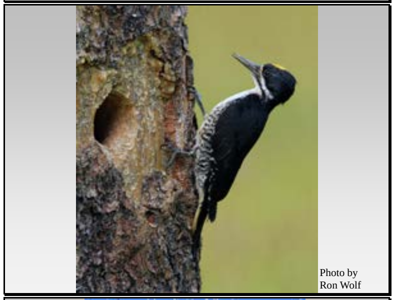
Slide 10

Or this.

Slide 11

Here are some plants and animals that thrive after that kind of fire:
… A beetle with heat sensors, so it can find fires and lay its eggs in just-burned trees.

Slide 12



… A black-backed woodpecker, which arrives soon after the fire to eat the beetles.

Slide 13

… Deer brush, whose seeds germinate after fire cracks open its hard seedcoats.

Slide 14

Here is another kind of fire in the Sierra Nevada.

This is a mixture of the two kinds of fire you've already observed. Many of those plants and animals can live here after fire.

Slide 15

Fire behavior and fire effects vary with topography, weather, and vegetation. Here are examples of fire behavior fires in the Sierra Nevada.

Slide 16

Slide 17

Slide 18

Slide 19

Slide 20

Slide 21

Fires in our forests can burn for a long time after the flames have passed. They may burn in tree trunks, roots, or in the soil itself.

Here is what a fire may look like after most of the flames have moved on (left photo). *Observe and sketch it (D).*

Wildland fires cause changes that last a long time, sometimes for hundreds of years. We'll learn more about all kinds of fire in the activities to come.