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FireWorks Curriculum Featuring Ponderosa, Lodgepole, and Whitebark Pines

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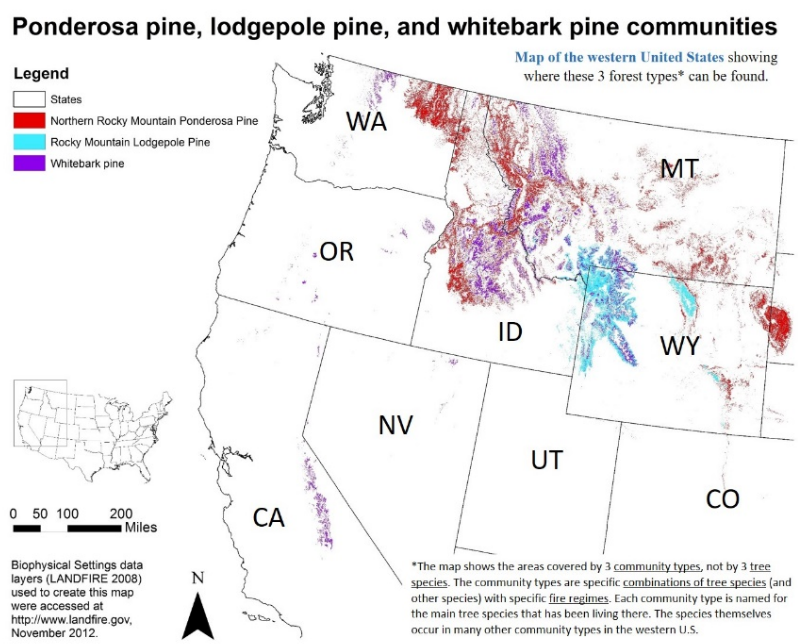
FireWorks: Why?

Change is an integral part of 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).

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 ecological communities (Lindholdt 1999; North American Association for Environmental Education 1999). This version of *FireWorks* focuses on 3 communities that occur from the northern Rocky Mountains through the "intermountain" region to the North Cascades: Northern Rocky Mountain Ponderosa pine[1] (dominated mostly by ponderosa



[1] Common names are used for all species mentioned in the text and associated materials. Corresponding scientific names are available online in the Fire Effects Information System (https://www.feis-crs.org/feis/).

pine and Douglas-fir, Rocky Mountain Lodgepole pine (dominated by lodgepole pine and subalpine fir, and Whitebark Pine (dominated by whitebark pine, sometimes with subalpine fir).

The 3 forest types featured in this curriculum have long, intimate relationships 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. **Table I-1** summarizes this information.

Table I-1—Summary of ecology and "fire story" of some forest communities of the northern Rocky Mountains and North Cascades.

Elevation		Low	Middle	High
Pine species (grows well in sunny, open areas with bare soil)		ponderosa pine	lodgepole pine	whitebark pine
Shade-tolerant species (grows better than pine in shady places and in litter and duff)		Douglas-fir	subalpine fir	subalpine fir
Pine traits for surviving or reproducing well after fire		Open, high crown thick buds thick bark	serotinous cones	Trees in clusters open, high crown seeds planted by nutcrackers
Historical fire regime	Fire severity	Majority of fires are low-severity; some mixed-severity & occasional stand-replacing	Stand-replacing and mixed-severity, with occasional low-severity	Often patchy, mixed-severity. Highly variable in size and severity
	Average fire interval	Ranges from about 6 years to 50 years	Ranges from about 90 years to more than 300 years	Ranges from about 40 years to more than 250 years
Some animals in this community (not limited to this community)		Pileated woodpecker Flammulated owl Elk (especially spring)	Black-backed woodpecker Mountain pine beetle Elk (hiding cover in fall)	Clark's nutcracker Grizzly bear Elk (summer)
Example of traditional use by Native Americans		Peeled bark for nutrition	Cut poles for tipis	Collected pine nuts for nutrition
Disturbances besides fire		Douglas-fir dwarf mistletoe	Mountain pine beetle	Mountain pine beetle, white pine blister rust

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).

Design and Layout of Lessons in This Curriculum

Each *FireWorks* activity has the following sections:

Lesson Overview
Lesson Goal
Objectives
Teacher Background
Materials and Preparation
Procedure
Assessment
Evaluation rubrics
Handouts (if needed)

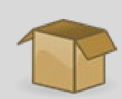
Subjects: Science, Writing, etc…

Duration: a guess

Group size: whole class, teams, etc.

Setting: classroom, lab, outdoors, etc.

Vocabulary (not needed in all lessons)



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 suggested vocabulary terms. 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 answer keys, 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 required curriculum and meet required standards by using hands-on materials based on science from the local area. To help teachers identify the ways in which *FireWorks* can be used to meet their curriculum requirements, each activity is linked to relevant standards from:

- Common Core State Standards in English Language Arts (CCSS-ELA), Math (CCSS-Math), History and Social Studies, Science, and Technical Subjects
- Next Generation Science Standards (NGSS)
- Excellence in Environmental Education: Guidelines for Learning standards (EEEGL)[2]

[2] 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)

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. This diagram shows how to use the table of standards provided with each activity:

1. Find the relevant grade(s).

2. Access the relevant publication (see the links in the footnote above).

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		

3. Open standards publication to the appropriate grade and section.

4. Locate these numbers and read the associated standards.

Safety

Many of the experiments in *FireWorks* use fire and natural fuels. 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 you run the activities smoothly and help your students grow in responsibility and competence regarding lab safety and fire safety:

- Inform 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 may be required to 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.

Three Curricula for Three Grade Levels

FireWorks includes curricula for 3 grade levels: Elementary (grades 1-5), Middle (grades 6-8), and High (grades 9-12). The Elementary curriculum encourages students to learn from demonstrations and simple models and to become acquainted with plants and animals in the local area. The Middle School curriculum challenges students to conduct experiments to answer questions and use information from technical readings to describe fire's role in various ecosystems. The High School curriculum asks students to design and conduct experiments and to apply information from technical articles to management questions. Activities for different grade levels may use the same materials, but the curricula differentiate across grade levels; content is more detailed and the activities are more challenging for older students. You can use **Table I-2** to compare activities on the same theme for different grade levels and select the best approach for meeting your objectives with your students.

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.

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

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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

Table I-2. *FireWorks* Curriculum Plan for the Northern Rocky Mountains and the North Cascades. Read across the table to find similar activities for students at all 3 grade levels.

Unit & Theme	ELEMENTARY	MIDDLE	HIGH
Unit I. Introduction to Wildland Fire	E01. Visiting Wildland Fire in the Northern Rocky Mountains and North Cascades	M01. Visiting Wildland Fire in the Northern Rocky Mountains and North Cascades	H01. Introduction to Wildland Fire in the Northern Rocky Mountains and North Cascades
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?	H11-1. 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	E08-1. What's a Community? All the Living Things in the Ecosystem	M11. Who Lives Here? Adopting a Plant, Animal, or Fungus	H14. Researching a Plant, Animal, or Fungus
	E08-2. Who Lives Here? Adopting 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 Lodgepole Pine Forest: Serotinous Cones	E11. Is appropriate for middle school	
		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' Annual Rings		
		M17-H16. Dating Fires Using Dendrochronology	M17-H16. Dating Fires Using Dendrochronology
		M18-H17. History of Stand-replacing Fire	M18-H17. History of Stand-replacing Fire
	E13-2. Tree Biography, Forest Biography	M19-H18. History of Low-severity Fire	M19-H18. History of Low-severity Fire
		M20. Fire History in Ponderosa, Lodgepole, and Whitebark Pine Forest Communities	H19. History of Mixed-severity Fire
	E14. Story Time: Fire and Succession	M21. Drama in the Forest: Fire and Succession, a Class Production	H20. Why Do Historical Fire Regimes Matter?
		M22. Fire Ecology Puzzler	
Unit VII. People in Fire's Homeland	E15. Carrying Fire the Pikuni Way	M23. Carrying Fire the Pikuni Way	H21. Carrying Fire the Pikuni Way
	E16. Homes in the Forest: An Introduction to Firewise Practices	M24. Homes in the Forest: An Introduction to Firewise Practices	
	E17. Revisiting Wildland Fire	M25. Revisiting Wildland Fire	H22. Northern Rocky Mountain and Northern Cascades Forests Today

Unit I.
Introduction to Wildland Fire

1. Visiting Wildland Fire in the Northern Rocky Mountains and North Cascades

Lesson Overview: Students view a narrated photo presentation that shows wildland fires and some of the plants and animals they will learn about in this curriculum. During the presentation, students record observations about fire behavior. Afterwards, they compare and contrast the kinds of fire they observed, and they describe their feelings about wildland fire. 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.

Subjects: Science, Writing, Speaking and Listening, Arts

Duration: one half-hour session

Group size: Whole class

Setting: Indoors

Vocabulary: *ecosystem, ecological community, fire behavior, wildland, wildland fire*

Lesson Goal: Increase students' understanding that wildland fire is a complicated process that has complicated effects and may generate complicated feelings.

Objectives:

- Students can draw different kinds of fire behavior.
- Students can compare and contrast different kinds of fire behavior.
- Students can describe their feelings about wildland fire.

Standards:		**6th**	**7th**	**8th**
CCSS	Writing	4,10	4,0	4,10
	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	4,7,10	4,7,10	4,7,10
EEEGL	Strand 1	A,E,F,G		
NGSS	Human Impacts	ESS3.B,C		
	Weather and Climate	ESS2.D		
	Matter and Energy in Organisms and Ecosystems	LS2.C,B		
	History of Earth	ESS2.A		
	Interdependent Relationships in Ecosystems	LS2.C, LS2.A, LS4.D		
	Natural Selection and Adaptation	LS4.C		

Teacher Background: If you walk through a recently burned area, you will probably encounter some places where all the vegetation looks dead and other places that have a lot of green vegetation left. You will probably see deep holes in the ground where roots have burned away and also patches of leaf litter that is barely 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 variation in fire behavior and its relationship to specific plants and animals.

This curriculum focuses on 3 kinds of plant communities that occur in the northern Rocky Mountains and the North Cascades: forests at low elevations dominated by ponderosa pine and Douglas-fir, middle-elevation forests dominated by lodgepole pine mixed with subalpine fir and other trees, and high-elevation forests of whitebark pine mixed with subalpine fir. See the **Introduction** for an overview of these ecological communities.

If you plan to teach the units on fire ecology (V and VI), consider having your students adopt a plant, animal, or fungus NOW, so students have time to prepare and you can spread their presentations out over several days instead of having them all at once. See **Activity M-11. Who Lives Here? Adopting a Plant, Animal, or Fungus** for details.

Materials and preparation:

- Load photo presentation ***M01_VisitingWildlandFire.pptx***
- Copy **Handout M01-1. Variety in forests and fires,** 1/student
- Write these terms on the board: species, ecosystem, ecological community
- Set up flipchart or other media for recording questions and feelings. You'll need this list for the final FireWorks activity, **Activity M21. Revisiting Wildland Fire.**

Procedure:

1. Explain to students: We will view a short presentation that shows fires in wildlands. In particular, we'll see different kinds of fire and different ecological communities. An ecological community includes all of the living things in an ecosystem – plants, animals, fungi, and microorganisms. An ecosystem includes the living things plus the nonliving parts of the ecosystem, such as soil, water, and air. Ask for examples of community members in your school. (Remember – only living things.) Ask for examples of the nonliving things in your school ecosystem. Ask which is more inclusive or "bigger" – community or ecosystem? (Ecosystem is "bigger," because it includes the community and also nonliving things.)
2. Explain: You will stop a few times during the presentation and ask students to make notes and sketch what they observe. After the presentation, they will compare and contrast different kinds of fires and also to describe their feelings about wildland fire.

3. Give each student a copy of Handout **M01-1. Variety in forests and fires**.

4. Show the presentation (below). Welcome students to discuss and ask questions about what they see. Record their questions on a flipchart or other medium, but don't try to answer them during the presentation. Instead, explain that the class will seek the answers during their study of wildland fire and will come back to their questions in **Activity 25. Revisiting Wildland Fire**. Be sure to save these questions for Activity 25.

Slide 1


Photo by Garon Smith

Here is a look at some of the wildlands that you might see in the northern Rocky Mountains and the North Cascades. We don't see any flames in this picture, but fire has visited here in the past. We're going to spend the next few days/weeks/months learning about fires in this land.

Slide 2


Photo by Ilana Abrahamson

Here is a fire burning in a forest of the northern Rockies/North Cascades. Explain: Look carefully at the flames in this photo and describe them: What parts of the plants are burning? What "layer" of vegetation is burning – just material on the ground? … only needles in the tree tops? In Part A of your handout, sketch the fire behavior and write a few words to describe it. Be careful to draw flames only in the parts of the vegetation that are burning in the photo.

Slide 3


Photo by Ilana Abrahamson

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

Slide 4


Photo by Emily Heyerdahl, USFS


Photo by Brady Smith, USFS

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

Slide 5

Photo by Ilana Abrahamson

Arrowleaf balsamroot, a wildflower that survives fire and then grows really well

Slide 6

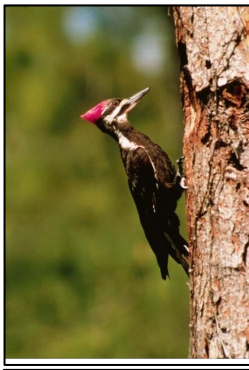


Photo by Superior National Forest

Pileated woodpecker, which loves big, old trees that have survived fires long ago

Slide 7

Photo by Dave Smith

Here is another kind of fire in the northern Rockies/North Cascades. Observe the flames – how tall they are and what layers of the vegetation they are burning. In Part B of your handout, write a few words to describe the fire and sketch the flames.

Slide 8

Photo by Hansueli Krapf

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

Slide 9

Photo by AG Prof. Schmitz

Here are some plants and animals that live in that forest after fire: A beetle with heat sensors, so it can find fires and lay its eggs in trees that are still hot from burning

Slide 10

Photo by Ron Wolf

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

Slide 11

Photo by Jim Peaco, NPS

A patch of fireweed that sprouted after fire and then produced millions of seedlings

Slide 12

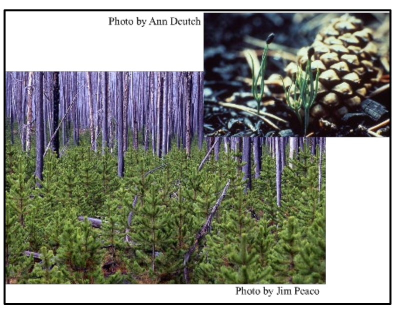


Photo by Ann Deutch

Photo by Jim Peaco

Lodgepole pines that grew from seed after fire

Slide 13

Photo by Bob Keane?

Here is a third kind of fire in the northern Rockies. In Part C of your handout, write a few words that describe the fire and then sketch the flames.

Slide 14

Photo by Ilana Abrahamson

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

Slide 15

Photo by Famartin

Here are some plants and animals that live in that forest after fire: A whitebark pine that has survived several fires

Slide 16

Photo by Michael Sulis

A Clark's Nutcracker, which harvests the seeds of whitebark pines and buries many of them underground so it can eat them later

Slide 17

Photo by Anna Schoettle

A clump of whitebark pine seedlings that sprouted from seeds that nutcrackers buried

Slide 18

Fires in our forests can burn for a long time after the flames have passed. These smoldering fires can burn in tree trunks, in roots, or in the soil itself, making changes that last a long time, sometimes for hundreds of years. In Part D of your handout, write a few words to describe the fire and sketch the flames. We'll learn more about all kinds of wildland fire in the activities to come.

After the presentation, have a brief discussion with the class about variety in fire behavior and also about their experiences with wildland fire and feelings about it. This discussion need not be long; it is a warm-up for the assessment.

Assessment:

Explain to students: Write on the back of the handout or on a clean sheet of paper:

a. a paragraph in which they compare the kinds of fire they observed, giving at least two examples of how the kinds of fire are the same

b. a paragraph in which they contrast the kinds of fire, giving at least two examples of how the kinds of fire are different

c. a list of three words or phrases that describe their feelings about wildland fire. Explain that people's feelings often differ without being "right" or "wrong," so all of the feelings are valid. Also, since their feelings could change over time, they will have a chance to record their feelings again after they've learned more about fire.

Keep the flipchart or other media with students' questions and their handouts so they can be used again in **Activity 25. Revisiting wildland fire**.

Evaluation:

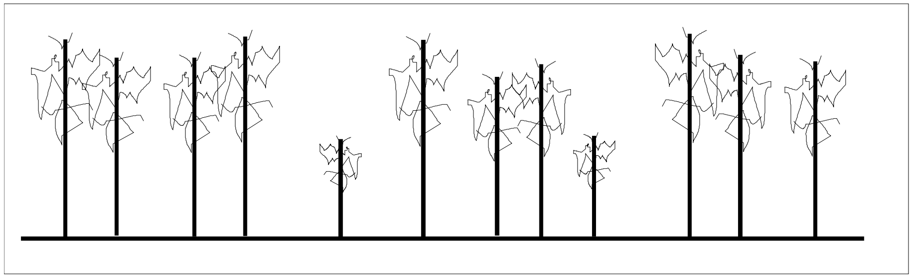
	Good	Fair	Poor
a. Fire Comparison Paragraph	Complete paragraph. Contained two examples of similar fire behavior	Incomplete paragraph. Contained one example of similar fire behavior	Incomplete paragraph. Did not contain examples of similar fire behavior
b. Fire Contrast Paragraph	Complete paragraph. Contained two examples of different fire behavior	Incomplete paragraph. Contained one example of different fire behavior	Incomplete paragraph. Did not contain examples of different fire behavior
c. Fire Feelings List	Three words or phrases about personal feelings about wildland fire	Two words or phrases about personal feelings about wildland fire	One word or no words or phrase about personal feelings about wildland fire

Handout M01-1. Variety in forests and fires

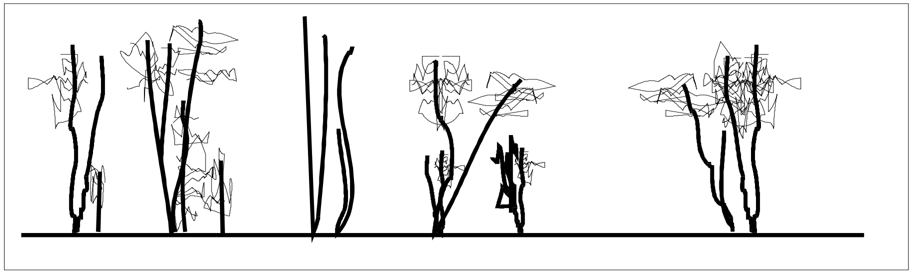
Name ____________________________

1. Color each sketch to show a typical fire in this location.

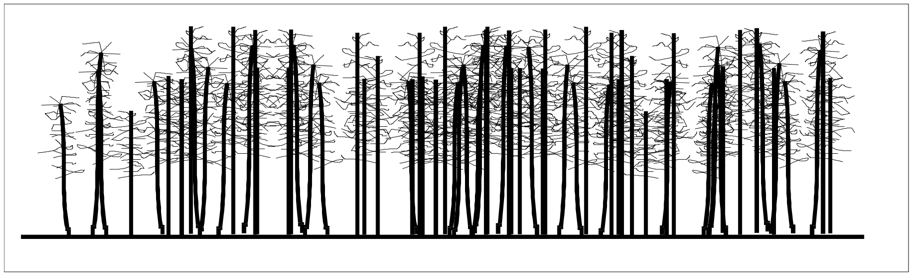
A. Ponderosa pine



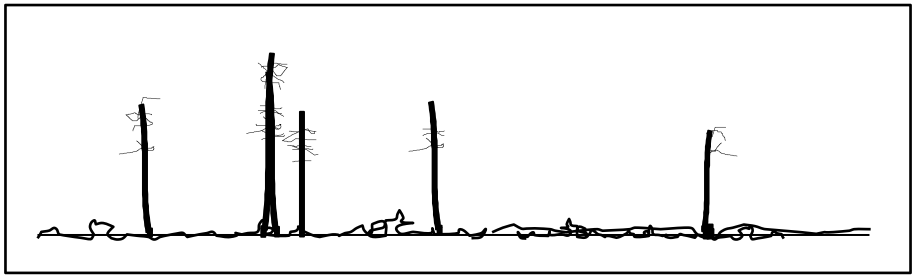
C. Whitebark pine



B. Lodgepole pine



D. Burning that lasts after the main fire:



2. Write:

A. One paragraph comparing the kinds of fire behavior, giving at least two examples.

B. One paragraph contrasting the kinds of fire behavior, giving at least two examples

C. Three words or phrases that describe your feelings about wildland fire.

Unit II.
Physical Science of Wildland Fire

2. Where Does Heat Go?
The Heat Plume from a Fire

Lesson Overview: In this demonstration, students observe the heat from a burning candle and a single match so they can describe the shape and size of a heat plume and explain how the energy from a fire is transferred. Since this is the first activity in FireWorks to use actual fire, we suggest it as a demonstration so the class can go through and observe safety procedures together.

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

Duration: one half-hour session

Group size: Do as demonstration to whole class.

Setting: Laboratory or outdoors area sheltered from wind

Vocabulary: *conduction, convection, heat plume, radiation*

Lesson Goals: Increase students' understanding of heat dispersal from fires. Prepare students to safely conduct experiments with fire.

Objectives:

- Students can list three ways in which energy is transferred from a burning object.
- Students can describe the shape and size of a heat plume from a burning match.
- Students can list some safe practices for doing laboratory experiments with fire.

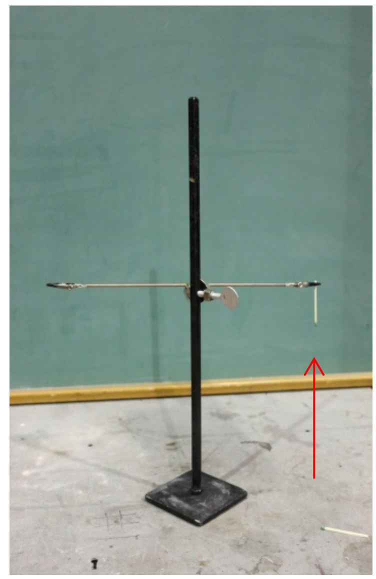
Standards		6th	7th	8th
CCSS	Writing	4,10	4,10	4,10
	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	4,7,10	4,7,10	4,7,10
NGSS	Structures and Property of Matter	PS3.A		
	Energy	PS3.A, B		
EEEGL	Strand 1	A,C,E,F,G		

Teacher Background: Most of the heat energy from a burning object usually disperses upward because the process of burning releases hot gases. The air at ground level is denser than that above because of gravity, so most of the hot, expanding gases of combustion tend to go upwards. The process in which warm gases and liquids generally move up, and cool ones move down is called convection. The heat plume from a fire does not always go straight up, however. A gust of wind, which can be thought of as a bubble of dense air, can push the hot gases sideways or even downward.

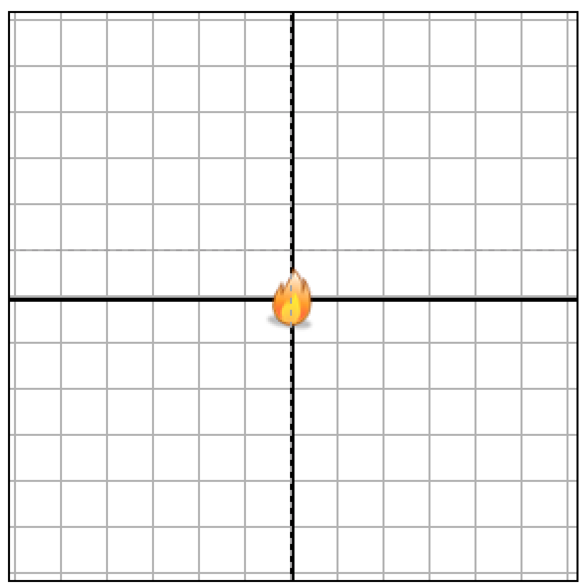
There are two other ways to transfer energy from a fire: conduction (the movement of energy from one atom or molecule to another in a solid) and radiation (the movement of energy through space by particles or waves). The demonstration in this activity explores all three means of heat transfer from a single burning match.

Materials and preparation:

Choose your location. This demonstration can produce flames 10-15 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? Do not try this demonstration outdoors because even the slightest wind will blow out a single match.



- Display the *FireWorks Safety* poster (***M02_FireWorks_Safety_poster.pptx***).
- Get a box of wooden kitchen matches.
- Fire extinguisher, fully charged
- Get a package of pre-wrapped hard candy. You'll need about twice as many pieces as you have students.
- Set up laboratory bench or other area to be used for demonstration with the following equipment (available in the trunk):
  - spray bottle, filled with water
  - ruler
  - metal tray (i.e., cookie sheet)
  - ashtray
  - votive candle
  - safety goggles
  - oven mitt
  - support stand
  - cross-piece for support stand. Has an alligator clip at each end.
  - clamp
- Set up the support stand with the clamp and cross-piece as illustrated above. Clip a match to one end with the ignitable tip pointing down.
- Draw the graph on the right on the board or project ***M02_GraphForDescribingHeatPlume.pdf***:



Procedure:

PART ONE: Students demonstrate the 3 methods of heat transfer

1. Explain: In this activity, the class will work together to make observations about heat transfer from fires. As background, you need to know three terms: convection, conduction, and radiation. We'll set up a human demonstration to learn what they mean.

2. Have students stand side by side in a long line, shoulder to shoulder. Explain and do:

    a. Conduction: If they were atoms within a solid object, like a metal, they would move heat energy by passing it from one atom to another, each atom absorbing some and passing some on. (Pass the bag of candy to the first student, who takes a piece and passes it to the next, who does the same… all the way to the end of the line.)

    b. Radiation: Get the candy bag back (if there's any left!). Now pretend you are a source of light and heat, like the sun, radiating energy. You transfer that energy by sending out particles or waves through space. The energy travels until it contacts an atom or molecule, which it then heats up. (Throw a few pieces of candy directly to a few students.) Radiation explains how you can get a sunburn from energy that travels through space. Amazingly, the molecules of your skin are the first ones that sunlight touches in its 93-million-mile journey!

    c. Convection is the expansion of a bubble of hot gases into the cooler gases surrounding it. Gravity holds Earth's atmosphere to the ground, so the air becomes "thinner" (less dense) as you go up in altitude. Since "up" has less resistance to expanding gases than "sideways" or "down," hot air and the hot gases produced by combustion generally rise. Ask the class to imagine that their shoulder-to-shoulder line is vertical rather than horizontal. Pick 1-2 students to walk with you, arm-in-arm, from one end – the imaginary bottom of the heat plume – toward the other end, the imaginary top. Give a piece of candy to each student you pass – this means that your bubble of hot gases is losing heat as you go up, warming the surrounding air. If you run out of candy, stop. This means your bubble is the same temperature (i.e., has the same amount of energy per volume) as the air around you.

3. Have students take their seats for the next steps.

PART TWO: Students measure the shape of a heat plume

1. Explain: The class will work with the teacher to SAFELY measure the shape of a heat plume and learn how a fire can transfer heat through conduction, radiation, and convection.

2. Go through the FireWorks Safety poster (***M02_FireWorks_Safety_poster.pptx***) with the class, checking your demonstration set-up to make sure all guidelines are met.

3. Demonstrate how to SAFELY light a match: Pull the match away from you, not toward you; hold it level or tilted slightly downward, not pointing directly downward; drop it into the ashtray or metal tray if it feels too hot. Always dispose of burned matches in the ashtray or on the metal tray.

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.

4. Get a volunteer from the class to be the **Observe**r. Make sure he or she is dressed safely, following the poster guidelines.

5. Get another volunteer to be the Measurer and another to be the data Recorder.

6. Explain to the **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.

7. Explain to the **Measurer**: After each match is out, you'll measure the distance from its tip to the observer's hand (in centimeters).

8. Explain to the **Recorder**: You'll mark the correct axis of the graph to show each measurement.

9. Light the first match. As soon as it is completely on fire, obtain a "side" measurement and record it. After the match goes out, USE THE OVEN MITT to remove it from the clip, put a fresh one in, and get the opposite "side" measurement… a "below" measurement… then an "above" measurement. If you forget the oven mitt, you will quickly – and painfully – learn

about conduction. Use as many matches as you need to get the 4 observations. Use the same Observer for all 4 measurements. If you want to see variation from different observers, have another student or two repeat the observations, and then calculate an average for each dimension on the graph.

10. Have the Recorder connect the marks on the four axes, making a roughly oval shape.

11. Refer back to the three ways in which heat is transferred in a fire – conduction, convection, and radiation. Discuss/explain: The heat plume's strong tendency to move upward demonstrates convection. Radiation sends energy in every direction; the heat you feel to the sides and beneath the flame is due to radiation. Conduction of heat is occurring from the fire into the metal clip, which is why you are using the oven mitt.

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

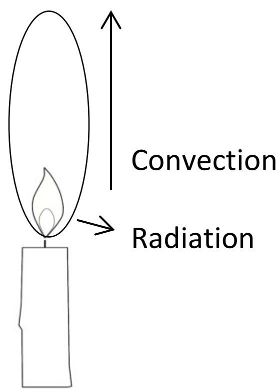
Assessment: Ask students to write/sketch answers to the following:

1. Where did the heat go? Use heat-transfer terms (conduction, radiation, convection) to describe the movement of heat upward, sideways, downward, and into the metal pieces.

2. Sketch a burning candle and show the shape of the heat plume. Label the diagram with words and arrows to show where convection and radiation are occurring.

3. Make a list of safety precautions that you should take when you get ready for school on days when fire experiments are scheduled. You can refer to the FireWorks Safety poster. Have students take the list home and post it in a place that they can refer to as they prepare for school.

Evaluation:

	Correct	**Incorrect**
1. Where did the heat go? Use vocabulary.	Most of the heat went upward through **convection,** the tendency of hot gases and liquids to rise. A little heat went in every direction through **radiation,** the process in which energy travels through space as particles or waves until it hits a molecule, which it heats up. Some heat went into the metal clip by **conduction** (the transfer of heat from particle to particle within a solid).	Student's descriptions did not reflect the correct use of the vocabulary term or a general understanding of the concept.
2. Burning Candle Diagram:		-Student does not have correct drawing of heat plume -Student does not show that convection moves heat upward. -Student does not show that radiation moves heat outward.
3. Fire Safety:	At least two fire safety rules, for example: -low-flammability clothing like cotton -no loose, floppy clothing -closed toed shoes -hair ties	Fewer than two safety rules were listed

3. What Makes Fires Burn?
The Fire Triangle 1—Heat and Fuel

Lesson Overview: In this activity and the next one, students learn about the concept of the Fire Triangle, then test it experimentally. This activity focuses on fire's requirement for fuel and a heat source.

Lesson Goal: Increase students' understanding of fire as a process of chemical change.

Objectives:

- Students can describe the chemical change that occurs in combustion.
- Students can explain why combustion is a chemical change.

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

Duration: One to two half-hour sessions

Group size: Whole class, working in teams of about 4 students

Setting: Indoors

Vocabulary: *atom, carbon, carbon dioxide, chemical change, Fire Triangle, fuel, heat, hydrogen, model, oxygen*

Standards		6th	7th	8th
CCSS	Writing	4,10	4, 10	4, 10
	Speaking and Listening	1,4,5	1,4,5	1,4,5
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	3,9,10		
NGSS	Structures and Property of Matter	PS1.A, PS1B, PS3.A		
	Chemical Reactions	PS1.B		
	Energy	PS3.A		
EEEGL	Strand 1	A, C, E, F, G		

Teacher Background: This activity and the next one explore 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 a good analog to the requirements for combustion: A triangle is very stable as long as all three legs are present (so stable, in fact, that it is used in the construction of buildings, furniture, and many other structures), and it collapses if one leg is removed. The triangle model is also appealing because it provides an easy way to introduce students to understanding a chemical change - the process of combustion. The three legs of the Fire Triangle actually represent the three inputs to the chemical equation for combustion, where H represents Hydrogen atoms, O represents Oxygen atoms, and C represents Carbon atoms:

Fuel	+ Oxygen	+	Heat	⟶	Carbon dioxide +	Water	+	Heat&Light
C&H atoms +	O_2	+	a little heat	⟶	CO_2	+	H_2O	+	Heat&Light

The equation above does not give a specific formula for fuels, because they could be any mixture of millions of compounds. The point is that all fuels contain a lot of carbon and hydrogen. They may contain oxygen and many other kinds of atoms as well. For example, the equation for combustion of glucose, with numbers of molecules balanced to show conservation of matter, is this:

$$C_6H_{12}O_6 + 6O_2 + \text{a little heat} \longrightarrow 6CO_2 + 6H_2O + \text{Heat/Light}$$

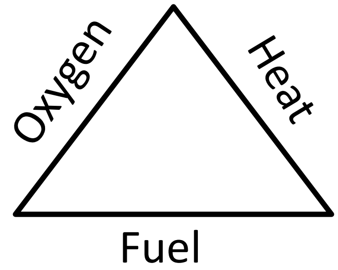
The same equation represents cellular respiration, the process by which cells convert sugar into the energy that keeps living things – including us – alive. Furthermore, this equation is the reverse of the chemical formula for photosynthesis! Thus the Fire Triangle can be used to introduce not only basic chemistry but also the basic principles of the biochemistry of life.

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

Handout **M03-1: Why Does the Match Go Out?** describes an experiment to demonstrate that both heat and fuel are essential for fire, and the heat must be able to reach the fuel for combustion to occur. In the next activity, students use an experiment to investigate the importance of oxygen in combustion, and they may also learn the difference between chemical change and phase change.

Materials and preparation:
Choose your location. If you burn in the classroom, be aware that this demonstration can produce flames 10-20 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 safe? Do not try to burn outdoors because even the slightest wind will blow out single matches and candles.

- The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.
- Get a package of hair bands to keep in your pocket so you can give them out as needed.
- Get four boxes of kitchen matches. The boxes need not be full.
- Draw the Fire Triangle on the board, labeling the sides. Make it big enough that you can add information next to and below it during class discussion:

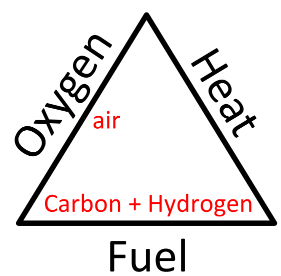


- Set up the teacher's lab bench with this equipment (mostly available in trunk):
  - Two spray bottles, filled with water
  - Fire extinguisher, fully charged
  - A votive candle
  - A box of matches
- Set up a lab bench or other safe space for each student team with the following equipment:
  - 1 ruler
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 1 box of matches
  - 1 pair safety goggles
  - 1 oven mitt
  - 1 support stand with cross-piece attached by clamp (see photo, at right)

- Have a METAL trash can or bucket WITHOUT A PLASTIC LINER available.
- Make 1 copy/student of **Handout M03-1**: **Why Does the Match Go Out?**

Procedure:

1. Explain: The Fire Triangle is one way to understand what makes fires burn and what makes them go out. It is a model – something that helps us understand a process and make predictions about it. In the last activity we made a physical model to demonstrate heat transfer (conduction, convection, and radiation). The Fire Triangle is a conceptual model. Let's briefly review and discuss the Fire Triangle model. Then we'll test it experimentally.



2. Ask students to name some fuels. List them on the board below the "Fuels" label on the Fire Triangle. Don't limit the list to wildland fuels; for example, gasoline, birthday candles, and coal can be included. When the list is fairly long, ask which fuels occur in wildland fires and underline them. Explain that all fuels are made up of many kinds of atoms all stuck together – especially carbon and hydrogen atoms. Inside the Fire Triangle and parallel to the "Fuels" label, write these element names. (You can add that fuels can contain dozens of other kinds of atoms, but carbon and hydrogen are the ones that are essential for combustion.)

3. Point out that, according to the list of fuels, burnable things surround us every day. Why aren't they on fire? (There is not enough heat available to ignite them.) Ask students to

name some heat sources for fire, and list them on the board next to the "Heat" label. Again, don't limit the list to ignition sources for wildland fire; for example, spark plugs and static electricity can be included. Underline the heat sources that can start wildland fires without human help (lightning and volcanic activity).

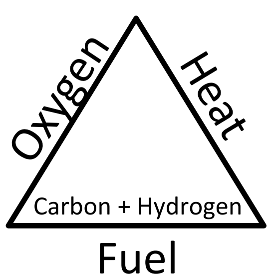
4. Ask where the oxygen for fires comes from. It is, of course, from air; oxygen comprises about 21% of the air we breathe. Write "air" next to the "Oxygen" label on the Triangle. By the way, we use only about 20 % of air's oxygen in a single breath. If we used all of it, the use of "rescue breaths" in cardiopulmonary respiration (CPR) wouldn't work!

5. **Do a safety briefing** in preparation for handling matches in these experiments. Demonstrate a safe way to light a match—that is, hold it level or pointing slightly down, strike away from you, and work over a noncombustible surface so you can drop it quickly but safely even if it is still burning. Review the location of spray bottles and fire extinguisher.

6. Give each student or team a copy of **Handout M03-1**, and tell them to follow the instructions on the handout. If they record multiple observations for (A) and (B), you may ask them to calculate means and medians. As a class, discuss their answers. In regard to (C):

   - The downward-pointing match probably burned almost completely. 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 also limited the oxygen that could get to the fuel.
   - The upward-pointing match probably went out before it burned completely, so it could not have been limited by fuel. Students may guess that it was limited by oxygen. You can respond to this by asking if they have any indication that the air around them is short of oxygen – were they having trouble breathing? The explanation lies in the relationship between heat and fuel: Most of the heat was moving up, away from the fuel, as they learned in **Activity M02**. If any heat was going down, it was not sufficient to keep the wood burning.

7. Below the Fire Triangle on the board, add the following line, which summarizes the chemical changes that occur during combustion. "C," "H," and "O" are abbreviations for the three kinds of atoms in this process.



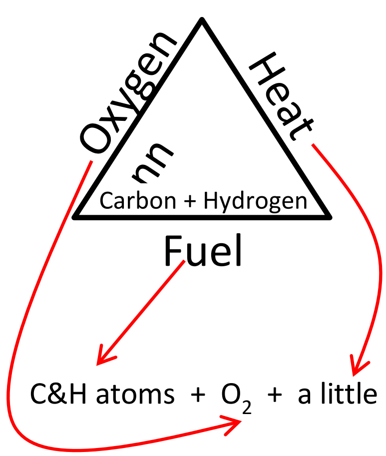
C&H atoms + O_2 + a little heat ⟶ carbon dioxide (CO_2) + water (H_2O) + lots of heat & light

Show and explain:

- The carbon and hydrogen atoms (C&H) in fuels provide the first ingredient for combustion, oxygen (O_2) is the second ingredient, and heat is the third "ingredient."
- Exactly the same kinds of atoms are present in the products of combustion (carbon dioxide and water), but they have been recombined. It is that rearrangement of atoms that produces so much heat and light.
- Combustion is a chemical change, a rearrangement of atoms that changes substances from one kind to another.
- Most chemical changes are hard to reverse. For example, baking a cake causes chemical changes – and it is very hard to turn a cake back into its original ingredients! In combustion, fuels and pure oxygen are changed into carbon dioxide and water, and the change produces heat and light.
- Plants are the only thing on earth that can easily reverse the combustion reaction. Photosynthesis combines carbon dioxide with water to form carbohydrates (comprised, as the name implies, mainly of carbon and hydrogen).

Assessment: Ask students to copy the Fire Triangle diagram and the chemical equation for combustion onto a piece of paper. On the paper, have them:

1. Draw an arrow from each leg of the Fire Triangle to each ingredient in the chemical formula for combustion.
2. Explain in writing why combustion is a chemical change.



C&H atoms + O_2 + a little heat ⟶ carbon dioxide (CO_2) + water (H_2O) + lots of heat & light

Evaluation:	Correct	Incorrect
1. Connect the Fire Triangle with the combustion equation	Student drew three lines from the three legs of the Fire Triangle to the appropriate parts of the combustion equation.	Student did not draw three lines correctly from Fire Triangle to the appropriate parts of the combustion equation.
2. Combustion as chemical change	Combustion is a chemical change because the atoms in the fuels and oxygen are broken apart and then recombined to form new substances – carbon dioxide and water.	Student did not communicate in writing an understanding of combustion as a chemical change.

Handout M03-1: Why Does the Match Go Out?

Name: ___________________________

Organize your team. Change jobs if you repeat the experiment. On a team of 4:

- The **Observer** should light the matches.
- The **Timer** should measure the duration of burning (in seconds).
- The **Measurer** should measure the length of flames.
- The **Recorder** should record data.

Steps:

1. Place the metal tray on a heat-resistant surface. Set the support stand in the center of the metal tray. Attach the clamp to the stand. Attach the cross-piece with alligator clips to the clamp, so it forms a "+" with the stand.
2. Clip a wooden match to each alligator clip. Attach one match so the ignitable tip points straight up. Attach the other so the ignitable tip points down.
3. Light a third match and use it to ignite the downward-pointing match. Record your observations (A and B in first column below). Always dispose of burned matches in the ashtray or on the metal tray.
4. Use another match to ignite the upward-pointing match. Record your observations (A and B in second column below).
5. You may repeat the experiment to get more observations. If you do, use the oven mitt to handle the alligator clips. If you forget, you will quickly learn about conduction.
6. Answer question C for the downward-pointing match, then for the upward-pointing match.
7. **Clean up:** Make sure all burned materials and matches are our 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 them in the trash.

Match is pointing…	Down	Up
A. With the ruler near the flame but not in it, measure the flame length (centimeters). Record up to 3 observations. Try to get a MAXIMUM flame length.		
B. How long did the match burn (seconds)? Record up to 3 observations.		
C. Use the Fire Triangle to explain why the match went out.		

4. What Makes Fires Burn?
The Fire Triangle 2—Oxygen

Lesson Overview: In this activity, students learn more about the Fire Triangle and further test it experimentally. **We describe 2 options for doing the experiment: Option A uses vinegar and baking soda; Option B uses dry ice.**

Lesson Goal: Increase students' understanding of combustion and the Fire Triangle model.

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

Duration: One half-hour session

Group size: Whole class, working in teams of about 4 students each

Setting: Indoors

Vocabulary: *molecule.* If you use Option 2 with dry ice*, add: phase change, sublime/sublimation*

Objective: Students can use the Fire Triangle to explain why various techniques work to stop fires.

Standards		6th	7th	8th
Common Core ELA	Writing	1,4,7,10	1,4,7,20	1,4,7,10
	Speaking/Listening	1,2,5	1,2,5	1,2,5
	Language Standards	1,2,3,6	1,2,3,6	1,2,3,6
	Reading Standards Science/Tech	9	9	9
	Writing Standards Science/Tech	2	2	2
NGSS	Structures and Property of Matter	PS3.A, PS1.A, PS1.B		
	Chemical Reactions	ETS1.B		
	Energy	ETS1.B		
	Engineering Design	ETS1.A, ETS2.B, ETS1.C		
EEEGL	Strand 1	A, B, C, E, F, G		

Teacher Background -- Initial background is in the previous activity (M03). Here is more: Students use 1 handout for this activity – either **M04-1** or **M04-02** (both entitled **Why does the candle go out?**). Both options use carbon dioxide gas to demonstrate that oxygen is required for fire.

- In <u>Option A,</u> the gas is produced by combining baking soda and vinegar; if you use this option, you can explore the chemical reactions between baking soda and vinegar.

- In Option B, the gas is produced from dry ice; if you use this option, you can explore the difference between phase changes and chemical changes.

About carbon dioxide gas: 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 the oxygen will rise to the top.

Option A background: These 2 equations describe the chemical changes that produce carbon dioxide gas from vinegar and baking soda:

[1]	vinegar	+	baking soda	→	carbonic acid	sodium acetate
	(acetic acid)		(sodium bicarbonate)			
	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] $H_2CO_3 \rightarrow CO_2(g) + H_2O$

Option B background: When a substance changes from one phase (solid, liquid, gas) to another, it undergoes a phase change. This is different from a chemical change. As described in the previous activity, in a chemical change the molecules in the ingredients are broken into their component atoms, and the atoms are recombined to form new molecules; the change cannot be reversed easily (for example, it's hard to un-bake a cake). In a phase change, the atoms in the ingredients are not recombined, and the change can be reversed fairly easily.

When you use dry ice for this experiment, you convert 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 phase to the gas phase – hence the term "dry" ice, as opposed to "wet" ice (frozen water). We say that the dry ice "sublimes," and the process is called "sublimation."

Option A: Experiment using vinegar and baking soda

Materials and preparation:
Choose your location. You will be burning individual votive candles. Can you do this in your classroom safely and without setting off a smoke alarm? Can you take your students to a lab where it will be safe? It's very difficult to burn outdoors because even the slightest wind will blow out the candles.

1. The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.
2. Get a package of hair bands to keep in your pocket so you can give them out as needed.
3. Get 4 boxes of wooden kitchen matches. The boxes need not be full.
4. Get 1 box of long fireplace matches.
5. Get a box of **baking soda** and a container of **plain vinegar**. You'll need a couple tablespoons of baking soda and about ¼ cup of vinegar for each student team.

- Set up the teacher's lab bench with this equipment:
  - Fire extinguisher, fully charged
  - Two spray bottles, filled with water
- Set up a lab bench or other safe space for each student team[1], using the following equipment:
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 1 box of matches
  - 2 votive candles
  - 2 beakers or freezer containers
  - 1 pair safety goggles
  - 1 oven mitt
  - 1 long fireplace matches (Students can re-light these and use them repeatedly rather than using a new match for every iteration of the experiment.)
- If possible, have a METAL trash can WITHOUT A PLASTIC LINER available.
- Print 1/student: **Handout M04-1. Why does the candle go out?**
- Post the FireWorks Safety poster (***M02_FireWorks_Safety_poster.pptx*** in **Activity M02**).

Procedure:

1. Explain: In the last activity, we saw that both fuel and heat are essential for fire to occur, but we didn't really look at the role of oxygen. That's what we'll explore in this experiment.

2. Review the "Oxygen" part of the Fire Triangle: It comprises about 21% of the air we breathe, and we use only about 20 % of that oxygen in a single breath. If we used it all in breathing, we couldn't use the "rescue breath" part of cardiopulmonary resuscitation (CPR) to help a person who is not breathing.

[1] The trunk is supplied with 4 sets of equipment.

3. Review/ask: What is a chemical change? A chemical change is a rearrangement of atoms that changes substances from one kind to another, producing a different kind of molecule.

4. Explain: You will combine vinegar and baking soda in a chemical reaction that produces carbon dioxide. When vinegar and baking soda are combined, they produce carbonic acid and sodium acetate. The carbonic acid breaks down into carbon dioxide and water. **Optional:** You may want to share the chemistry below.

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

5. Do a safety checkup with students using the FireWorks Safety poster (***M02_FireWorks_Safety_poster.pptx*** in **Activity M02**).

6. Give each student or team a copy of **Handout M04-1**. **Why does the candle go out?** Have students go over the instructions. Answer questions. Then give out materials and have them conduct the experiment.

7. After students have finished, discuss their responses to A-D at the bottom of the handout. Soon after vinegar has been added to the baking soda in the container, they should find it impossible to light the candle. Why? Carbon dioxide has filled the bottom of the container. It is heavier than oxygen, so it doesn't rise and mix with the surrounding air. Instead, it crowds the oxygen out. Without oxygen, the candle won't burn.

Assessment – both Option A and Option B:

1. Ask: What are some techniques for putting fires out? List these on the board. Select one of them. In a discussion, get students to use concepts from the Fire Triangle to explain why the technique works. Then erase this technique from list, leaving the rest for the Assessment.

2. Select one of the techniques listed on the board for putting fires out.
   a. Write down the technique you've chosen.
   b. Explain why the technique works. Use at least one complete sentence, and use one or more components of the Fire Triangle.

Evaluation – both Option A and Option B:

-Student named the technique chosen. -Explanation was logical. -Used 1 or more components of the Fire Triangle.	-Student named the technique chosen. -Explanation was logical. -Did not use components of Fire Triangle.	-Student did not name a technique. -Explanation was illogical. -Did not reference Fire Triangle.

Handout M04-1. Why does the candle go out?

Name: ______________________________

1. Place one votive candle on the metal tray and light it. You will light your long match from this candle, and you'll probably use the long match more than once.
2. Place the other candle in a beaker or other container.
3. Light the long fireplace match from the burning candle on the metal tray. Then use it to light the candle in the container. If either candle is hard to light, you may need to scrape some wax from around the wick. This step proves that the candle in the container can be lighted.
4. Blow out the candle in the container.
5. Spoon 1-2 tablespoons of baking soda around the base of the candle, about enough to coat the bottom of the container. Be careful not to get the baking soda on the candle. Alternative: Add the baking soda to an empty container and then replace the candle.
6. Light the candle to make sure that the baking soda did not alter its ability to burn. Then blow it out.
7. 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.
8. Relight the fireplace match from the candle on the metal tray. Then use it to relight the candle in the container.
9. Try different techniques for lighting the candle in the container.
10. Use complete sentences to answer the questions below.

A. Describe what you observed when you mixed vinegar and baking soda.
B. Describe what you observed when you were lighting the candle in the container after vinegar was added.
C. Describe any other techniques you used to light the candle in the container, and explain how well each technique worked.
D. Use the Fire Triangle to explain your observations.

Handout M04-1 Answer Key. Why does the candle go out?

A.	Describe what you observed when you mixed vinegar and baking soda. The mixture foamed. Then a white substance accumulated at the bottom of the container, and it was covered by a clear liquid.
B.	Describe what you observed when you were lighting the candle in the container after vinegar was added. It was impossible to light… unless the air in the room was turbulent or someone blew into the container.
C.	Describe any techniques you used to light the candle in the container, and explain how well each technique worked. This is a fun part of the experiment. Students may try moving more quickly; this won't work. They may try tipping the container sideways; this may work because you are pouring some of the carbon dioxide out. They may also try taking the candle out and pouring the carbon dioxide onto the lighted candle on the tray; that will probably extinguish the flame.
D.	Use the Fire Triangle to explain your observations. A chemical reaction produced carbon dioxide from vinegar and baking soda. Carbon dioxide is heavier than oxygen, so it stays in the container while the oxygen is pushed out. Without oxygen, the candle cannot be lit.

Option B: Experiment using dry ice

Materials and preparation:

Choose your location. You will be burning individual votive candles. Can you do this safely in your classroom, without setting off a smoke alarm? Can you take your students to a lab where it will be safe? This experiment isn't likely to work outdoors because even the slightest wind will blow out the candles.

3. The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.
4. Get a package of hair bands to keep in your pocket so you can give them out as needed.
5. Get 4 boxes of wooden kitchen matches. The boxes need not be full.
6. Get 1 box of long fireplace matches.

- Set up the teacher's lab bench with this equipment:
  - Fire extinguisher, fully charged
  - Two spray bottles, filled with water
  - Tongs for handling dry ice
- The morning of the experiment, get 2-3 pounds of dry ice from a local supermarket. Store it in a cooler or freezer until class time. Find a hammer or something else for crushing the dry ice.
- Set up a lab bench or other safe space for each student team[2], using the following equipment:
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 1 box of matches
  - 2 votive candles
  - 2 beakers or freezer containers
  - 1 pair safety goggles
  - 1 oven mitt
  - 1 long fireplace matches (Students can re-light these and use them repeatedly rather than using a new match for every iteration of the experiment.)
- If possible, have a METAL trash can WITHOUT A PLASTIC LINER available.
- Print **Handout M04-2. Why does the candle go out?** for each student.
- Post the FireWorks Safety poster (***M02_FireWorks_Safety_poster.pptx*** in **Activity M02**).

Procedure:

1. Explain: In the last activity, we saw that both fuel and heat are essential for fire to occur, but we didn't really look at the role of oxygen. That's that we'll explore in this experiment.

[2] The trunk is supplied with 4 sets of equipment.

2. Review the “Oxygen” part of the Fire Triangle: It comprises about 21% of the air we breathe, and we use only about 20 % of that oxygen in a single breath. If we used it all in breathing, we couldn’t use cardiopulmonary resuscitation (CPR) to help a person who is not breathing.

3. Review: Ask students to describe the nature of a chemical change (a rearrangement of atoms that changes substances from one kind to another, which produces a different kind of molecule).

4. Explain: As dry ice changes from the solid phase to the gas phase, the atoms are <u>not</u> rearranged and a different kind of molecule is <u>not</u> produced. The process of subliming dry ice is a phase change as opposed to a chemical change. Other familiar phase changes are the melting of “regular” ice into water and the evaporation of liquid water into water vapor. Phase changes are usually easy to reverse if you add or remove heat. For example, we can thaw ice (change from solid to liquid) and easily refreeze the liquid water back to ice again. In contrast, consider how hard it would be to un-bake a cake!

5. **Do a safety checkup** with students using the FireWorks Safety poster (***M02_FireWorks_Safety_poster.pptx*** in **Activity M02**). Then explain**: You’ll be using “dry ice.”** This is frozen carbon dioxide, and it’s very cold (−78.5 °C (−109.3 °F)) – much colder than ice made from water. Because it is so cold, it should never be handled without tongs or thick gloves. If you leave dry ice in a container for a while, it will disappear because the solid carbon dioxide is subliming—going from the solid phase to the gas phase without a liquid phase in between. Gaseous carbon dioxide is invisible and comprises about 1% of air.

6. Give each student or team a copy of **Handout M04-2. Why does the candle go out?** Have students go over the instructions. Explain that you will provide them with dry ice when they have finished the first 4 steps in the experiment. Answer questions. Then give out materials and have them conduct the experiment. When each team is ready for dry ice, use the tongs to place a few pieces in their candle container. (The volume of about 2-3 ice cubes will do.)

7. After students have finished, discuss their responses to A-C in the table on the handout. Soon after the dry ice has been added to the container, they should feel the cold around the container and it should be impossible to light the candle inside. They may also observe fog in the container. This is not gaseous carbon dioxide. (Remember, carbon dioxide is invisible.) Instead, it is water vapor condensing out of the room’s air because the gas in the container is so cold. Carbon dioxide has filled the bottom of the container. It is heavier than oxygen (and it is cold so it is much denser than it would be at room temperature), so it doesn’t rise and mix with the surrounding air. Instead, it crowds the oxygen out. Without oxygen, the candle won’t burn.

Assessment and Evaluation: Same as for **Option A** above.

Handout M04-2: Why does the candle go out?

Name: ________________________

1. Place one votive candle on the metal tray and light it. You will light matches from this candle.
2. Place the other candle in a beaker or other container.
3. Light the long fireplace match from the burning candle on the metal tray. Then use it to light the candle in the container. If either candle is hard to light, you may need to scrape some wax from around the wick. This step proves that the candle in the container can be lighted.
4. Blow out the candle in the container.
5. Ask the teacher to place some pieces of dry ice next to the candle in the container. <u>If you need to handle the dry ice, use the oven mitt.</u>
6. Relight the fireplace match from the candle on the metal tray. Then use it to relight the candle in the container.
7. You may repeat the experiment and use different techniques to light the candle in the container.
8. Answer the questions below.

A. Describe what you observed when you were relighting the candle in the container.
B. Describe techniques you used to try to light the candle in the container. Explain how well each technique worked.
C. Use the Fire Triangle to explain your observations.

Handout M04-2 Answer Key. Why does the candle go out?

A. Describe what you observed when you were relighting the candle in the container. The container was cold. It may have had fog inside. It was impossible to light the candle… unless the air in the room was turbulent or someone blew into the container.
B. Describe techniques you used to try to light the candle in the container. Explain how well each technique worked. This is a fun part of the experiment. Students may try moving more quickly; this won't work. They may try tipping the container sideways; this may work because you are pouring some of the carbon dioxide out. They may also try taking the candle out and pouring the carbon dioxide onto the lighted candle on the tray; that will probably extinguish the flame.
C. Use the Fire Triangle to explain your observations. Carbon dioxide is heavier than oxygen, so it stays in the container while the oxygen is pushed out. In addition, carbon dioxide gas that has just sublimed from dry ice is very cold, so it is much denser than it would be at room temperature – again, staying put in the container while oxygen is pushed out. Without oxygen, the candle cannot be lit. Students may think that it is too cold inside the container to light the candle, so the "heat" component of the Fire Triangle is missing. That is unlikely, but this experiment doesn't provide a good way to test the hypothesis. Perhaps they can come up with an experiment to do so!

Unit III.
The Wildland Fire Environment

5. How Do Wildland Fires Spread? The Matchstick Forest Model

Lesson Overview: In this activity, 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, Health and Safety, Writing, Speaking and Listening

Duration: Two to three half-hour sessions

Group size: Whole class, working in 4 teams to prepare demonstrations

Setting: Indoor laboratory or outdoors

Vocabulary: *backing fire, crown fire, density/stand density, experimental variable, ground fire, head fire, slope, stand, standing fuels, surface fire, topography*

Objectives:

- Students plan experiments and make observations to investigate the effect of one variable at a time on fire spread.
- Students use the Fire Triangle (from **Unit II**) to explain how slope and density of trees (or other standing fuels) affect fire spread.

Standards:		**6th**	**7th**	**8th**
CCSS	Writing	4,10	4,10	4,10
	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language	1,2,3,4,6	1,2,3,4,6	1,2,3,4,6
	Writing: Science and Technology	2	2	2
NGSS	Structures and Property of Matter	PS3.A		
	Energy	ETS1.B, ETS1.B		
	Human Impacts	ESS3.C		
	Weather and Climate	ESS2.D		
	History of Earth	ESS2.A		
	Engineering Design	ETS1.A, ETS2.B, ETS1.C		
EEEGL	Strand 1	A,B,C,E,F,G		

Teacher Background: Now that students understand the basic principles of combustion as described by the Fire Triangle, they will apply that understanding to how fires behave in wildlands. In this activity, they will use a physical model called the "matchstick forest" to investigate two of sides of the Fire Environment Triangle (also called Fire Behavior Triangle):

- slope (a feature of topography)
- the density of trees or other standing fuels

In the matchstick forest model, standing fuels are represented by single matches. For safety's sake, it is important to note that the flames in this experiment can reach a foot or more in height. Plan accordingly. If you do the burning outdoors, even the slightest breeze will dramatically affect fire spread. In this case, the experiments may illustrate mainly that fire spread is complex and often unpredictable. You can investigate the effects of wind on fire behavior in Activity M08.

The activity consists of 2 experiment sets. Experiment Set 1 investigates the effect of slope on fire behavior. We suggest you discuss the experimental design, hypotheses, and measurements as a class while you do Set 1, to prepare students for doing the same thing on their own in Experiment Set 2. Set 2 investigates the effect of stand density (the spatial arrangement of trees or other standing fuels).

While the activity is especially well suited to studying tree density, the principles apply to any vertical fuel array – tall shrubs or grasses, for example. Here are explanations for the fire behavior that you may see in the experiments:

> Experiment 1. If a fire is burning on a hillside, the fuels above it tend to be dried and warmed by its convective heat and the flames are quite close to these fuels, while the fuels below are affected very little – at least until burning materials roll downhill and ignite new fires below. Thus fires tend to spread upslope, and a fire that starts at the bottom of a hill is likely to spread faster than one that starts on a hilltop.
>
> Experiment 2. If a fire is burning in dense forest, it may spread from treetop to treetop (crown fire). In more open forests, crown fires are less likely. Here is a caveat, however: Surface fires may spread more rapidly in open than dense stands because the wind speed is usually greater in openings.

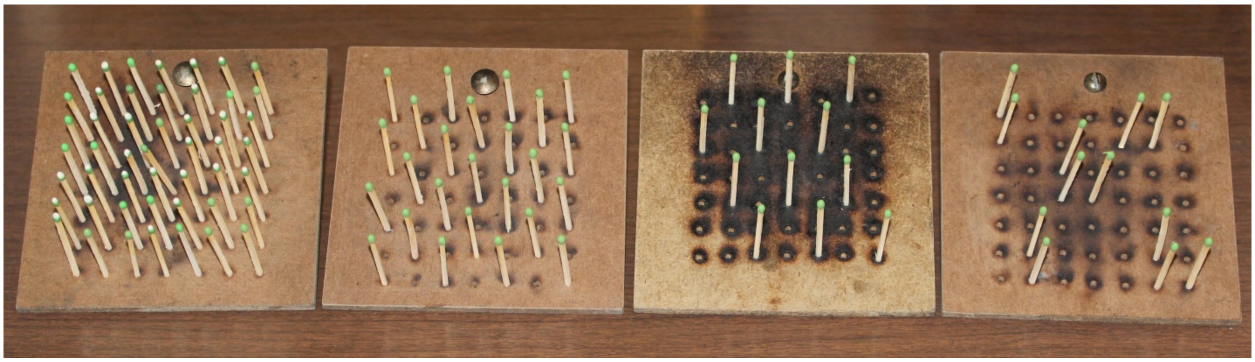
Table M05-1: describes the experiments included in this activity. Use Experiment Set 1 to learn about the effect of slope. Then use <u>either</u> Experiment Set 2A <u>or</u> 2B to learn about the effect of stand density. Students' directions for each experiment set, which you can project as needed, are in ***M05_MatchstickForestExperimentDesigns.pptx***.

- Use Experiment Set 2A if you want students to learn about stand density as it applies to ALL kinds of plant communities subject to fire (ANY kind of forest, woodland, shrubland, or even grassland, the world over).
- Use Experiment Set 2B if you want students to learn about stand density as it applies to specific kinds of fire histories in your geographic area. In this version of FireWorks, this demonstration covers dense lodgepole pine forests, open ponderosa pine forests, and high-elevation whitebark pine forests.

Table M05-1: Experiments for investigating the effect of slope and density of standing fuels on fire spread.

Experiment Set & Experimental Question	Potential hypotheses & explanations	Experimental setup
Experiment Set 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 upward by convection, it dries and heats the fuels above. In addition, flames are closer to uphill fuels than to those on level ground or downslope.	Use 4 boards (4 experiments). Use 49 matches/board. Lay 1 board flat. Use short bolts to model 2 forests on moderate slopes. Use a long bolt to model a forest on a steep slope. Ignite an entire row of matches along the edge of each board: • On flat board, ignite one side. • On 1 moderately steep board, ignite from the top row (backing fire) • On the other moderately steep board, ignite from the bottom row (head fire). • On steep board, ignite one row from bottom (head fire).
Use EITHER Experiment Set 2A or 2B.		
Experiment Set 2A. How does stand density affect fire spread?	Fires generally spread faster and combustion is more complete in dense standing fuels than in sparse fuels. Thus crown fire is more likely in dense than sparse forests. Clumping of fuels also affects potential for crown fire. **Explanation:** In a dense stand, heat and flames are more likely to reach nearby fuels.	Use long bolts for all models. Use the following matchstick densities/board (Figure M05-1): • 49 matches • 25 matches (50%), distributed evenly • 12 matches (25%), distributed evenly • 12 matches (25%) in clusters Ignite all boards from the bottom row.
Experiment Set 2B. How does stand density resulting from different fire histories affect fire spread?	Fires generally spread faster and combustion is more complete in dense forest stands, such as lodgepole pine stands that have not burned in a long time, than in more open forests, such as ponderosa pine stands that have been burned frequently. When trees occur in clusters, as in whitebark pine stands, an entire cluster may burn but the fire may not spread to others clusters. **Explanation:** Heat and flames are more likely to reach fuels that are close together, drying	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 lodgepole pine stands that originated 50-100 years ago after a crown fire • 49 matches, some short and some tall, to represent a stand with a mixture of pines and firs that has not had a fire in 100 years or more • 5 matches, spaced far apart, to represent open-grown ponderosa pine stands that have experienced frequent fires • 13 matches, distributed in clusters, to represent high-elevation whitebark pine stands

	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.	Ignite all boards from the bottom row.



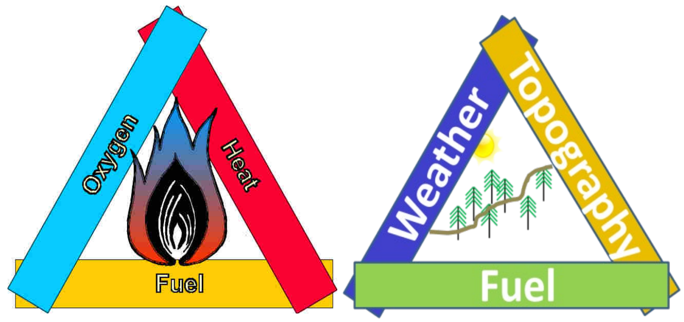
Setup of matches for Experiment Set 2A.

Materials and preparation:
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 stand density. In windy outdoor conditions, consider using a fireplace lighter and having students hold poster board around the matchstick stand to protect it from wind.

Have students work in teams to set up the matchstick forests for this activity, then *ignite them one at a time* so all students can observe all fires. You could also have student volunteers set up the matchstick forests ahead of the class period.

- The day before doing this activity, display the FireWorks Safety poster (***M02_FireWorks_Safety_poster.pptx*** from **Activity M02**) and remind students to follow safety guidelines about clothing and hair when they get ready for school tomorrow.

- Get a package of hair bands to keep in your pocket so you can give them out as needed.
- Get four boxes of wooden kitchen matches (not provided in the trunk).
- Display the Fire Triangle poster (***Fire TrianglePoster.pdf***) and the Fire Environment Triangle poster (***M05_FireEnvironmentTriangle.pdf***)
- Download ***M05_MatchstickForestExperimentDesigns.pptx*.**
- Set up the teacher's lab bench with this equipment:
  - Fire extinguisher, fully charged
  - Two spray bottles, filled with water



- Set up a lab bench or other safe space for each student team, using the following equipment (available in the trunk):
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 1 box of matches
  - 1 matchstick forest board
  - 1 ruler
  - A short and long bolt and 1 nut from the matchstick forest kit
  - 1 pair safety goggles
  - 1 nail (for removing burned matches from boards)
- 1 copy of **Handout M05-1** for each student
- Have a <u>metal trash can without a plastic liner</u> available in the room.

Procedure:

1. Do a **safety checkup** with students using the FireWorks Safety poster (***M02_FireWorks_Safety_poster.pptx*** from **Activity M02**).

2. Explain, using both the Fire Triangle poster and the Fire Environment Triangle poster: You already know about the Fire Triangle, which describes the basic nature of combustion. Wildland fire professionals use the Fire Triangle to understand combustion. Fire professionals also use a second model, the Fire <u>Environment</u> Triangle (also called the Fire Behavior Triangle). This triangle describes the complexities of fire when it burns in wildland fuels – which are a lot messier than the tidy matches and candles that we've been studying. The Fire Environment Triangle reminds managers of three things that control how fires behave in wildlands: fuel, weather, and topography. In this activity, we'll study the effects of slope (one facet of topography) and different arrangements of standing fuels – that is, patches ("stands") of trees or other vegetation, such as shrubs that have long stems and thick crowns and even grasses. In these experiments, we'll try to <u>not</u> change anything about weather conditions, although we may not be able to control that completely.

3. Discuss experimental design with the class, including the idea that you change only one variable at a time to learn its effects. An experimental variable is whatever you're investigating – in this case, slope (Experiment Set 1) or stand density (Experiment Set 2).

4. Hand out copies of **Handout M05-1**. Explain: We'll do this first set of experiments together and talk through the answers (not writing them down). Then you'll do the second set of experiments on your own and use the handout. Read through it with me, but don't write on it now.

5. Show students your materials, especially the matches and the matchstick model (masonite board, nuts and bolts). Ask: Can you see how we could use these materials as a model of a forest? Brainstorm. Here is the way the materials are used in this activity: The board represents the ground surface. Individual matches represent individual trees or other standing fuels. Match tips represent tree crowns.

6. Ask: What aspects of fire behavior can we try to investigate with this model? Brainstorm. Here are some possibilities: Slope, location of fire origin (from the side, bottom, top), extent of ignition (1 match on fire, a group of matches, a whole row of matches).

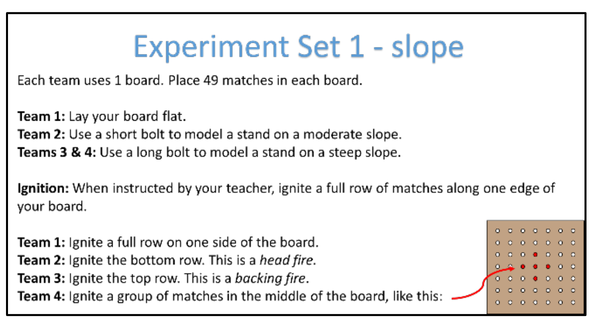
7. The model is most often used to investigate crown fires, that is, fires that burn through the tops of trees or shrubs, as opposed fires that burn on the forest floor (called surface fires) or in the organic material of the soil (called ground fires). We don't think of grass fires as crown fires, but the matchstick forest results can be applied to these standing fuels too.

8. Read **Question 1** on the handout. Explain: In the upcoming demonstration, we'll investigate the effect of slope on fire spread. When you do your individual experiments, you'll investigate at least 1 other variable.

9. Read **Question 2**. Ask students for hypotheses about how slope will affect fire spread. Write them on the board.

10. Read **Question 3**: What observations do we need to test the hypothesis? We suggest:
    - Time of ignition and time when fire goes out (used to calculate fire duration) or fire duration measured by stopwatch/timer
    - Number of match tips burned
    - Approximate maximum flame length (estimated at safe distance from flames)

11. Project **Slide 1** in ***M05_MatchstickForestExperimentDesigns.pptx***. Assign one part of the experiment to each student team. Explain: We'll ignite the matchstick forests one at a time, so the whole class can observe and record data from all 4 fires.



12. On the board, make 4 blocks for recording data, as shown below. Explain: This is the way you'll report data on your hand out during

the second experiment. For this part of the activity, we'll make observations and record data from each team on the board:

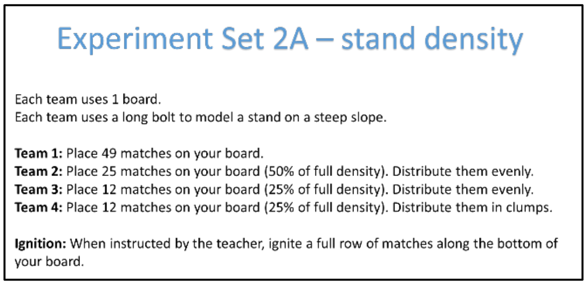
Question 4:	**Team 1**	**Team 2**	**Team 3**	**Team 4**
a. Condition of experimental variable:				
b. Measurements & calculations:				

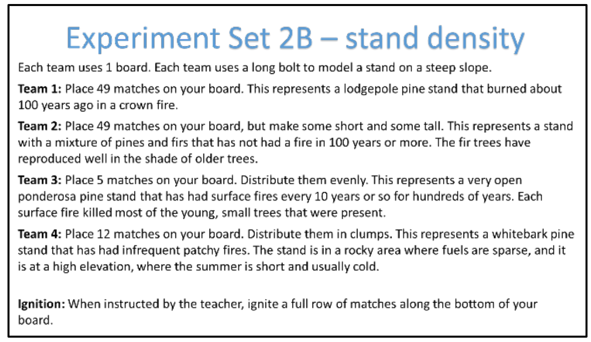
13. Have each team assign roles: Igniter (unless you want to do this yourself), timer, flame measurer, and data recorder. Remind students to dispose of burned matches in the ashtray or on the metal tray.
14. When all teams are ready, one team at a time:
    - Have them describe their setup.
    - One board at a time, have students ignite the boards by lighting a full row of matches.
    - Have the team members make the measurements and record them on the board.
15. After all 4 teams have burned their board of matches, complete any calculations (such as duration of burning). Then Discuss **Questions 5-6** on the handout together
16. Ask: How is this model like a real forest? It has flammable fuels with spaces between, highly ignitable "crowns" – which occur in some wildlands and not others ….
17. Ask: How is the model not like a real forest? There are no surface fuels. Trees are uniformly distributed across the area.…
18. Ask: How is the board not like a patch of land? The terrain is even and uniform. Trees tilt with the slope.…

Assessment:

1. Explain: Now we'll investigate the effect of a different variable - stand density - on fire spread. Stand density is the arrangement of standing fuels on a patch of land. Now it is time to write on your handout.
2. Have students answer **Questions 1-3** on the handout.

3. Project <u>either</u> **Slide 2** <u>or</u> **Slide 3** from ***M05_MatchstickForestExperimentDesigns.pptx***, depending on which experiment set you plan to use:





4. Explain: Each team will set up one part of the experiment. When all are ready, we'll burn the setups one at a time, so we can all observe every fire and share data.
5. Assign each student team to prepare one of the experiments. Use either 2A <u>or</u> 2B.
6. When all boards are ready, have the teams burn them <u>one team at a time</u>. As the burns proceed, have students complete **Question 4** on their handouts – recording results from all four teams, not just their own.
7. Have students answer **Questions 5-6** on their own.
8. **Clean up:** Have students do cleanup. 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.

Evaluation. See the Answer Key below.

EXTENSION #1: After you do Experiments 1 and 2A or 2B, you can extend this activity to help students develop and test their own hypotheses. Here are some questions that they could explore using the same experimental materials:

1. What is the best placement and size for a fireline (where a swath of fuels is removed) in forests with various slopes and stand densities?
2. How does ignition pattern affect fire spread? (Compare ignition from a single point, a whole row of matches (from top, bottom, and sides), and all matches around the edge of the board.)
3. How useful is it to remove selected trees for the sake of reducing potential for crown fire on sites with different slopes?
4. If you were planning to build a home in this plot of land, what would be the best location for it? Would you make any changes to the tree density around the home?

EXTENSION #2: You can also extend this activity by exploring other variables that affect fire spread, such as moisture, matchstick height, wind, and location of fire start (corner, middle, single tree, multiple trees).

Handout M05-1: Matchstick Forest.

Name(s): ________________________

1. **Experimental question:** What is the effect of ______________________ on fire spread? This is the condition that will be changed – "varied" - from one experiment to the next, so it is called the *experimental variable.*

2. **Hypothesis:**

3. **Measurements needed:**

   Calculations needed, if any:

   How do you plan to ignite – from the top, side, or bottom row of matches?

4. The data blocks below (Teams 1-4) refer to each team's experimental trial. Record data from each team as they report it.

   Team 1:

   a. What is the condition of the experimental variable? That is, how many matches are being used and how are they arranged?

   b. Measurements and calculations:

   Team 2:

   a. What is the condition of the experimental variable?

   b. Measurements and calculations:

Team 3:

a. What is the condition of the experimental variable?

b. Measurements and calculations:

Team 4:

a. What is the condition of the experimental variable?

b. Measurements and calculations:

After all experiments are done, answer the following:

5. Review your hypothesis (Question 2 above). Based on your observations, do you think your hypothesis was correct? If not, write a better one here:

6. Write a paragraph that answers Question 1 above. Show how the results of your experiments demonstrate your answer. Use your understanding of the heat plume and the Fire Triangle to explain.

Handout M05-1: Matchstick Forest Answer Key.

1. **Experimental question:** What is the effect of stand density on fire spread?

2. **Potential hypotheses:**
   - Fire will spread more easily through a dense stand than through an open stand.
   - Fire will spread easily through clumps of trees but will not spread easily through big openings between clumps.
   - If a clump of trees is uphill from a burning clump, it will ignite more easily than if it is downhill than the burning clump.

3. **Measurements needed:**
   - duration of burning
   - maximum flame height
   - number of matches burned…

   Calculations needed, if any:
   - Percentage of trees burned
   - Duration of burning if measured with a start time and an end time. Not needed if measured with a stopwatch.

   How do you plan to ignite – from the top, side, or bottom row of matches?
   Bottom row of matches

4. Obtain from ***M05_MatchstickForestExperimentDesigns.pptx***, Slide 2 or 3. Obtain data from each team.

After all experiments are done, answer the following:

5. Review your hypothesis (Question 2 above). Based on your observations, do you think your hypothesis was correct? If not, write a better one ….

6. Write a paragraph that answers Question 1 above. Show how the results of your experiments demonstrate your answer. Use your understanding of the heat plume and the Fire Triangle to explain. Fires spread faster and burn more completely in dense standing fuels (like the boards with 49 matches) because heat and flames are more likely to reach nearby fuels. This is especially true when dense fuels are standing uphill from the burning fuels, because heat is rising convectively and heating the unburned fuels.

6. Ladder Fuels and Fire Spread: The Tinker Tree Derby

Lesson Overview: In this activity, students use a physical model to learn how the vertical arrangement of fuels affects the potential for fires to spread into tree crowns. This activity applies mainly to forests, shrublands, and woodlands. It is especially relevant to ponderosa pine/Douglas-fir forests in the northern Rocky Mountains and North Cascades, where surface fires have been excluded for nearly a century.

Subjects: Science, Writing, Health and Safety

Duration: One to two half-hour sessions

Group size: Whole class, working in 4 teams to prepare

Setting: Indoor laboratory or outdoors

Vocabulary: *ladder fuels, succession*

Lesson Goal: Increase students' understanding of the relationship between fuel arrangement and vertical fire spread, especially in forests, shrublands, and woodlands.

Objectives:

- Students can design a model tree that can keep a surface fire from spreading into the crown.
- Students can differentiate between forest stands based on the spatial arrangement of fuels.
- Students can describe the kinds of fuels that contribute to surface fires and crown fires.

Standards		6th	7th	8th
CCSS	Writing	4,10	4,10	4,10
	Language	1,2,3,4,6	1,2,3,4,6	1,2,3,4,6
	Writing: Science and Technology	4,10	4,10	4,10
NGSS	History of Earth	ESS2.A		
	Human Impacts	ESS3.B, ESS3.C		
	Engineering Design	EST1.A, ETS1.B,ETS1.C		
EEEGL	Strand 1	B, C, E, F, G		

Teacher Background: This activity explores the potential for a surface fire (burning in vegetation on the forest floor) to spread up into the crowns of overhanging trees. The more continuous the fuels, the more likely this will happen. Fuels that enable fire to climb from the forest floor to the crowns of trees are known as ladder fuels. Once fire is in a tree crown, it could spread directly from one tree crown to the next, especially if the winds are strong. Such crown fires are usually much more dangerous and harder to control than surface fires. Ladder fuels have increased in many forests of the northern Rocky Mountains and the North Cascades over the past century, increasing the likelihood of crown fire. This is especially typical of ponderosa pine/Douglas-fir forests, where large trees were harvested in the 1900s and surface fires, which had reduced Douglas-fir regeneration in the past, were eliminated.

The Tinker Tree Derby is a competition among student teams. Each team constructs a "tinker tree" from a support stand, wire rods, and newspaper fuels. The goal is to design a tree that can “survive” a fire passing beneath (surface fire) and still has plenty of leaves in its crown so it can photosynthesize (continue to grow and produce seeds). A team’s success is tested by experimental burning. The tree that survives burning with the greatest potential for photosynthesis is the winner. Note that **potential for photosynthesis is quantified by the length of branch with unburned “foliage” (newspaper strips on branches) remaining after the fire – not by removing and weighing the newspaper “foliage.”** Figure M06-1 below shows how to set up the tinker trees.

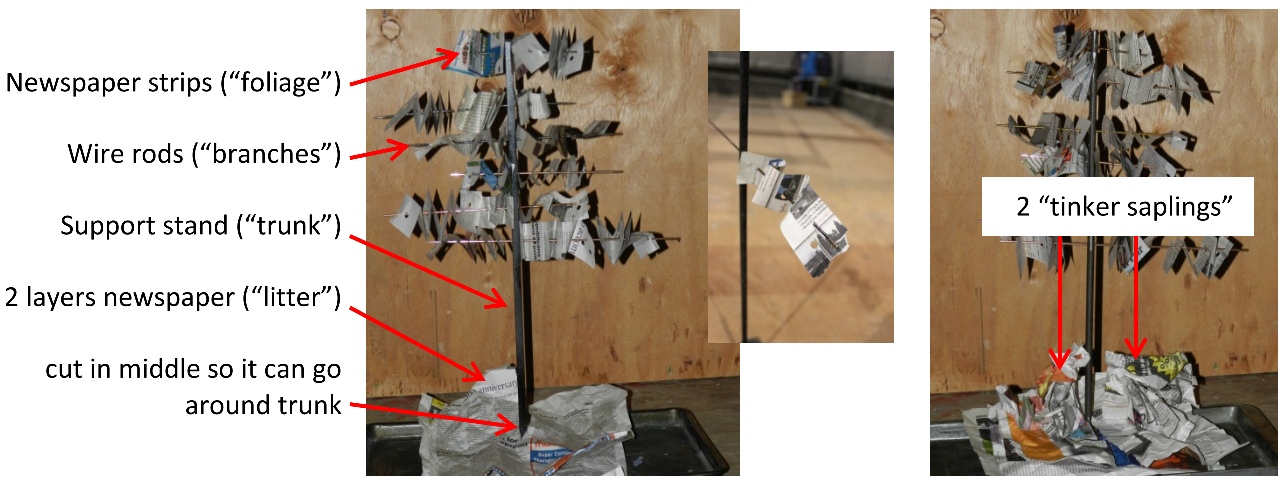


Figure M06-1. Setting up a tinker tree model. Place support stand (“trunk”) on metal tray. For **Phase 1** (shown at left), place 2 crinkled sheets of newspaper (“litter”) around base of tree. Students insert as many wire rods (“branches”) as desired into trunk. They thread hole-punched pieces of newspaper (“foliage”) on branches. At outside end of foliage strips, use rod to punch hole (shown at center). For **Phase 2** (shown at right), add 4 crinkled sheets of newspaper around base of tree and place 2 crumpled sheets (“tinker saplings”) on top of them, 1 under each side of the tree.

The Tinker Tree Derby has two phases; these enable students to see the effects of two different arrangements of fuels. Phase 1 uses relatively light surface fuels, and Phase 2 uses twice as much surface fuel and ladder fuels as well. Any tinker trees that survive Phase 1 (the “Qualifying Round”) will be tested again in Phase 2 (the “Championship Round”). **Thus it is important to not moisten or disturb the “trees” after they are burned in Phase 1.** The 2 phases model the potential for accumulation of surface fuel and development of the understory (tree saplings and shrubs) over time during the process of succession (change in a plant community over time). We recommend that you don’t give students any details about Phase 2 until after they’ve completed Phase 1.

Materials and preparation:
Do this activity in a laboratory with good ventilation and a hood or a high ceiling. Smoldering pieces of newspaper can rise as high as 20 feet on the heat plume from these experimental fires. If your laboratory space is not adequate, consider igniting the model trees outdoors - but not on a windy day. Use a large area that is far from dry grass, bark chips, and other fuels. Have a bucket of water and a hose available, with the water on. Have another adult help "patrol" for burning materials.

The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow. Also a day or more ahead, get students to prepare

- four bags (1 per team), each containing about 30 strips of newspaper approximately 40 cm long and 4 cm wide. Each strip has to be folded accordion-wise and hole-punched so it can be threaded onto a wire rod to represent tree foliage. The strips represent tree foliage in the tinker tree model.
- 24 half-sheets of newspaper, 25 x 35 cm. These represent litter in the model.
- 8 quarter-sheets of newspaper, approximately 25 x 20 cm. These represent saplings in the model.

Set up four stations. Each station should have these items from the trunk:

- 1 Tinker Tree support stand (To make new Tinker Tree support stands, see the instructions here).
- 1 pair of safety goggles
- 1 oven mitt
- 1 ashtray
- 1 metal tray
- 10-15 segments of wire rod
- 1 spray bottle, filled with water

In addition, you will need from the trunk:

- 1 measuring tape
- 1 fire extinguisher (make sure it is charged and know how to use it)
- 1 "Tinker Trees" kit with 4 pendants (awards for the winners in each phase)

Also place at each work station:

- 6 half-sheets of newspaper, 25 x 35 cm
- 1 bag of newspaper strips (about 30 strips, hole-punched)
- 2 quarter-sheets of newspaper
- paper towels for clean-up

You must supply:

- 1 box of kitchen matches
- A handful of hair ties, in case students need them
- An empty METAL trash can WITHOUT A PLASTIC LINER

Display these posters:

- FireWorks safety poster (***M02_FireWorks_Safety_poster.pptx*** from **Activity M02**)
- Fire Environment Triangle (***FireEnvironmentTriangle.pdf***)

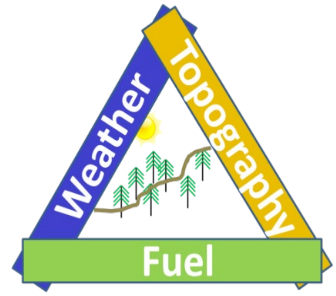
Download and project ***ladder_fuels.jpg*** (see Step 2 below)


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.



Make 1 copy/team of **Handout M06-1. Tinker Tree Derby instructions and Rules**
Make 1 copy/student of **Handout M06-2. Tinker Tree Model vs. Reality**

Copy these headers onto the board (or onto a sheet of paper if you're burning outdoors):

Team name	Qualifying Round: Surviving foliage (cm)	Championship Round: Surviving foliage (cm)

Procedure:

1. Explain: In this activity, we'll look more carefully at the Fuels side of the Fire Environment Triangle (***FireEnvironmentTriangle.pdf***, also known as the "Fire Behavior Triangle"). We'll think about how fuels are arranged – especially in forests and shrublands – and how the arrangement of fuels changes as plant communities change over time, a process called succession.

2. Project the image at right (***ladder_fuels.jpg***). Explain: If fuels are continuous from the forest floor into the tree crowns, we call them ladder fuels. A surface fire can climb them like a ladder and get into the crowns, where it becomes much more powerful than a surface fire and more difficult to control.

3. Distribute **Handout M06-1: Tinker Tree Derby Instructions and Rules**. Explain: This is a competition between teams, where you apply what you know about fuels to design a model tree that can "survive" a surface fire without having the fire climb into the treetops and become a crown fire. The winning tree will not just avoid being burned up; it must also have lots of foliage left, so it can continue to photosynthesize, grow, and reproduce after the fire. Therefore, your task is to have your tree **avoid crown fire** and at the same time **have lots of foliage left** after the surface fire.

4. Have each team read **Handout M06-1** together. Ask them to tell you one thing that will disqualify them from competition. Any moisture that they add to their model will disqualify the team. Answer any questions.

5. Show students how you will determine the **tree's score:** You will measure the length of branch (cm) that still has unburned newspaper ("live foliage") on it – NOT the total amount of newspaper or its weight. They can place the "foliage" as loosely or tightly on the branch as they want, but that will not affect the tree's score.**Do a safety briefing** using the FireWorks Safety poster (***M02_FireWorks_Safety_poster.pptx*** from **Activity M02**). Review the location of spray bottles and a fire extinguisher.

6. Give the students ~10 minutes to construct their trees. Watch for moisture violations!

7. **Phase 1 - Qualifying round:**

   A. One team at a time…

   - Ask for the team name and have a student write it on the board.
   - Check and modify the litter layer to make it similar among trees so this variable will not confound the results. (Explain that they are testing the tree's resistance to crown fire, not the influence of different arrangements of the litter layer.)
   - Have the students start the fire **by igniting two corners along one long edge** of the metal tray. (See the illustration in **Handout M06-1**.) If they all use the same ignition pattern, this variable will not confound the results.
   - When the fire is out, use the measuring tape to determine the **tree's score: the length of branch (cm) that still has unburned "foliage."** Have a student record this on the board under "Qualifying Round" for that team.

   B. After all teams have completed a burn, determine the winner of the Qualifying Round, that is, the team with the greatest total branch length with living foliage.

   C. Award Tinker Tree Derby Champion badges to the winning team. They get to wear the badges until the end of class.

8. **Phase 2 – Championship Round:**

   A. Explain: Surface fuels often accumulate as plant communities change over time without fire. During this process, which is called succession, trees reproduce, seedlings grow tall, litter accumulates, and shrubs develop under the forest canopy. We're going to model those changes.

   B. For all teams whose tinker trees survived the Qualifying Round, have students leave the surviving foliage intact but gently remove the ash of the burned surface fuels and replace it with 4 new layers of litter (crumpled half-sheets of newspaper). Teams with trees that did not survive the Qualifying Round (zero centimeters of unburned foliage) get to observe.

C. Have each team take two smaller pieces of newspaper (quarter-sheets), crumple them up, and place one on each side of their tinker tree trunk **under the branches**. These are "tinker saplings," young trees that have grown up under the old survivor.

D. **One team at a time**, check their litter layer… have them ignite… and determine the tree's score. Determine the winner, if any. Award Tinker Tree Grand Champion badges to the winning team. They get to wear these until the end of class.

9. **Ask/discuss:** Do the trees that survived surface fire resemble any of the trees that we saw in the "Visiting Wildland Fire" slide show (**Activity M01**) or the trees that grow around our communities, or the forests that we modeled with "matchstick forests" (**Activity M05**)? Open discussion. One point that may emerge: The surviving trees may resemble ponderosa pines with a history of frequent surface fire (i.e., they occur in open stands and they have no low-hanging branches).

Assessment: Have each student complete **Handout M06-2: Tinker Tree Model vs. Reality.**

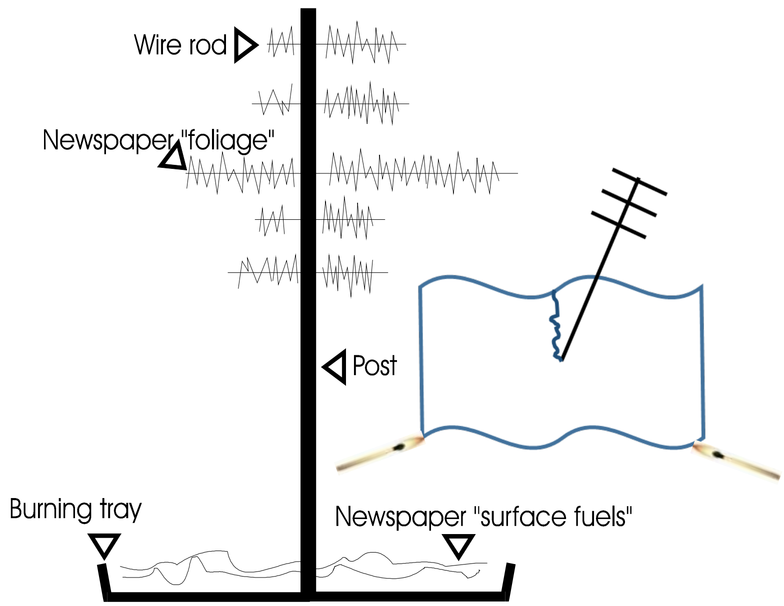
Evaluation:

	Excellent	Good	Fair	Poor
1. Changes to Tinker Tree	>2 changes	2 changes	1 change	0 changes
2. How Tinker Tree is not real	>2 examples	2 examples	1 example	0 examples
3a. Paragraph structure	Wrote a coherent paragraph, including topic sentence.	Wrote a coherent paragraph.	Wrote a sequence of sentences.	Did not use full sentences.
3b. Compare fuels and potential fire behavior	-Described 2 or more differences in fuels/density and explained 1-2 differences in potential fire behavior.	-Described 2 differences in fuels/density and explained at least crown fire potential.	-Described 1 difference in fuels/density or explained crown fire potential.	-Did not address questions.
3c. Use terms (surface fire, crown fire, ladder fuels, stand density)	-Correctly used 4 terms	-Correctly used 3 terms.	-Correctly used <3 terms.	-Correctly used 0-1 terms.

Handout M06-1: Tinker Tree Derby Instructions and Rules

A tinker tree is a two-dimensional model of a tree. Its trunk is a lab support stand. Its branches are rods stuck through holes in the trunk. Its leaves are strips of newspaper. Your goal is to design and build a tinker tree with a crown that does not burn when a fire burns the surface fuels beneath it. Your job could be easy—just put together a tree with no leaves. But your tree must also have foliage (leaves) to win the Tinker Tree Derby – the more, the better. You have to figure out how much foliage to use and how to arrange it on the tree so the tree can survive a surface fire.

Procedure:



1. Place a support stand (metal post) in the center of the metal tray.
2. Crumple up two half-pages of newspaper. These are your litter and other surface fuels. Flatten them out a bit, but make sure that some air can get between the layers.
3. Cut or tear a line from one edge of the newspaper pieces to the middle. Then place both layers on the support stand base, with the stand's post at the center.
4. Slide wire "branches" through the holes in the post. You may use as many or as few branches as you want.
5. Use the long, narrow strips of newspaper for foliage. Slide a foliage strip onto each tinker tree branch. For short branches, you may shorten the newspaper strip. Use the branch to poke a small hole at the outer end of the foliage strip rather than using a punched hole, so the newspaper won't fly off the branch once you start burning.
6. Teams will ignite their tinker trees one at a time. When the teacher tells you it's time to ignite yours, start the fire by igniting two corners along **one long edge of the metal tray**.

Rules:

- Do not use any moisture on your tinker tree or experimental setup before it is burned. **If you do, your tree will be disqualified.**
- Do not move or moisten your tree's foliage after you have underburned it.
- Do not hang foliage so it dangles into the branches below.

Keeping score: After you have underburned your tinker tree, the teacher will assign it a score: **the number of centimeters of branch still covered by unburned foliage**. If your score is greater than zero, your tree has qualified for the Championship Round of the Tinker Tree Derby. Do not change anything about it until you receive further instructions.

Handout M06-2. Tinker Tree Model vs. Reality

Name ________________________

1. List at least 3 changes you would make to your Tinker Tree or surface fuels to increase the tree's chances of surviving a surface fire. Explain why you would make each change.

2. List at least 3 three ways in which the Tinker Tree model does <u>not</u> resemble a real tree.

3. Study the photographs below. Write a paragraph that answers these questions:
   - How are the fuels in "A" different from those in "B"?
   - How are the different fuels likely to affect the kind of fire that would occur there on a dry, windy day?
   - How is stand density (the Matchstick Forest Model, covered in the last activity) likely to affect the kind of fire that would occur in each stand on a dry, windy day?

   Use all of the following terms correctly in your explanation: surface fire, crown fire, ladder fuels, stand density.

A.

Dave Powell, USDA Forest Service, Bugwood.org.

B.

Dave Powell, USDA Forest Service, Bugwood.org.

Answer Key to Handout M06-2. Tinker Tree Model vs. Reality

Question 1. List at least 3 changes you would make to your Tinker Tree or surface fuels to increase the tree's chances of surviving a surface fire. Explain why you would make each change. Assess changes individually.

Question 2. List at least 3 ways in which the Tinker Tree model does not resemble a real tree. Here are some examples of model shortcomings:

- Tinker tree's metal trunk cannot be damaged by fire.
- Tinker tree is two-dimensional (has foliage only on 2 sides of trunk).
- Foliage is not alive, so it has no moisture and is not changing with the seasons.
- Tinker tree has no roots that could be damaged by fire.
- Tinker tree does not grow taller, gain new branches, or shed old ones as years go by and succession occurs.

Question 3. Write a paragraph that answers these questions. Use the following terms correctly in your explanation: surface fire, crown fire, ladder fuels, stand density.

- How are the fuels in "A" different from those in "B"? A has more surface fuels, larger surface fuels, more **ladder fuels**, and more closely-spaced tree crowns than B.
- How are the different fuels likely to affect the kind of fire that would occur there on a dry, windy day? A is more likely to have a **crown fire** on a dry, windy day than B. B is likely to have only **surface fire.**
- How is stand density (the Matchstick Forest Model, covered in the last activity) likely to affect the kind of fire that would occur in each stand on a dry, windy day? Fire can move more easily from one crown to another in Stand A, which has higher **stand density**, than in Stand B. Surface fire could occur in either stand. Surface fire is likely to spread more rapidly in Stand B than Stand A because B is more open (i.e., lower stand density), which means that wind at the ground surface is likely to be stronger. In addition, surface fuels in B are likely to be hotter and drier than in A because of exposure to sun and wind.

  Here is an additional idea not covered in this activity: Because of its heavy fuels, a surface fire in A is likely to be much more severe than in B (releasing more heat into tree trunks and the ground). This could kill the trees without burning their crowns.

7. 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, how long they are likely to burn, and how completely they consume the fuels available. Students consider various combinations of fuels ("fuel recipes"), predict how they will burn, then test their hypotheses. Then students demonstrate what they have learned in discussion and in writing.

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

Duration: Two to three half-hour sessions

Group size: Teams of 3-4

Setting: Outdoors or laboratory with good ventilation

Vocabulary: *duff, fuel arrangement, fuel load, fuel moisture*

Lesson Goal: Increase students' understanding of properties of wildland fuels and how they affect fire spread, fire duration, and burn completeness.

Objectives:

- Students can arrange specific fuels in a way that will maximize their ignitability, the fire's duration, and the completeness of the burn.
- Students can discuss the ignition and burning of various combinations of wildland fuels in relation to 4 properties: amount, size, moisture, and spatial arrangement.

Standards:		6th	7th	8th
CCSS	Writing	4,7,10	4,7,10	4,7,10
	Speaking and Listening	1,4,6	1,4,6	1,4,6
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	4,7,10	4,7,10	4,7,10
NGSS	Energy	ETS1.A,B		
	Structure and Property of Matter	PS3.A		
	Structure, Function, and Information Processing	LS1.A		
	Engineering Design	ETS1.A,B		
EEEGL	Strand 1	A,B,C,E,F,G		

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 (known as fuel load or loading),
size,
moisture content, and

spatial arrangement.

These properties determine how the fuels are heated and how much oxygen contacts them, and thus how quickly they will ignite, how long they will burn, and how much fuel will be consumed. Information useful for your discussion is given below, with connections to the Fire Triangle in **bold print.**

1. How much fuel is there? All other things being equal, the more **fuel** you have, the longer your fire can burn and the more **heat** it can produce… if you can get the fuels to ignite.
2. What sizes are the fuels?
   - The smaller the fuel particles, the more easily **heat** can engulf them and raise their energy to ignition temperature. Also, the smaller the particles, the more **oxygen** available to their surface for burning. Example: Consider the challenge of igniting a big, dead log versus a dead pine needle. 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. Because they are small, they burn up quickly.
   - Large fuel particles tend to burn slowly because it takes time for the outside surface to burn away, exposing a new layer of fuel to **heat** and **oxygen**. If there isn't enough heat to sustain combustion, large particles will not burn completely.
3. How moist are the fuels? The drier the fuels, the less **heat** needed to dry them out, so the more easily they will ignite and the more completely they will burn. Moisture makes fuels hard to ignite, makes them burn slowly, and creates more smoke because they burn less efficiently. This is because incoming **heat** must remove the moisture before the particle can be heated to ignition temperature.
4. How are the fuels arranged?
   - How "fluffy" are the fuels? The fluffiness of fuels determines how much **oxygen** is available for combustion and whether **heat** is "trapped" in the complex of fuels rather than "escaping" into the open air. An important skill in building a campfire is to get the spatial arrangement of fuels "just right" so heat reaches the **unburned fuels** and plenty of oxygen is available among fuel particles. Fuels have to be somewhat near each other for fire to spread from one piece to another. The pieces can be too loosely packed for heat to reach from one particle to the next, making it hard for fire to spread. For example, if you crumple up 20 pieces of newspaper and scatter them across a large room, the **heat** from one burning piece will "escape" into the open air rather than heating other pieces of newspaper. Thus the fire will not spread from one piece to another. But the pieces can also be too tightly packed for **oxygen** to be available as they are heated up. For example, a tightly piled stack of newspapers is hard to start on fire and burns slowly. It may smolder for a long time or go out (leaving much of the fuel unburned), depending on the amount of heat and the availability of oxygen.
   - How fuels arranged vertically? If easy-to-ignite fuels are placed below hard-to-ignite fuels, the rising **heat** is trapped in the complex of the fuels above and helps ignite them. We use this principle in building a campfire when we place small particles ("fine fuels" such as newspaper and kindling) near the bottom of the fuel bed and large ("coarse") fuels above. Land owners who want to prevent crown fires notice heat's tendency to rise too, so they make sure there are big gaps between surface fuels (grass, shrubs,

small trees) and tree crowns. Heat will disperse from the fuels in these gaps and escape into the open air. If the gaps are small, the heat is trapped and combustion continues, spreading up through ladder fuels and reaching the tree crowns. Students examined this principle experimentally in **Activity M06.**

This activity investigates one aspect of the Fire Behavior Triangle directly: fuels. Indirectly, it also investigates weather (which controls the moisture of fuels) and topography (which influences the dispersal of heat).

Materials and preparation:
This activity is best done outdoors because it can be messy and smoky; however, do not do the activity outdoors on a windy day. Use a large area that is far from dry grass, bark chips, and other fuels. Have a bucket of water and a hose available, with the water turned on. Have another adult help “patrol” for safe use of matches and watch burning materials. If you do the activity indoors, use a laboratory with good ventilation (i.e., a hood).

- 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.
- Make sure you have enough dry peat moss (representing duff) to do the activity. Some is usually included in the trunk.
- The day before you do the activity, remind students to dress appropriately for burning. Post and refer to the FireWorks safety poster (***M02_FireWorks_Safety_poster.pptx***).
- The day before you do the activity, collect enough green conifer needles to do the activity.
- Project ***FuelRecipesToDisplay.pdf*** or copy the ingredients for the fuel recipes onto the board (or a poster, if you plan to do the activity outdoors):

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

3	Small twigs Duff Big sticks
4	Duff Big sticks Green conifer needles

- Set up your teacher area with:
  - The Fuel Recipe box (from the trunk – or print it yourself from here). Be sure to select the recipes labeled "M" for Middle School students.
  - 5 boxes or grocery bags containing fuels (dead, dry conifer needles; small twigs (<0.5 cm diameter); dry peat moss, which serves as duff; big sticks (2-3 cm diameter); green needles). (Some of these fuels may be available in the trunk.) Label the bags. You can use the tie-on labels from the trunk.
  - Fire extinguisher.
  - 2 spray bottles (from the trunk), filled with water, and additional water (bucket, charged hose, etc.) to ensure you can easily put a fire out.

- Set up 4 student work stations on lab benches or other surface that will not be damaged by heat. Each station needs:
  - one 9" diameter aluminum pie tin with tilted edges
  - 1 match box with **7 matches**
  - 1 ashtray (from the trunk)
  - 1 pair of safety goggles (from the trunk)
  - 1 oven mitt (from the trunk)

- Have a METAL TRASH CAN WITHOUT A PLASTIC LINER on hand.

Procedures:

1. Explain: Students will work in teams to build small "campfires" using specific combinations of fuels. <u>This is an investigation rather than a competition.</u> The experimental questions are:

   - What kinds of fuels are easiest to ignite?
   - What kinds of fuels burn longest?
   - What kinds of fuels are most likely to burn up completely, and what kinds are likely to go out leaving some material unburned?

2. Explain what duff is: partly decomposed plant and animal matter lying on or in the soil. There can be a huge amount of duff on the ground – as under an old tree or in a peat bog that may have "organic soils" a meter deep or more. Or there can be very little duff – as in dry places where plants grow slowly. Remember from **Activity M05** that a fire burning in the duff is called a ground fire. In this experiment, dried peat moss can be used to represent duff.

3. Refer to the recipes written on the board or projected (***FuelRecipesToDisplay.pdf***). Ask students to "vote" on:

   - which will be easiest and hardest to start on fire
   - which will burn out in the shortest time and which will last longest
   - which will burn the fuels most completely and which will leave the most fuel unburned

   Record the votes on the board. These represent the class's hypotheses.

4. Group students into 4 teams.

5. Do a safety check. The whole team is responsible for safety. If any student is injured, the team must alert the teacher and use water to put out their campfire.

6. Explain: Each team will…

   a. Draw a recipe from the Recipe Box.

   b. Collect the three 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. **Your 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. **Your 7 matches** can be used to ignite the campfire or added into the fuel array. Obviously, at least one must be used for ignition.

   d. Have a teacher or other adult verify that you have met the requirements before ignition.

   e. After ignition, do not rearrange the fuels, but you may blow on the fire. Dispose of burned matches in the ashtray or in the campfire.

7. Have the students ignite their campfires. Monitor their progress and watch for safe practices.

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. **Clean up:** Make sure all burned materials and matches are completely out before you dispose of them – that is, there is no smoke and no heat being released. Especially check large sticks and duff, which can smolder for a long time. Stir the fuels and feel for heat. Use an empty metal trash can without a plastic liner. If in doubt, dump fuels in a bucket of water and leave them there overnight before draining and putting in trash.

Assessment: The first part of the assessment is based on discussion. (OPTION A is based on informal discussion, OPTION B on highly structured discussion.) The second part of the assessment is written. **Base discussion on the following questions:**

- Were any of our hypotheses correct? Were any incorrect?
- Which recipe was easiest to start on fire? Which was hardest? Use the Fire Triangle to explain.
- Which recipe burned out quickest? Which recipe burned longest? Use the Fire Triangle to explain.
- Which recipe burned the fuels most completely? Which recipe left the most fuel unburned? Use the Fire Triangle to explain.
- How did fuel amount – i.e., loading - affect fire?
- How did fuel moisture affect fire?
- How did fuel size affect fire?
- How did the fluffiness of fuels affect fire?
- How did the vertical arrangement of fuels affect fire?

Information for guiding the discussion is in the **Teacher Background** above.

OPTION A: Unstructured. Ask: How do the results of your experiments confirm or contradict the hypotheses that the class developed (see Step 3 above)? Discussion.

OPTION B: Highly structured. Set up the following "Dynamic Socratic Circle with Brilliance Board." In this activity, students will discuss the class's hypotheses, fuel properties, heat transfer, and concepts from the Fire Triangle. Instructions:

a. Divide the class into three groups (A, B, C). Then arrange the chairs in the room to make an inner circle of chairs (enough chairs for each student in group A) and an outer circle of chairs (enough chairs for each student in group B). Have each student in group C stand by the board and be ready to write.

b. Give the individuals in the inner circle a question that they must discuss. All must contribute to the discussion. Students in the outer circle can join the conversation in the inner circle by tapping the shoulder of a student in the inner circle who has contributed. Then these two students will switch places. While groups A and B (inner and outer circle) are speaking and listening, group C at the board is writing down brilliant and important points and questions that come up during the conversation. Tell Group C that it is good to repeat points because after the discussion the class will analyze the board for trends.

c. Rotate the groups so each has had a turn at each station. When there is little left to be said or information is being repeated, change the question.

Evaluation:

1. Participation in OPTION A or OPTION B above. If you used OPTION B, use the table below for evaluation.

2. Have each student write down the specific recipe his/her team used and then use the four fuel properties (amount, size, moisture, arrangement) to explain why this recipe burned as it did (easy or hard to ignite, burning out quickly or slowly, burning completely or incompletely).

<u>Use for OPTION B</u>, Dynamic Socratic Circle with Brilliance Board				
	Excellent	**Good**	**Fair**	**Poor**
Inner Circle	Built upon peers' comments, contributed to conversation, and encouraged others to speak.	Contributed to conversation.	Did not contribute but was actively listening.	Disruptive to conversation
Outer Circle	Tapped in once a student had spoken, encouraged others to tap into the inner circle.	Student was willing to leave the inner circle when tapped out.	Did not tap in but was actively listening	Disruptive to conversation
Brilliance Board	Consistently wrote brilliant points and questions on the board.	Student was actively listening and occasionally wrote on the board.	Did not participate but was actively listening.	Disruptive written remarks.
Written explanation of recipe's success	Addressed 4 fuel properties in regard to experimental fire. Addressed ease of ignition, duration of burning, and completeness of combustion.	Addressed 3 fuel properties in regard to experimental fire. Addressed 2 of these: ease of ignition, duration of burning, completeness of combustion.	Addressed 1-2 fuel properties. Addressed 2 of these: ease of ignition, duration of burning, completeness of combustion.	Assessed 0-1 fuel property. Addressed 0-1 of these: ease of ignition, duration of burning, completeness of combustion.

8. Managing a real fire: Weather, fuels, topography, and models

Lesson overview: In this activity, students study the history of a real wildland fire, the Lolo Peak Fire of 2017 in western Montana. They view and discuss a presentation and 2 short videos to learn how managers used information on weather, fuels, and topography to manage the fire. Then they identify patterns in weather data that are correlated with fire behavior. They synthesize day-by-day reports from the official records of the **Incident Command (IC) Team** and news articles to create podcasts on the fire's progress. Finally, they interpret maps and slides in a presentation that shows the fire's growth and the variety in its severity.

Subjects: Science, Mathematics, Geography, Reading, Speaking and Listening
Duration: 3-4 class periods
Group size: small groups
Setting: Classroom
Vocabulary: *basal area, contained* (status of fire)*, Incident Command (IC) Team*, mop-up, suppression repair, synthesize*

*These and other technical terms about fire management are defined in the *Glossary of Wildland Fire Terminology* (https://www.nwcg.gov/glossary/a-z).

NOTE TO TEACHER: A more complex version of this lesson, which involves technical reading and creation of a video production, is available in the High School curriculum, Activity H10-1.

Lesson Goals: Increase students' understanding of the

- interactions of weather, topography, and fuels as they influence fire behavior.
- ways in which fire managers use data, modeling, and experience to manage a wildland fire.
- variation in severity of a wildland fire.

Objectives: Given weather data, reports from an Incident Command Team, and news articles, students can

- explain why a wildland fire showed rapid spread at times and showed little or no spread at other times.
- synthesize information on the progress of a wildland fire into a podcast for a national audience.
- interpret maps and photos that illustrate the fire's growth and severity.

Standards:		6th	7th	8th
Common Core ELA	Reading Informational Text	1, 4, 7, 10	1, 4, 7, 10	1, 4, 10,
	Writing	1, 3, 4, 6, 10	1, 3, 4, 6, 10	1, 3, 4, 6, 10
	Speaking/Listening	1, 2, 4, 5, 6	1, 2, 4, 5, 6	1, 2, 4, 5, 6
	Reading Standards Science/Tech	1, 4, 10	1, 4, 10	1, 4, 10
	Writing Standards Science/Tech	1, 2, 6, 9, 10	1, 2, 6, 9, 10	1, 2, 6, 9, 10
NGSS	Weather and Climate	ESS2.D		
	Natural Hazards	ESS3.B		
EEEGL	Strand 1	C, F, G,		
	Strand 2	A		

Teacher background: From activities in **Units II** and **III**, students have gained a theoretical understanding of combustion and wildland fire behavior. In this activity, they apply their understanding to a real wildland fire, the Lolo Peak Fire of 2017 in western Montana. The fire began with a lightning strike on July 15, 2017, and was contained 87 days later, in early October. ("Contained" means that a fire is fully surrounded by control lines and other features that can be reasonably expected to stop its spread.) It burned more than 53,000 acres and cost approximately 48 million dollars. One firefighter died on the fire when he was struck by a falling tree. Two homes were burned. A major highway was closed for several days, and hundreds of residents were evacuated – some of them more than once.

A tremendous amount of information is available about the Lolo Peak Fire. You could use this activity as the basis for a research project and have students locate their own information and evaluate its quality, but that would be very time consuming. To help meet the objectives of the activity in a shorter time, we have selected a subset of the information available and packaged it in 6 **Fire Reporting Packets**, which students use to report on the fire at 6 different times while it was burning. The packets are available in the trunk or downloadable as zipped files, which are named **FireReportingPacket…** followed by a range of dates in yymmdd format. Information in the packets includes:

- **Narratives:** Excerpts from the official record of the fire as published on "Inciweb" (https://inciweb.nwcg.gov/). Inciweb is the official database for reporting on national emergencies such as fires, floods, and hurricanes. Each of these emergencies is managed by an Incident Command (IC) Team, whose members have extensive training and experience.

- **Articles** from local newspapers - the *Missoulian* and the *Ravalli Republic*. We selected news reports and guest editorials from scientists and other experts.

- **Statistics:** Daily reports of fire size, number of personnel on the fire, and estimated cost.

At the beginning of the activity, students review the Fire Environment Triangle, which was introduced in **Activity M05** (the "matchstick forest" activity). Then they view a presentation about the origin of the Lolo Peak Fire and plans for managing it

(***WeaFuelsTopog_OpeningAndVideo.pptx***). The presentation includes links to 2 short videos created by the IC Team shortly after the fire started. IC Team members in the videos describe their plans for managing the fire and the use of modeling to inform their plans.

After viewing the presentation, students work in 6 teams to examine data on weather and fire growth so they can develop explanations of why the fire behaved as it did at various times. They identify weather variables that influenced the fire's biggest single run on August 19, 2017, and the variables that influenced it as it died down in early September. Then they explain their ideas to the class.

NOTE: Atmospheric inversions influenced the behavior of the Lolo Peak Fire and caused poor air quality throughout the region during the summer of 2017. This activity does not address smoke and inversions, but **Activity M09** does. It explains the nature of inversions and challenges students to identify inversions during the time of a wildland fire and predict the resulting impacts on air quality.

This activity has two **Assessment** sections. In the first, each student team creates a 5-minute podcast on the progress of the fire during 1 of 6 time periods. The information needed for student reports is contained in the **Fire Reporting Packets** described above. Student reports must describe how weather, fuels, and/or topography influenced the fire's growth (or lack of it) during that specific time period.

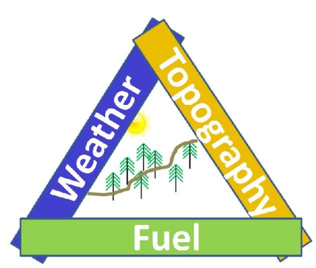
In the second assessment, which is much less formal, students explain maps and photos in a presentation that describes the fire's progress (***WeaFuelsTopog_ClosingAndVideo.pptx***) and summarizes its severity.

If you are interested in exploring the history of other wildland fires or the current status of fires throughout the United States, consult some of these websites:

http://inciweb.nwcg.gov/	Information on the size, status, and other features of current fires throughout the United States
http://www.nifc.gov/fireInfo/fireInfo_main.html	National Interagency Fire Center – coordination and information for wildland fire programs nation-wide
http://gacc.nifc.gov/	Geographic Area Coordination Center – a portal for each major geographic region in the United States. Content differs by region, but most sites feature regional news, maps, and other detailed information.

Materials/Preparation:

1. Download and prepare to give the"opening" presentation, which gives background on the Lolo Peak Fire (***WeaFuelsTopog_OpeningAndVideos.pptx***) at the start of the activity. This presentation includes links to two short (~3-minute) videos created by the IC Team in late July. Click on this icon (embedded in the slides) to start the videos. Here are the links, so you can preview the videos:
   - "Lolo Peak Fire Strategy and Tactics" (https://www.youtube.com/watch?v=4CCHIzM5Tzk&feature=youtu.be).
   - "Fire Science on the Lolo Peak Fire" (https://www.youtube.com/watch?v=Cxr2rq4dCy4&feature=youtu.be).
2. Download the "closing" presentation (***WeaFuelsTopog_Closing.pptx***), which you will ask the students to narrate. This is a review of the fire's behavior and management.
3. Find the 6 copies (1/team) of the ledger-size display of fire weather and fire growth data in the trunk **or** have students view them electronically from **WeatherGrowthTimelines.jpg or** print 6 copies from **WeatherGrowthTimelines_LedgerSize.pdf**. (This document is designed for 11 X 17" (ledger size) paper. However, if that size of paper is not available, it will print OK on two pages of 8.5 X 11" paper.)
4. Find and display the poster-size display of fire weather and fire growth data in the trunk **or** display it from **WeatherGrowthTimelines.jpg**.
5. Find the **Fire Reporting Packets** in the trunk or make them available from zip files entitled **FireReportingPacket...** with a range of dates attached. There are 6 packets, one for each time period to be covered by a student report. The contents of the packets are described in **Teacher Background** above. If you are using pre-printed packets from the trunk, remove the **Graphics** printout from each. It is there for the High School version of this lesson (**H10-1**) but is not needed for this version.
6. Decide whether or not to use a student host for the National Weather Radio podcasts. If you decide to do this, explain to the student that he or she only needs to give a very short introduction of each presentation, and he or she will also be on one of the 6 reporting teams.
7. Decide on the format to be used for podcasts – (a) live but hidden, so the students can only hear the "broadcast", (b) live but visible, so the students can see who is speaking and how the sound effects are produced, (c) pre-recorded, so the students can listen on their own. Set up whatever technology is needed.
8. Display the Fire Environment Triangle poster from **Activity M05** in the classroom (**FireEnvironmentTrianglePoster.pdf**).
9. Print 1 copy/student or team: **Handout M08-1. Podcast on the status of the Lolo Peak Fire.**



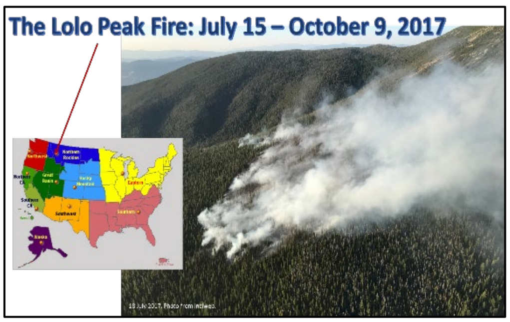
Procedure:

<u>Part 1 (1 day)</u> – Background and introductory videos

1. Refer to the Fire Environment Triangle poster on display (**FireEnvironmentTrianglePoster.pdf** from **Activity M05**). Explain: We've studied the theory of combustion and fire spread. Now we'll apply our knowledge to a real wildland fire, the Lolo Peak Fire, which occurred in western Montana in the summer of 2017. We're going to use what we already know, and we'll also pick up information from the experts who managed the fire. Then we'll try to figure out why the fire actually behaved as it did.

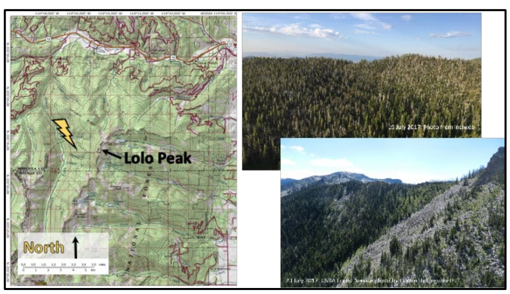
2. Go through the "opening" presentation, which includes 2 short videos (***WeaFuelsTopog_OpeningAndVideo.pptx***):

Slide 1



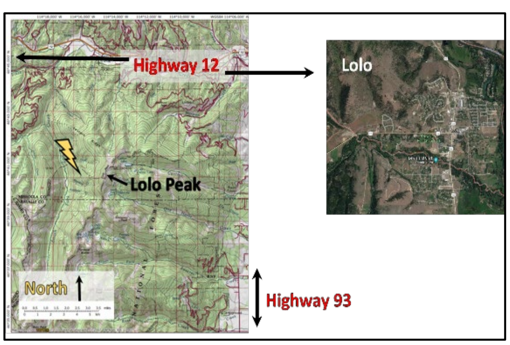
Lightning started the Lolo Peak Fire on July 15, 2017. The lightning strike was just west of Lolo Peak in the Lolo National Forest. The Lolo Peak Fire was one of 68 new fires that started in the northern Rocky Mountain area that day, so managers and planners were very busy, and "resources" – firefighters, helicopters, airplanes, and equipment – were in high demand throughout the region.

Slide 2



The fire started within a wilderness area, so there was no road access. It was surrounded by dense forest to the south, west, and north. To the east, uphill from the fire, the forest gave way to steep, rocky ridges and mountaintops.

Slide 3



About 5 miles north of the fire, U.S. Highway 12 follows the wide, east-flowing drainage of Lolo Creek. The highway comes out of Idaho (to the west of this map) and goes through the town of Lolo (just off the map to the east). In Lolo, it meets U.S. Highway 93 and then goes north into Missoula. About 4,000 people live in Lolo. More than 100,000 people live in the broad Bitterroot and Clark Fork River valleys to the south, east, and north of the fire.

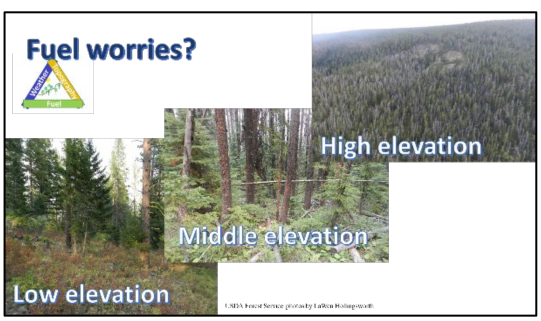
Slide 4

Managers and residents were worried about this fire. Why were people so worried? What problems or dangers do you think they were concerned about? Open discussion. Here are some points that could come up: There are a lot of people living near the fire. A lot of people use this area for recreation and enter the Forest from dozens of small roads. There are hundreds of homes, ranches, and businesses along the two highways. (How can the people and property be protected? How can people be contacted if they are camping in the wilderness?) The terrain is very rugged and inaccessible by road. Over much of the area, there's continuous forest – so there's no place for firefighters to go for safety if the fire starts a fast, dangerous run.

Slide 5

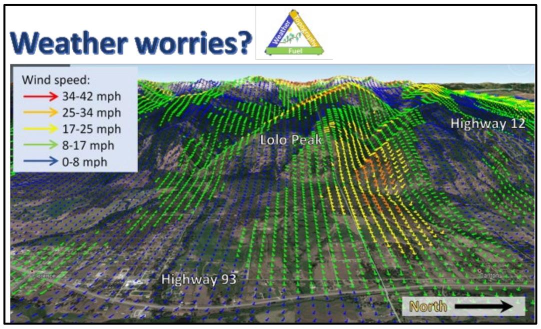
Big national crises, including fires, floods, and hurricanes, are usually managed by an *Incident Command (IC) Team*, a group of experts in handling wildfires and other emergencies. On July 21, management of the Lolo Peak Fire was assigned to a "Type I" IC team. Type I is the highest level of training and experience available in the United States, and Type I team members have worked together in emergency management for many years. **Click the link to view the 3:12-minute video "Lolo Peak Fire Strategy and Tactics."** Explain: As you watch the video, jot down some of the speakers' concerns. Are they the same ones we have identified? New ones? Do they make sense? After the video, discuss.

Slide 6



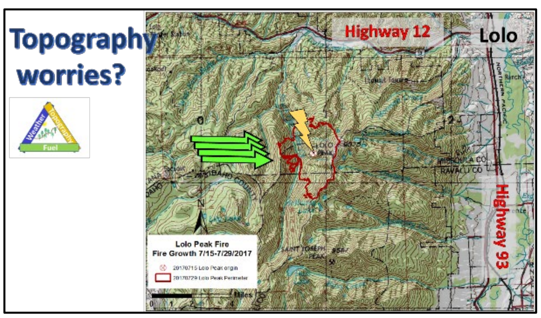
We're going to try to figure out why the fire behaved the way it did over the 87 days when it was burning. Let's review a little first, by applying what the IC team said in the video to what we know about the Fire Environment Triangle. First, fuels: Here are a few photos of fuels in the area. Low-elevation forests have a lot of ponderosa pines and more openings than middle-elevation forests. Middle-elevation forests have a mixture of tree species, including a lot of dead lodgepole pines – both standing snags and fallen logs. High-elevation forests have abundant subalpine firs of all ages and sizes. Do you remember what the Fire Behavior Analyst in the video said about subalpine firs? When subalpine firs burn, they produce a lot of embers that are likely to start spot fires – possibly a long way outside the fire's perimeter.

Slide 7



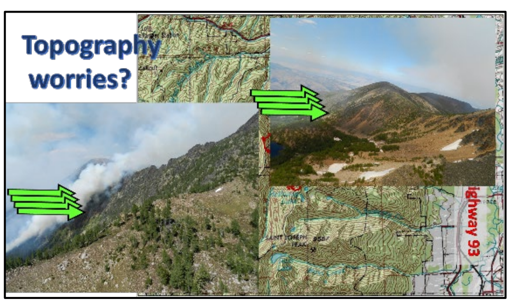
The video didn't talk much about weather, so let's look at additional information that was in their official "Incident Decision" – the 48-page document that explained how they planned to manage the fire. The report emphasized that strong winds and summer thunderstorms usually occur in the middle of August, and they often come from the west. This diagram shows the speed and direction of winds on July 20. On that day, the wind was coming out of the west – that is, it was coming from the background straight toward us. Look how it spills forward, down the mountainsides. How strong are these winds? The green arrows predominate; they show wind speeds from 8 to 17 mph (measured 20 ft above the ground). This is enough wind to push a steady surface fire with some torching. The diagram shows pockets of winds around 20 mph and even one steep slope with downhill winds of more than 30 mph. These winds are strong enough to knock down trees, especially the many standing dead ones in the Lolo Fire area.

Slide 8



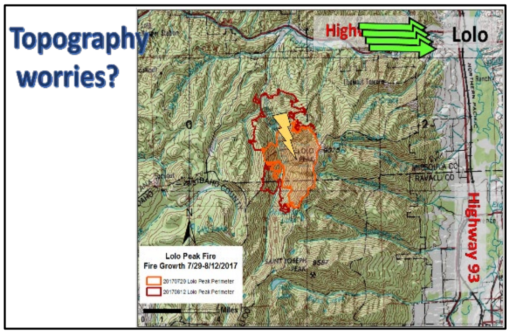
Here's a topographic map of the fire area. The red line shows the perimeter of the fire when the IC team made the video. The fire was staying within a deep, north-south drainage. Strong winds from the west would push it up toward Lolo Peak. Remember what the topography is like up there?

Slide 9



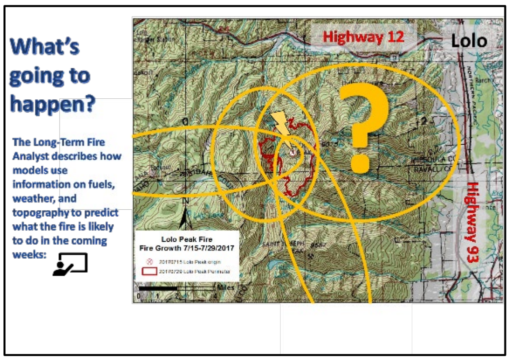
The topography is steep, with lots of rocky ridges and barren openings. What are the fuels like? Fuels are patchy and very sparse along the ridge tops. What will the fire do when strong westerly winds arrive? Surface fire probably can't spread over the ridge to the east because surface fuels are so patchy. There's a lot of subalpine fir at these elevations though. A strong westerly wind could cause these to torch, loft thousands of embers to the east, and ignite multiple spot fires.

Slide 10



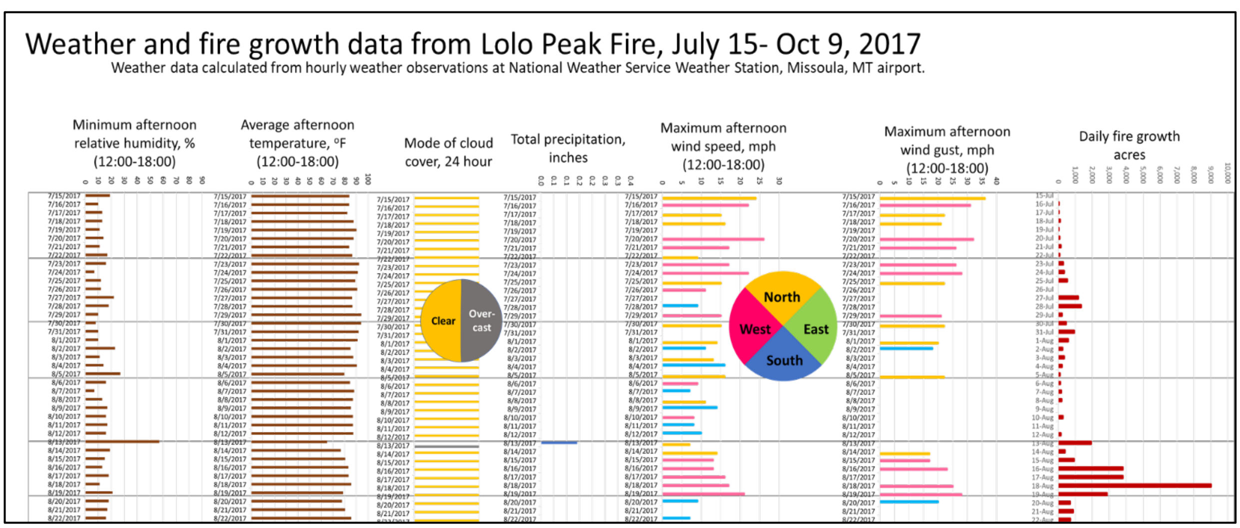
But the IC Team expected the fire to move north, into the wide drainage that contains Highway 12. And over the next 2 weeks, it began to do that. What's going to happen when the fire moves out into that valley and then strong westerly winds arrive? The wind is likely to push the fire very rapidly through that valley, toward the town of Lolo.

Slide 11



Click the link to view the 2:58-minute video "Fire Science on the Lolo Peak Fire."

3. Explain: Now that we know a how experts planned for the fire and predicted what it would do, we're going to work in teams to figure out why it did what it ACTUALLY DID. We'll look at information on weather, topography, and fire spread.
4. Set up 6 student teams. Give each team a copy of the weather and fire growth graphs (**FireWeatherAndGrowth_LedgerSize.pdf**) or provide a way for them to view it electronically from **WeatherGrowthTimelines.jpg**. The top of the graph display is shown here:



5. Refer to the poster-size copy of this file from the trunk or projected from **WeatherGrowthTimelines.jpg**. Explain: Each team has a copy of these graphs. They show some of the data recorded during the fire each day, plus information on how much the fire

grew each day. Notice that the information on wind incorporates BOTH weather AND topography, because it is color-coded to show you what direction the wind is coming from. In your team, discuss the graphs and come up with an explanation of:

- how weather and topography contributed to the big fire run on August 19
- how weather and topography slowed the fire's spread in early September

6. Have 1 member of each team give the team's explanation of the big fire run on August 19; the 6 teams may have different explanations, which would be great! Have them refer to the poster version of the graphs on display. It is not easy to find a clear connection between weather and fire growth, but there are clues in the data: Think about the ALIGNMENT of strong westerly winds with east-west drainages that was referred to in the video "Lolo Peak Fire Strategy and Tactics". The most useful graphs are the two that show wind speed and direction.

7. Have a different student from each team explain the decline in fire growth that occurred in early September. Students probably won't have much trouble finding the time when the fire died down: It is associated with cooler temperatures, high humidities, increased cloud cover, and precipitation – all of which occurred in early September.

Part 2 (1-2 days) – Podcast assessment:

1. Explain: The National Weather Service, which provides weather reports and forecasts for the entire United States, has its own radio station, National Weather Radio (http://www.nws.noaa.gov/nwr/). The station provides forecasts and warnings of severe storms, but it also features news stories about weather-related events. Weather experts at the station have heard that there's a wildfire brewing in western Montana – the Lolo Peak Fire – that could be of national interest. They've invited our class to report on this fire in a series of 5-minute podcasts, which will be broadcast on Saturday evenings. We're going to respond to their invitation by working in teams to produce podcasts for 6 different time periods during the Lolo Peak Fire.

2. Explain: **You do not have to do the detective work** for this report. That might be fun, but you'd have to sift through hundreds of websites and news articles to do it, and you don't have enough time. Instead, your team will use a **Fire Reporting Packet** for your time period, which contains everything you need.

3. Give each team their packet.

4. Explain the role of the student host if you plan to use one.

5. Give each student or team a copy of **Handout M08-1**. **Podcast on the status of the Lolo Peak Fire**. Assign a time period to each team from this table. Go over the assignment and answer questions. Explain the deadline. Consider making it short (1 class period). That may not be much time, but that's journalism! Then have the class listen to the podcasts. If you record them, this could be done individually.

Team	Time period (2017)
1	July 15 through July 29
2	July 30 through August 12
3	August 13 through August 19
4	August 20 through August 26
5	August 27 through September 9
6	September 10 through October 9

<u>Part 3 (1 day)</u> – Slide show assessment:

6. Ask: How severe do you think this fire was? Do you think it killed most of the plants and animals inside the fire perimeter? Discussion.

7. Go through the "closing" presentation (***WeaFuelsTopog_Closing.pptx***). Have students narrate most of it, keeping the discussion informal, encouraging students to use what they've learned and also a little imagination. Have each student speak at least once. The handout notes below give information on the slides, which you can use to prompt speakers and add ideas that they may not know about.

Slide 1

Explain: Now that you've studied the IC Team's reports, you can explain maps and photos from the fire. Put yourself into the position of the Incident Commander or the Fire Behavior Analyst or a firefighter, use a little imagination, and share some thoughts about the maps and photos as we go along. Both of these photos are from early in the fire. What are your thoughts about them? (Comments on all photos in this presentation go clockwise from left.) ~~~The left photo shows multiple hot spots within the very steep, deep valley where the fire originated. ~~~The right photo shows convection columns from 2 sides of the fire converging above the valley. There may be firebrands in that column, and it could pull the 2 sides of the fire together underneath. How safe would fire crews be in the valley below?

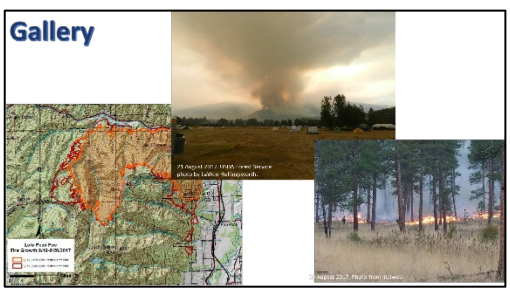
Slide 2

Here's the last map we looked at, which was made when the fire hadn't yet spread into the east-west-oriented Lolo Creek drainage along Highway 12. What's going on in the 3 photos? ~~~Crews are removing fuels from a road, which is probably a primary control line. ~~~Fire engines are in position near developed areas in case they have to put out structural fires. (Structural firefighters have different equipment and training from that of wildland firefighters.) ~~~Wildland fire staff meet for a briefing ("morning briefings" are held each morning before crews head out for day shift work). What kinds of jobs do these people have? The staff on a big fire includes the Incident Commander and other IC Team members, safety specialists, ground crews and heavy equipment operators, pilots and staff who manage helispots and aircraft, fire behavior specialists, fire modelers, ecologists who know the land and vegetation and locations of weedy areas, people who provide information to the public, and people who find and order equipment and crews – and make sure they get paid!

Slide 3

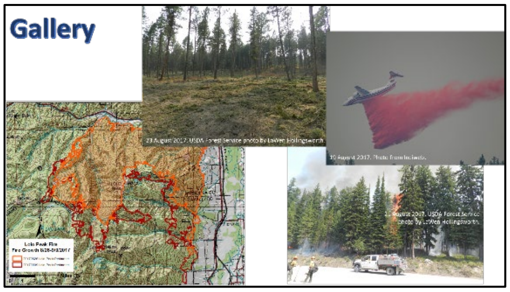
Here's the fire map a week later. What does it show? ~~~It shows the big, 4-mile fire run that occurred on August 19. What's going on in the photos? ~~~Sheriff's deputies are getting information about areas that need to be evacuated, roads that are closed (and must be patrolled so people don't go in and possibly be trapped by the fire), and locations that have already been evacuated (and must be patrolled so looters don't take advantage of the situation). ~~~The convection column/smoke plume from the fire's big run looms above a home. (The photo was taken from a location nearly 15 miles from the fire.) The smoke is rising high enough to punch through the cloud layer above. ~~~The fire's rapid run on August 19 continued into the night, so viewers from 10-15 miles away could see flames hundreds of feet above the crowning fire.

Slide 4



Here's the map from the next week. What has the fire been doing? There was gradual fire spread to the west, and the fire began to spread south along the Highway 93 corridor. Some of the new red patches along the Highway 93 corridor are probably from "burnouts" used by firefighters to reduce fuels between the fire and control lines. Notice that the fire has not (yet) made a major run eastward across the rocky, barren top of the Bitterroot Divide. Describe the photos: ~~~The view of the smoke column is not from a regular campground; it is from the fire camp, where the IC team, staff, and firefighters set up individual tents for sleeping. A big fire camp also contains showers (brought in by semitrailer), a kitchen (also brought in by semi) and dining tent, and a few tents for meeting and planning. ~~~Crews are "burning out" fuels to reduce the fire's intensity as it comes closer to developed areas and control lines. Flames in this photo are mostly less than 3' high, whereas they were hundreds of feet high during the August 19 run.

Slide 5



Here's the map two weeks later. What has happened? ~~~The fire has spread more to the south. In spite of a retardant line being maintained along the Bitterroot Divide, the fire has crossed the Divide in one location and spread eastward. Some of the fire growth during this period was "burned out" by fire crews to reduce fuels between the fire and control lines. Describe the photos: ~~~Trees have been cut in this forest stand and low branches may have been pruned off, so there are openings between tree crowns and few ladder fuels. This makes crown fire unlikely. However, slash remains on the ground, and it must be burned or removed to reduce the potential for severe surface fire. ~~~A plane unloads retardant on the fire. Recall that several of the IC reports talked about thousands of gallons of water and retardant being used. ~~~Crews burn out between a road and the fire, causing some torching in the stand behind the truck.

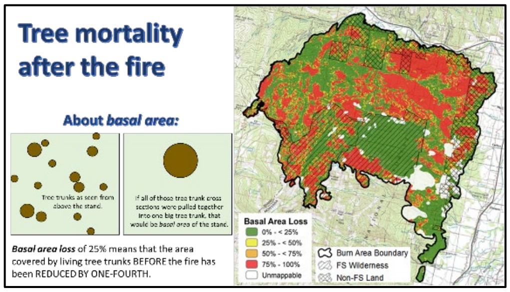
Slide 6

Here's the final fire perimeter. Explain the map and photos: ~~~There was little fire spread during this time, and some of that was in burnouts by fire crews. On October 9 the fire was declared *fully contained* (meaning it was completely surrounded by line and/or areas with no fuel, so it was not going to spread further). ~~~Crews were *mopping-up* (meaning that they were extinguishing spots still burning in the interior of the fire, especially near control lines). ~~~*Suppression repair* work was being done (meaning that logging slash was removed or pulled over the bare soil to reduce erosion; and culverts were cleaned out or rebuilt so spring runoff would flow through them).

Slide 7

Here are a few photos taken during the last month of the fire. How would you describe the fire severity? ~~~The lower-left photo shows a variety in severity. The landscape is a "mosaic" – or "patchwork" that ranges from green forest (unburned or very lightly underburned) to scorched (the orangeish edges of black patches) to completely burned (blackened trees, crowns consumed). ~~~The top photo is a close-up of a severely burned area; notice there is no soil cover. ~~~In contrast, the photo on the right is a close-up of an area with burned and scorched fuels on the ground and some tree scorch. Most of the vegetation on this site will survive, and dead foliage will fall from the scorched trees, further protecting the soil from erosion.

Slide 8



Here's Here's a map of fire severity, described in terms of tree mortality. (Severity can also be described in terms of effects on soil – which we'll study in Activity M10). Tree mortality is measured as loss of BASAL AREA: Basal area is the area of the ground covered by the boles of living trees (as measured 4.5' above the ground). Think of it as the space covered by tree trunks if you bundled them all together into one big tree trunk. Ask: How well does this map match your expectations about fire severity? How well does it match the news coverage about the fire? Discussion. People are sometimes surprised to learn that most wildland fires produce a mosaic of severities. Much of the area inside a fire's perimeter may be unburned or show less than 25% tree mortality – and the green color on this map shows a lot of such low severity in green. The map shows relatively little area of moderate severity (yellow-orange); it occurs mainly along the edges of the high-severity areas. News media tend to cover a forest fire only when it does something spectacular and kills a lot of trees, like the Lolo Peak Fire's huge run that occurred on August 18-19. Much of the area in that run was burned severely and is shown here in red.

Evaluation:

	Excellent	**Medium to Poor**
Podcast assessment:		
Structure: Introduction, Transitions, Conclusion, and Creativity	All present	Not all present
Length and sound effects	The presentation was close to 5 minutes long (give or take 15 seconds) and included 3 relevant sound effects that enhanced the podcast.	The presentation was more than 15 seconds less than or greater than five minutes. The presentation failed to include 3 or more sound effects or included sound effects that were irrelevant or distracting.
Information about how weather, topography, and/or fuels affected fire spread	Accurate, based on information in packet (or other factual information with sources documented)	Inaccurate or not present; if based on information not in packet, not documented.
Human interest angle	Present, credible, and engaging	Not present, not credible, or not engaging.
Slide show assessment:		
Interpretation of map and/or photo in presentation	Contributed accurate and imaginative thoughts	Contributions were inaccurate – or did not contribute.

Handout M08-1: Podcast on the status of the Lolo Peak Fire

The National Weather Service has invited our class to report on a fire that is burning in western Montana, the Lolo Peak Fire. They will air six podcasts from our class on National Weather Radio (http://www.nws.noaa.gov/nwr/). Each podcast will cover one of the time periods listed here. **Circle the time period assigned to your team.**

Team	Time period (2017)
1	July 15 through July 29
2	July 30 through August 12
3	August 13 through August 19
4	August 20 through August 26
5	August 27 through September 9
6	September 10 through October 9

Your team's Fire Reporting Packet contains all of the information you need:

- **Narrative** contains excerpts from the IC Team's narrative report for each day.
- **Statistics** contains daily reports of the fire's growth and size, the number of personnel on the fire (if reported), and the current cost estimate (if reported).
- **Articles** contains one or more newspaper articles about the fire and related issues.

You may look for additional information, but – if you use it – you must explain your source.

If you find a term that you do not understand, look it up. You may find it in the official glossary of the National Wildfire Coordinating Group (https://www.nwcg.gov/glossary/a-z).

Here are the requirements for your podcast:

1. Make it exactly 5 minutes long, give or take 15 seconds. If you make it longer or shorter, you will mess up the National Weather Radio's daily programming.
2. Tell your audience about the fire's recent behavior and how topography, fuels, and/or recent weather have affected it.
3. Give the audience some reason to care about the fire – some human-interest angle. For example, perhaps they can identify with local residents who are worried about safety and evacuations. Perhaps they can identify with problems posed by highway closures, risks to firefighters, or effects on the local economy. Perhaps they are concerned about the fire's effects on plants and animals. Perhaps you can persuade them that the fire has national significance because of its size or expense, or because it is an example of other such emergencies.
4. Include at least three appropriately placed sound effects.

It will help to have a written outline or script before you present/record.

Be as creative as you can. This is your opportunity to be artistic, unique, and show that you can apply what you know about wildland fire!

Unit IV.
Fire Effects on the Environment

9. Smoke from Wildland Fire: Just Hanging Around?

Lesson Overview: From a lab demonstration or video, students learn how smoke disperses (or doesn't), depending on atmospheric conditions. They learn how smoke affects visibility and human health, especially if it sticks around for days or weeks instead of dispersing into the upper atmosphere. Finally, they apply health guidelines regarding smoke to the issue of protecting students' breathing while planning athletic events on smoky days.

Lesson Goal: Increase students' understanding of smoke from wildland fires, how it disperses, its effects on human health, and how we can protect ourselves from its effects.

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

Duration: 2-3 half-hour sessions

Group size: Entire class

Setting: Classroom

Vocabulary: *inversion, normal atmospheric conditions, particulate/particulate matter, PM2.5, smoke, stable/unstable conditions, thermal belt*

Objectives:

- Students can interpret data on inversions and air quality during a wildland fire.
- Students can make a decision about how to protect respiratory health during sports events.

Standards:		6th	7th	8th
CCSS	Speaking and Listening	1,2,4,5	1,2,4,5	1,2,4,5
	Language	1,3,6	1,3,6	1,3,6
NGSS	Weather and Climate	ESS2.D		
	Earth's Systems	ESS3.A		
	Human Impacts	ESS3.B,C		
EEEGL	Strand 1	B, C, E, F, G		

Teacher Background: There's no wildland fire without smoke, but the amount of smoke produced and the way in which it disperses differ from one fire to another and 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 result we notice 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. These conditions may be hazardous, especially for anyone who has asthma or other respiratory illness and for those who engage in strenuous exercise.

In this activity, students learn about smoke dispersal. From a demonstration, they learn that air – and the smoke it may contain - can disperse readily into the atmosphere under *normal* conditions or be trapped near the ground during *inversions*. Then they compare data on particulate matter during a wildfire in 2017 with guidelines provided by the Montana Department of Environmental Quality to decide if smoke from a wildland fire may be hazardous to students' health during athletic events.

Summary of content: On most summer days, sunlight warms the earth's surface and the layer of air lying on the earth's surface. The warming air rises due to convection. As it rises, it expands and cools. If the air is dry, the temperature falls about 1°C for every 100-meter rise in altitude (about 5° F for every 1000 ft)[1]. 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 normal day-time circumstances, we call the air unstable.

Every night, when the sun is no longer warming and stirring up the atmosphere, cold air from the mountain tops – which is more dense than warm air - flows downhill into the valleys. Sometimes the sun doesn't warm the surface air back up in the morning. Perhaps clouds are blocking the incoming light… or smoke is blocking it… or (in winter) snow is reflecting the light rather than absorbing it. When this happens, the cold air is stuck on the ground. It is not expanding, therefore not rising, and therefore "trapped" on the ground until something stirs up the atmosphere. This is called an inversion because the normal daytime pattern (warm air on the bottom, rising into cooler air on top) is upside-down. The blanket of warm air that lies on top of the cold air is called a thermal belt. 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, which may be so dense that you can't see very far and the city streetlights come on in the middle of the day. When seeds of some plants are exposed to dense smoke, it becomes easier for them to germinate. But when people are exposed to dense smoke, it becomes harder to breathe. Dense smoke is especially dangerous for babies, older adults, and anyone with respiratory illnesses (such as asthma) or heart disease. It is a good idea for people to stay indoors (provided the indoor air is clean) or limit aerobic activities until the air quality improves.

For further background, see the readings and presentations included in this lesson and in Activity H11 in the High School curriculum.

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[1] Although metric units of measure are used in most of this curriculum, we used "standard" units of measure in parts of this lesson because fire managers still use mostly standard units. This is because they rely on fire behavior models developed in the 1960s, which use standard units of measure.

Materials and preparation:

1. Download 2 presentations:
   - ***M09_SmokeDispersion.pptx*** (just 3 slides – to be used at the start of the activity)
   - ***M09_InversionsAndMeasuringSmoke.pptx*** (used right after the lab. Introduces the **Assessment**)
2. **OPTIONAL: You may want students to hear a 7:49-minute feature from a 2017 broadcast on Montana Public Radio.** If you want to use it, make sure you can access it at https://www.mtpr.org/post/summer-smoke-exposes-need-clean-indoor-air-montana.
3. Decide how to make "Recommendations for Outdoor Activities Based on Air Quality for Schools and Child Care Facilities" (**M09_ActivityGuidelinesForWildfireSmoke.pdf** or http://4cleanair.org/sites/default/files/Documents/Montana-ActivityGuidelinesforWildfireSmokeEvents.pdf) available to students – on a printout or electronically.
4. Decide how to demonstrate atmospheric inversions in **Step 6** below: by viewing an online video (https://www.youtube.com/watch?v=LPvn9qhVFbM), creating the same demonstration in class, or creating a demonstration that compares temperatures and air circulation above ice vs. boiling water (described in **M09_InversionDemonstration_Boiling-vs-Ice.pdf**).

Procedures:

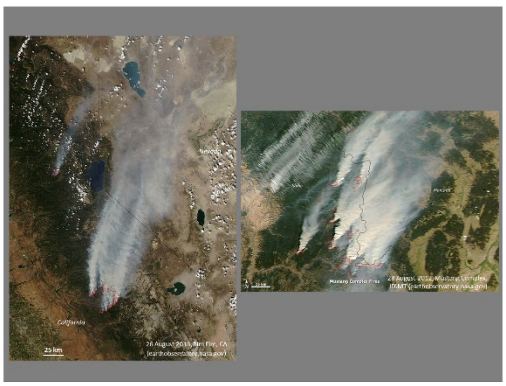
1. **Hook:** Select 3-4 students to sit in a circle around a prop (box, book, stool, other object) that represents a campfire. Have them pantomime some fun things to do. Maybe they'll start a song, roast marshmallows, add sticks to the fire, etc. Then have another student be wind and circulate around the fire or back and forth, blowing on the smoke. Ask those sitting around the fire to pantomime their reactions. As they cough and hack or move to a different spot, ask what the problem is. SMOKE BOTHERS US!
2. **OPTIONAL:** Listen with the class to the 7:49-minute radio broadcast on smoke from wildland fires in western Montana during the summer and fall of 2017: https://www.mtpr.org/post/summer-smoke-exposes-need-clean-indoor-air-montana.
3. Ask: 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.
4. Explain: In this activity, we'll learn about where the smoke from wildland fires goes and how we can protect ourselves from its harmful effects.

5. Go through the 1st presentation (***M1_SmokeDispersion.pptx***):

Slide 1

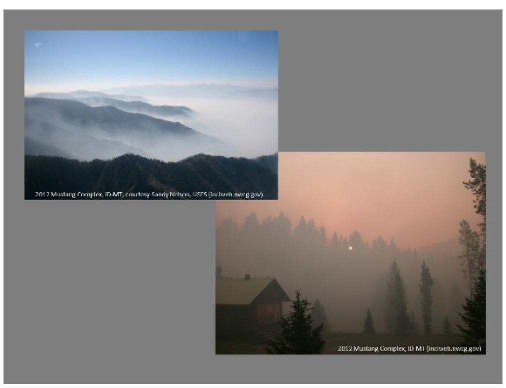
Where does the smoke from wildland fires go? You can make some guesses from these photos. It usually goes up, just like heat does. It cools off as it rises. When its temperature is about the same as that of the surrounding air, it stops rising and just travels wherever the wind takes it.

Slide 2



Satellite photos show that smoke can travel a long way. Use the 25-km scale on the photos to estimate the width of these smoke plumes: 50-75 km on the Rim Fire (left) and 100-200 km on the Mustang Complex (right). About how far has the smoke traveled? 300 km or so. What are some towns or other landmarks that far from <u>our</u> location?

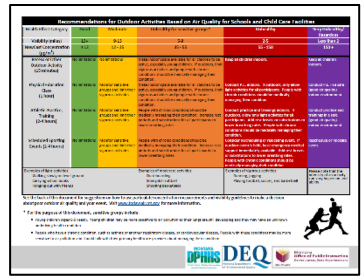
Slide 3



But smoke doesn't always move up and away. Sometimes it settles 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. This thick, messy, hazardous air is often caused by a weather pattern called an inversion.

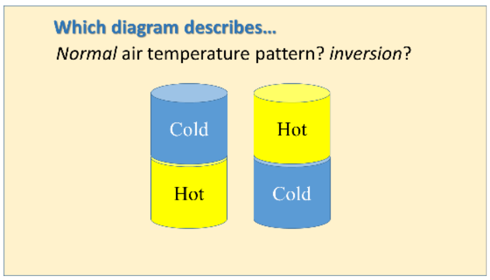
5. Explain: A demonstration will help us understand inversions better.
6. Choose one of these options:
   a. View the 2:49-minute video about inversions from "Steve Spangler Science" (https://www.youtube.com/watch?v=LPvn9qhVFbM).
   b. Create the demonstration described above in class.
   c. Create the demonstration described in **InversionDemonstration_Boiling-vs-Ice.pdf**, which compares temperatures and air circulation above ice vs. boiling water. The trunk contains supplies needed for this demonstration.

7. Give each student a copy of - or electronic access to - “Recommendations for Outdoor Activities Based on Air Quality for Schools and Child Care Facilities” **(M09_ActivityGuidelinesForWildfireSmoke.pdf** or http://4cleanair.org/sites/default/files/Documents/Montana-ActivityGuidelinesforWildfireSmokeEvents.pdf). Explain that they’ll use it at the end of the presentation.



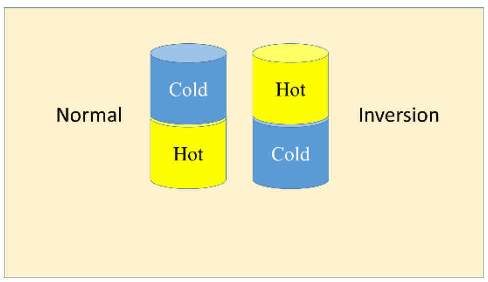
8. Use the 2nd presentation (***M09_InversionsAndMeasuringSmoke.pptx***) to further explain the concept of inversions and then help students interpret data on inversions, particulates, and the relationship of air quality to health:

Slide 1



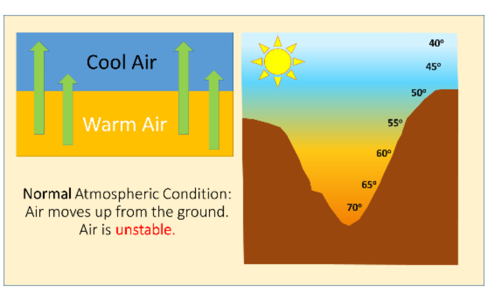
Ask: If the cylinders represent parcels of air, which diagram shows normal conditions and which one shows inversion conditions? Normal conditions are on the left, inversion conditions on the right.

Slide 2



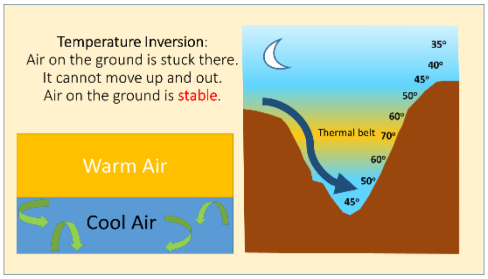
Discuss:
If you viewed or created the demonstration in the video: The demonstration with warm water on the bottom and cold water on top represents *normal* conditions. With warm water below cold water, the liquids were *unstable*; the warm water was expanding, the liquids were circulating – moving - and the colors were mixing. With cold water below warm water, the liquids were *stable* – not moving, not circulating - and the colors were not mixing. These stable conditions represent an *inversion*.
If you used the ice/boiling water demonstration: The air above boiling water showed *normal* conditions because the air was *unstable*, even turbulent; the hot air and water vapor were rising rapidly, and any pollutants in the air would be dispersing upward. The air above ice showed an *inversion* because the air was very *stable* – too dense to rise into the warm air above; any pollutants in the cold layer of air would be trapped and would not disperse.

Slide 3



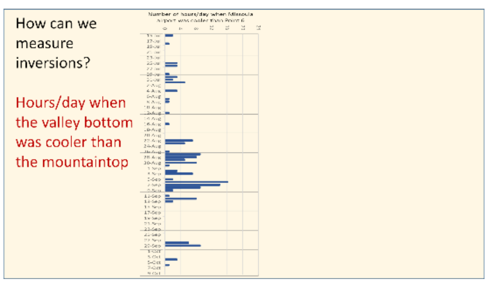
Review: *Normal* atmospheric conditions occur when sunlight warms the earth’s surface in the morning, and this warms the air on the ground. The warming air expands and therefore rises. As it rises, it gradually cools off. If the air is dry, the temperature falls about 1°C for every 100-meter rise in altitude (about 5° F for every 1000 ft). As a result of this natural cooling, mountain tops are usually cooler than valleys on hot summer days. Due to all the air movement, these conditions are described as *unstable*.

Slide 4



Review: Inversions occur when air at the earth's surface is cold. It is not getting warmed by the sun, so it is not expanding and rising. It is stuck on the ground. It cannot be dislodged until it is heated or stirred up by wind. We say the cold, surface air is very *stable.* Inversions often occur at night. The cool air on the mountain tops is denser than the warm air in the valleys. When the sun goes down and stops stirring up the surface air, the cool, dense mountaintop air flows downhill into the valley bottoms and pushes the warm surface air uphill. This blanket of warm air at middle elevations is called the *thermal belt.*

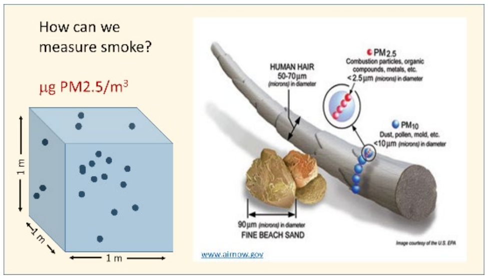
Slide 5



Explain: We're going to make some decisions about high school sports events based on data about inversions and air quality. We'll take on the roles of the school nurse and a sports coach while the 2017 Lolo Peak Fire was burning in western Montana. (We studied this fire in **Activity M08.**) To make informed decisions, we need some measurements. First, how can we measure inversions? We have records of the temperature every hour of every day during the fire. The records are from two weather stations that are located about 15 miles from the fire. One station is in a valley - at the Missoula Airport. The other station is on a mountain top called "Point 6." The blue bars on this graph show the days when inversion conditions existed in the Missoula valley. The length of the bar shows how many hours those conditions existed. Try some examples: On the first day of the fire, July 15, was there any time when the Missoula airport (valley bottom), was cooler than Point 6 (mountain top)? Yes, and those conditions lasted just 2 hours. What about the end of that week (after July 18) - were there any inversions? No, Point 6 was cooler than the airport – or at the same temperature – all of the time from July 19 through July 24. What was the day with the longest-lasting inversion? September 6, when the valley bottom was cooler than the mountain top for 16 hours. When would you expect the worst air quality? During the long period from the end of August through early September, when inversions occurred almost every day and lasted many hours. When might you expect good air quality? The weeks of Sept. 17 and Aug. 13 are both good candidates, since the weather data from those periods shows almost no sign of inversions. (Write these hypotheses on the board.)

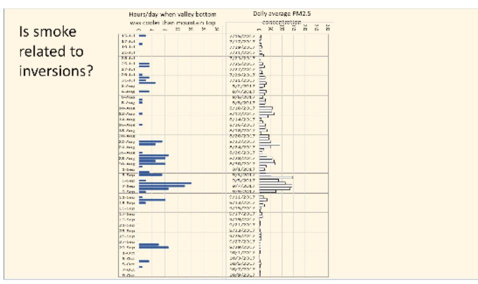
This graph shows measurements of inversion conditions. Now we need a way to measure smoke.

Slide 6



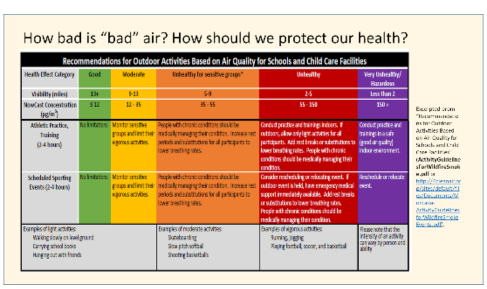
Explain: We'll use a measurement based on the <u>weight</u> of tiny particles in the air, which are the most common health hazard in smoke. Smoke monitoring equipment determines the weight of particles less than 2.5 microns (that is the same as micrometers) in diameter that are found in 1 cubic meter of air. We call the measurement "PM2.5" for short. So we're measuring the micrograms of PM2.5 per cubic meter of air. The drawing on the right shows just how tiny those 2.5-micron particles are, relative to the diameters of a particle of sand and a human hair; they are smaller than 1/20th the width of a human hair!

Slide 7



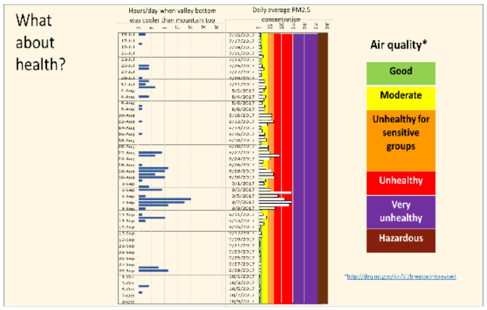
Explain: The graph with blue bars on the left, which we've already looked at, shows the record of inversions during the Lolo Peak Fire. The graph with white bars on the right shows the record of PM2.5 in the Missoula valley during that same time. How well did we predict the smoke pollution from inversion data? Students probably predicted the smoky and clean air episodes pretty well. However, there are a lot of periods without inversions that had fairly high levels of particulates. Why? The mountain top weather station could have been above the thermal belt, so the air above the inversion had cooled before it reached the mountain top sensors. Also, meteorologists have described a high pressure "ridge" that stayed in the upper atmosphere over the region during much of the summer; this made the surface air hot and reduced circulation even without inversion conditions. Finally, keep in mind that the smoke in the Missoula valley was not all from the Lolo Peak Fire. There were dozens of large fires burning in the West that summer.

Slide 8



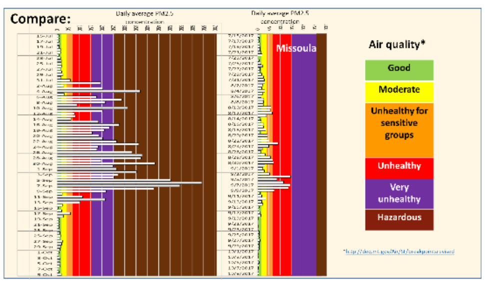
Explain/ask: For us to make good decisions on sports events during the 2017 fire season, we will use recommendations from the Montana Department of Environmental Quality. This slide is taken from your "Recommendations" handout, but it shows only the rows that apply to athletic practice and sports events. (Go through the Health Effect Categories and recommendations with students so they know how to use the table. Ask them to notice or describe how the limitations are cumulative – that is, activities are more and more limited – and more and more people are affected – with each step to the right, as air quality worsens.)

Slide 9



Ask: When particulate levels were high, how bad was the air quality… and what were the recommendations for limiting activity to protect health? Have students refer to their copies of the “Recommendations” to discuss. Air quality was UNHEALTHY for several days in early September. Who are “sensitive groups”? They can find this at the bottom of Page 1 of the “Recommendations.” How are recommendations for sensitive groups different from general recommendations? Have them use the handout.

Slide 10



Explain: The Missoula air was unhealthy for several days during the summer of 2017, but it could have been worse. The Rice Ridge Fire, about 40 miles northeast of the Lolo Peak Fire, burned 3 times as much area as the Lolo Peak Fire. Smoke in the little town of Seeley Lake, on the edge of the fire, had much MUCH worse air than Missoula did. Both of these graphs are on the same scale. Compare the air quality in Seeley Lake with that in Missoula. Compare the recommended limitations for people in the Seeley Lake area.

Keep this slide on display as you introduce the **Assessment.**

Assessment:

1. Have the students work in pairs.
2. Explain the assignment. As you do, note key information on the board:
   a. One person in each pair should be the school nurse, and the other should be a coach for a sports team. You pick the sport. You know that 2 members of your sports team have asthma.
   b. It is the morning of Friday, September 8, 2017 in Missoula, Montana. About 10 miles from your school, the Lolo Peak Fire has been burning for nearly 2 months. Your team has a big game/meet scheduled for tonight. A rival team is planning to come from 150 miles away. They plan to leave school around noon.

c. But your area is surrounded by fires: To the southwest, the Lolo Peak Fire has already burned 49,000 acres. To the east, the Rice Ridge Fire has burned more than 120,000 acres so far. For the past week, the air in your valley has been smoky. (Refer to the final slide in the presentation above.) You have been smelling smoke from the fire throughout the school as well. Yesterday, the valley you live in was under a strong inversion. Visibility was limited outside, and the classrooms, cafeteria, and gym smelled smoky. What was the concentration of PM2.5 in your area yesterday? From the final slide in the presentation, estimate the PM2.5 concentration for September 7. Be sure to use the Missoula data rather than the Seeley Lake data. The actual concentration was 143.9 $\mu g/m^3$. What was the air quality? UNHEALTHY, in the red range on the graph. Today, the forecast says that the inversion will weaken a little, but the concentration of PM2.5 will probably not change much. (The actual measurement for September 8 was 135.4 $\mu g/m^3$.)

d. Talk the situation over together. Use “Recommendations for Outdoor Activities Based on Air Quality for Schools and Child Care Facilities” to help you decide whether to hold the event as scheduled, cancel it, or hold it with some limitations - and specify what those limitations would be. You have to decide by noon so the visiting team can cancel their travel plans if you will not be playing.

e. Together, you will report to the class:

- what sport you discussed
- what the choices “Recommendations for Outdoor Activities” suggest for the amount of smoke predicted
- what you decided to do and why.

3. Have the teams for each sport report together.

Evaluation:

Excellent	Good	Poor
- The team identified the sport they discussed. - The team correctly identified the forecast air quality as being UNHEALTHY. -The team made an appropriate decision: - For indoor sports, students found out if indoor air quality has been degraded because of the previous week(s) of smoke pollution. If indoor air is OK, hold the event as planned. - For outdoor sports, students chose 1 of these 2 options: (1) Reschedule or relocate the event. (2) Hold the event, but have emergency medical support immediately available. Add rest breaks or substitutions to lower breathing rates. Have the 2 asthmatic students careful to medically manage their condition.	- The team identified the sport they discussed. -The team correctly identified the forecast air quality as being UNHEALTHY. -The team made an appropriate decision: - For indoor sports, hold the event as planned. The team did not consider the possibility of indoor air pollution. - For outdoor sports, the team chose to hold the event as planned, but they did not make plans for emergency medical support and/or adding rest breaks or substitutions and/or gave inappropriate plans for the asthmatic students.	- The team identified the sport they discussed. - The team did not correctly identify the forecast air quality as UNHEALTHY. - The team's decision did not indicate understanding of relationships between sports activity, smoke levels, and health.

10. Fire, Soil, and Water Interactions

Lesson Overview: In this activity, students view and take notes on a presentation. Then they either observe (in a video) or conduct an experiment that illustrates how wildland fires affect the potential for soil erosion. They learn that soil burn severity varies greatly even within small areas in a burn. They also learn that, when fires remove the litter, duff, and plant cover on the ground, the risk of soil erosion increases.

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

Duration: One half-hour session

Group size: Entire class

Setting: Classroom

Vocabulary: *burn severity, erosion, litter, soil burn severity, vegetation burn severity*

Lesson Goal: Increase students' understanding of the effects of wildland fire on soil properties and the likelihood of erosion after fire.

Before beginning this lesson, watch the video demonstration of precipitation's impact on bare soil versus vegetation-covered soil: https://www.youtube.com/watch?v=im4HVXMGI68. Decide if you want to do the demonstration in class or just view the video. If you decide to do the demonstration in class, you need a container containing young grass stems that were started from seed 2-4 weeks before. You may be able to use a cut piece of sod instead.

Objectives:

- Students understand how fires affect the soil.
- Students understand that the effects of fire on soils are variable, even within small areas.
- Students understand that if fires consume the litter, duff, and plant cover on the ground, this increases the chances of soil erosion.

Standards:		6th	7th	8th
CCSS	Writing Standards	4,10	4,10	4,10
	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language Standards	1,2,4,6	1,2,4,6	1,2,4,6
	Writing: Science and Technology		4,10	
EEEGL	Strand 1		A,B,C,E,F,G	

Teacher Background: Soil burn severity is the degree of change in soil characteristics caused by fire. These include the depth of char, loss of organic matter, alteration of color and structure, and reduction of infiltration.

After fire, common changes to the soil include:

- loss of ground cover due to consumption of litter and duff;
- surface color change due to char, ash cover, or soil oxidation;
- changes in soil structure due to consumption of soil organic matter;
- consumption of fine roots in the surface soil; and
- formation of water-repellent layers that reduce infiltration.

The degree of soil burn severity varies widely from fire to fire and within individual burns. It depends on many factors, including the **weather** at the time of burning, fire behavior, the amount, type, and distribution of **fuels**, type of soil, and **slope**. Notice that the Fire Environment Triangle studied in **Activity M05** covers many of these factors. For more detailed information about fire and soils, view the presentation provided below: ***M10-1_FireSoilAndWater.pptx***. Supplemental information is available in the article by Parsons and others (2010) cited below, which provides extensive descriptions and photographs of soils burned with different severities.

The more severe fire's effects on the soil, the more likely those soils will erode in subsequent rainstorms – especially in places with steep slopes. Erosion after fires can cause tremendous damage to people's homes and other structures in the first year or two after a fire. This topic is covered briefly in the presentation ***M10-1_FireSoilAndWater.pptx***. Ecological effects of fire on streams and aquatic organisms are not covered in this curriculum, but the articles by Rieman and others (2012) and Howell (2006) cited below provide an overview and one example of primary research on this complex topic.

Activity M15. Bark and Soil: Nature's Insulators is a good companion lesson to this one. It provides information about heat transfer in the soil under a protective layer of duff.

Sources and additional reading:

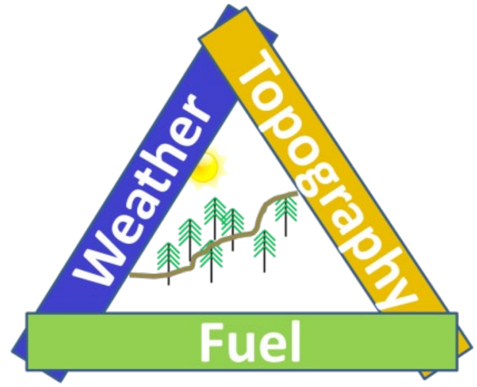
Parsons, Annette; Robichaud, Peter R.; Lewis, Sarah A.; Napper, Carolyn; Clark, Jess T. 2010. Field guide for mapping post-fire soil burn severity. Gen. Tech. Rep. RMRS-GTR-243. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p. http://www.treesearch.fs.usda.gov/pubs/36236

Rieman, Bruce; Gresswell, Robert; Rinne, John. 2012. Fire and fish: a synthesis of observation and experience. In: Luce, Charles; Morgan, Penny; Dwire, Kathleen; Isaak, Daniel; Holden, Zachary; Rieman, Bruce, eds. Climate change, forests, fire, water, and fish: building resilient landscapes, streams, and managers. General Technical Report RMRS-GTR-290. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 159-175. https://www.fs.usda.gov/rm/pubs/rmrs_gtr290/rmrs_gtr290_159_175.pdf

Howell, Philip J. 2006. Effects of wildfire and subsequent hydrologic events on fish distribution and abundance in tributaries of North Fork John Day River. North American Journal of Fisheries Management. 26: 983-994. https://www.tandfonline.com/doi/abs/10.1577/M05-114.1

Materials and preparation:

1. Display the Fire Environment Triangle (AKA Fire Behavior Triangle) poster (***M05_FireEnvironmentTriangle.pdf***).



2. One copy of **Handout M10-1. Fire and Soil** per student.

3. Download and view the presentation: ***M10-1_FireSoilAndWater.pptx***. The presentation and handout are used together in Step 4 below. Each slide contains a little information, a question that students should answer on their handouts, and discussion points.

4. View this video about the relationship between vegetation cover and soil erosion: https://www.youtube.com/watch?v=im4HVXMGI68 Decide whether you will watch the video in step 3 (below) OR do the activity as it is shown in the video. If you do the activity, you will need:
   - Three empty-2 liter plastic soda bottles
   - Three empty plastic soda bottles (about 1 liter size)
   - Three pieces of string/yarn
   - Soil
   - Dead leaves/needles
   - Grass seed (planted in the soil a couple of weeks ahead of time)
   - Pitcher of water

Procedures:

1. Explain: Fires change more than the plants above ground; they change the soil too. Think about the three parts of the Fire Environment Triangle (***M05_FireEnvironmentTriangle.pdf***): fuels, weather, and topography. All of these things influence how fires affect soils. That's what we'll learn about today.

2. Explain: We'll go through a presentation. You'll use information from each slide to answer questions on the handout. After you answer each question, we'll discuss the answer.

3. Give each student a copy of **Handout M10-1. Fire and Soil.**

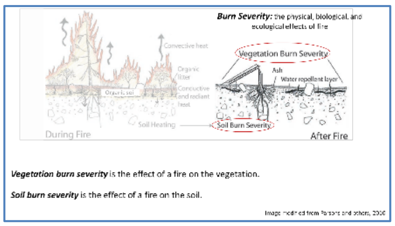
4. Show the presentation. On each slide:
   a. Introduce the new information using the slide notes (in black print below).
   b. Have students answer the associated question on the handout.
   c. Do a short follow-up discussion (using the notes in red print below).
   d. If you wish, let students revise their answers on the handout.

Slide 1

Explain: This image shows where the heat from wildland fire goes. **Recall the 3 methods of heat transfer:** convection, conduction, and radiation. **Answer Question 1 on the handout.**

Discussion: Convection is lifting much of the fire's heat up, away from the soil. Conduction and radiation are transferring heat into the surrounding fuels and the soil.

Slide 2



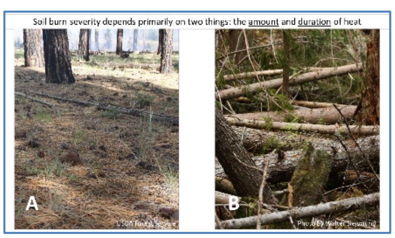
Ask/explain: What does the heat from burning fuels do to plants, ground cover, and soil? It depends on many things, so it varies! The physical, biological, and ecological effects of fire – all lumped together – are called burn severity. **Use this slide to answer Question 2 on the handout.**

Discussion: In the right-hand diagram, we can see the how the ecosystem has changed as a result of the fire. This is burn severity.

Vegetation burn severity describes the effects of fire on the vegetation. Vegetation burn severity is likely the first thing you notice when you look at burned forest, and we'll study it more in later lessons.

But we can also see changes in the soil surface and even deep into the soil. This is soil burn severity - the effects of fire on the soil. That's what we'll study today.

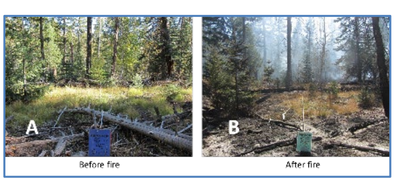
Slide 3



Explain: Soil burn severity depends mainly on 2 things: amount of heat and duration of heating. If a fire burned the surface fuels in these 2 photos under the same conditions, which fire would produce more heat? Which would burn for a longer time? **Answer Question 3 on the handout.**

Discussion: Recall lesson M07 about fuel properties. The logs in the right photo (B) would produce more heat and would burn longer. So it is likely that a fire burning the heavy fuels in the right photo would cause much higher soil burn severity than a fire in the pine litter in the left photo. (Litter is the layer of dead leaves and other plant matter, not yet decayed, that lies at the top of the forest floor.)

Slide 4



Explain: Let's think about soil burn severity in a small area, not much bigger than our classroom. The left photo (A) shows this area before it was burned by a prescribed fire. The right photo (B) shows what it looked like afterward. Look for diversity in soil burn severity. **Answer Question 4 on the handout.**

Discussion: Can you find patches that show no evidence of fire? How about patches that are "lightly burned" – that is, the ground surface is black and some woody fuels remain? How about patches that are "severely burned" – that is, the ash is completely white (no carbon left) and woody fuels are nearly gone? The lines of thick white ash, where the logs were before the fire, are places where the soil probably experienced hotter temperatures for longer periods of time than most of the other areas in this photo. That is, the areas underneath the logs experienced <u>very high soil burn severity</u>.

Slide 5

Explain: Here is a video of a fire moving though a forest. **Answer Question 5 on the handout.**

Discussion: Notice how the flames appear to be moving through the surface vegetation relatively quickly. If there is not much heavy fuel (like logs) underneath the vegetation, the soil burn severity will probably be low. Notice all of the heavy fuels from a previous fire. These include snags, stumps, and fallen logs. After the flames move through the vegetation, the logs and stumps will continue to flame and smolder, causing high soil burn severity in those spots.

Slide 6

Explain: This is a photo of that same fire. The fire is spreading forward and to the left. The area to the right and in the background has already burned. **Answer Question 6 on the handout.**

Discussion: The flames have gone out in many patches behind the flaming front. We can see how the flames are concentrated in stumps and logs. The areas where the fire has gone out will probably have low soil burn severity. The areas that still show flaming combustion and glowing fuels – mostly stumps and downed logs - will probably have high soil burn severity.

Slide 7

Explain: We've seen that soil burn severity can vary greatly even over small areas. In this photo, which areas do you think have the highest soil burn severity? Which areas burned less severely? **Answer Question 7 on the handout.**

Discussion:

- You can see lightly burned surface and ground fuels in the back-left corner of the photo. Chances are the soil there experienced low or moderate burn severity.
- In the middle of the photo, you can see areas of white ash and no remaining stems of small trees or shrubs. You can also see white lines where logs have been completely consumed, leaving nothing but white ash. If the site had duff cover before the fire, it is all gone from these patches. Underneath some of these white ash patches may be patches of severely burned soil.
- In the left foreground, it looks like some of the surface fuels are consumed and some remain. Maybe the soil burn severity was moderate.

Note that, just because the vegetation appears severely burned, the soil burn severity may not be great, and vice-versa. That is, VEGETATION BURN SEVERITY DOES NOT EQUAL SOIL BURN SEVERITY. Why? It could be caused by variation in soil composition, texture, moisture content, or other factors.

Slide 8

Explain: Both of these photos show places where most of the vegetation and ground cover have burned away. There seems to be very little duff on the ground. With no cover, the soil does not have any protection from raindrops. **Answer Question 8 on the handout.**

Discussion: If an area has no litter, duff, plant cover, or plant roots to hold the soil in place after fire, the soil is vulnerable to washing away, especially after heavy rains. Loss of ground cover is the aspect of soil burn severity that is most likely to increase soil erosion and runoff.

Slide 9

Explain: In the corner, you can see the splash from a single raindrop. What happens when lots of rain falls on an area with severely burned soils? What if the area is on a steep hillside? **Answer Question 9 on the handout.**

Discussion: Areas with severely burned soils on steep slopes are the most vulnerable to erosion. Sometimes heavy rain on these soils causes big mudslides.

Slide 10

Explain: This photo is on your handout. **Use what you have learned in this activity to answer Question 10.**

5. Either watch this video as a class: https://www.youtube.com/watch?v=im4HVXMGI68 OR do the activity in the video.

Assessment: Handout M10-1. Fire and Soil.

Evaluation: See Answer Key M10-1. Fire and Soil.

Most of the answers to the handout were covered in the presentation, so you use a fairly high standard for grading:

9-10 correct: excellent
7-8 correct: acceptable
<7 correct: poor

Handout M10-1. Fire and Soil

Name: ____________________

1. What 2 forms of heat transfer are able to move heat down into the soil?

2. Write the definition of each term:
   a. Burn severity:

   b. Vegetation burn severity:

   c. Soil burn severity:

3. Which photo shows a place that is likely to experience high soil burn severity? Why?

4. Describe the soil burn severity in the photo on the right (B).

5. What places in the video will probably experience low soil burn severity? Why?

6. In the area behind the flaming front, where the fire has already passed through, what fuels are continuing to burn and produce heat?

7. In the photo, circle and label an area likely to have:
   a. *low soil burn severity*
   b. *high soil burn severity*

8. What is likely to happen if it rains after a fire has removed all of the litter, duff, and plant cover from the soil?

9. After a fire, what kinds of places are most likely to have severe erosion?

10. In the photo, circle and label 3 areas:
    a. A place likely to have high soil burn severity
    b. A place likely to have low soil burn severity
    c. A place that is likely to have severe erosion

Answer key for Handout M10-1: Fire and Soil

1. What 2 forms of heat transfer are able to move heat down into the soil? Conduction and radiation.

2. Write the definition of each term:
   a. Burn severity: **the physical, biological, and ecological effects of a fire**
   b. Vegetation burn severity: the effect of a fire on the vegetation
   c. Soil burn severity: the effect of a fire on the soil

3. Which photo shows a place that is likely to experience high soil burn severity? Why? The photo on the right (B) has a lot of large, heavy fuels. They would produce more heat and burn for longer time (once ignited) than the fuels in photo A.

4. Describe the soil burn severity in the photo on the right (B). Soil burn severity varies a lot. In some areas, the forest floor is unburned. Some areas are covered with black ash, and they have some large pieces of wood left. Other areas are covered with white ash. In some places, white ash is all that remains of large logs.

5. What places in the video will probably experience low soil burn severity? Why? Places without large fuels will probably experience low soil burn severity because the flames will pass through too quickly to transfer a lot of heat into the soil.

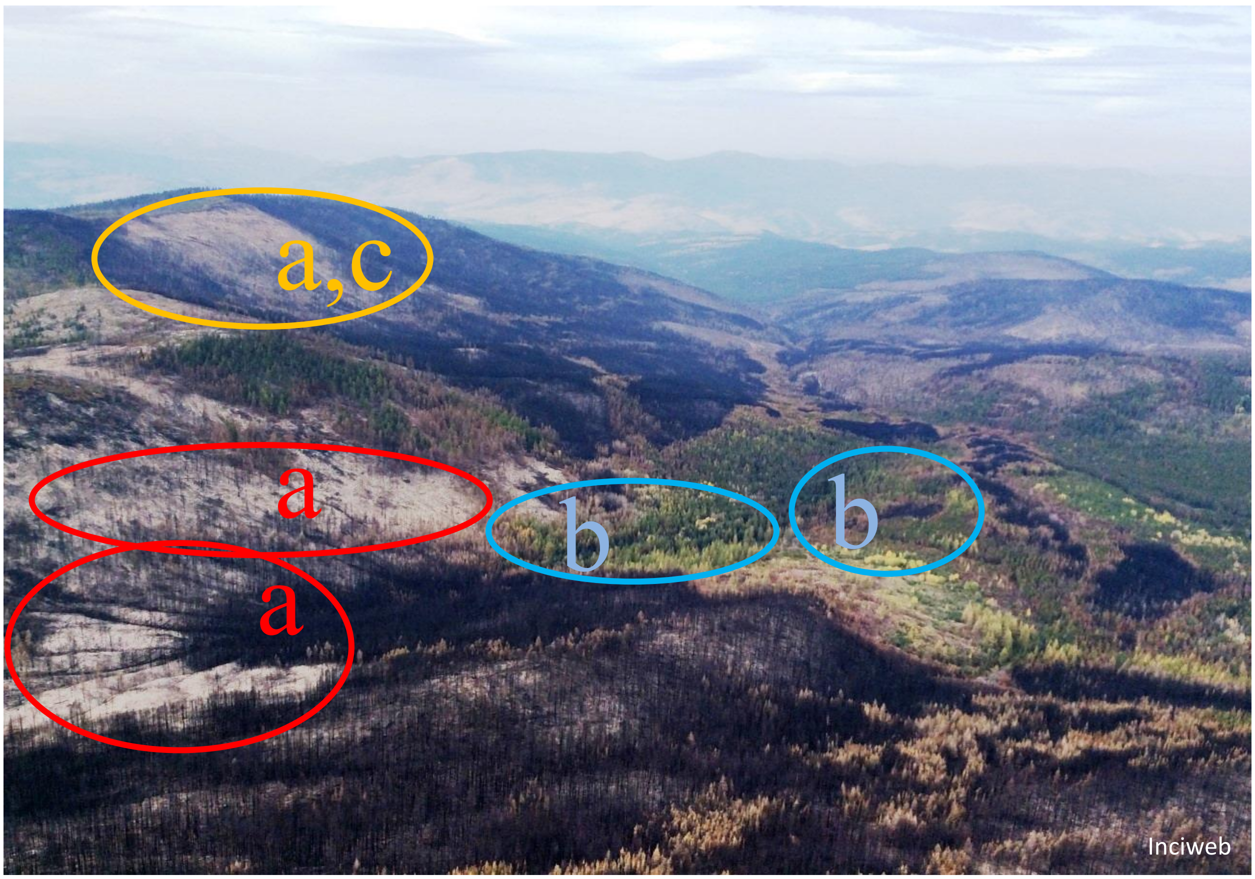
6. In the area behind the flaming front, where the fire has already passed through, what fuels are continuing to burn and produce heat? Large fuels like stumps and logs.

7. In the photo, circle and label an area likely to have:
   a. *low soil burn severity*
   Blue circle is an example: The fire burned around or under small trees without burning their foliage, and the ash is black.
   b. *high soil burn severity*
   Red circle is an example: The fallen logs have burned and the ash around them is white.

8. What is likely to happen if it rains after a fire has removed all of the litter, duff, and plant cover from the soil? If there is no litter, duff, or plant cover to hold the soil in place, the soil is vulnerable to *erosion* (washing away), especially after heavy rains.

9. After a fire, what kinds of places are most likely to have severe erosion? Areas on <u>steep slopes</u> with <u>severely burned soils</u> are the most vulnerable to erosion.

10. In the photo, circle and label 3 areas:
    a. A place that is likely to have high soil burn severity
    b. A place that is likely to have low soil burn severity
    c. A place that is likely to have severe erosion



Red circles (a) indicate areas that are likely to have high soil burn severity. Where they are on steep slopes (golden circle, c – and also steep areas within the "a" circles), they also have high risk of soil erosion. Blue circles (b) indicate areas that are likely to have low soil burn severity. In this picture it is difficult to tell if the green patches of forest are unburned or experienced a surface fire and have surviving trees in the canopy. These areas are at low risk for erosion because they are relatively flat and likely have something covering the forest floor (litter, duff, live plants). Most of the areas with blackened trees probably burned in crown fire; many of them have patches of both black ash and white ash on the ground, suggesting that they burned with a mixture of soil burn severities.

Unit V. Fire's Relationship with Organisms and Communities

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

Subjects: Science, Reading, Writing, Speaking and Listening
Duration*: 1-2 class periods for student preparation, 3-4 minutes for each presentation
Group size: Whole class
Setting: Classroom
Vocabulary: *biodiversity*

Overview: This activity introduces a suite of organisms that live in forests of northern Rocky Mountains and North Cascades. It features species representative of 3 forest communities: those dominated by ponderosa pine, lodgepole pine, and whitebark pine. Each student "adopts" an organism, learns about its characteristics and its relationship to fire, and gives a presentation on it to the class – illustrated by some form of art work[1].

There is no need to finish this activity before doing further lessons in the curriculum. In fact, it may be helpful to spread the student presentations over several class periods, two or three at a time. Make sure they are done by the time you get to **Activity M21**, in which the students will use a role-play to illustrate fire and succession in forests dominated by ponderosa, lodgepole, and whitebark pine.

Goal: Increase students' understanding of ecological communities, ecosystems, and biodiversity by learning about some of the plants, animals, and fungi that live in forests of northern Rocky Mountains and North Cascades.

Objective: Given reference materials from the *FireWorks Encyclopedia* (**Middle_FireWorksEncyclopedia_NRM-NC.pdf**):

- Students can prepare a mask, costume, puppet, or other art work and use it in a 3- to 4-minute presentation that describes the biology of their organism and its relationship to fire.
- Students can understand that individual species have specific ways to survive the fires that were historically typical in the ecosystems where they live.

[1] For a very abbreviated version of this activity, have students perform charades. Assign each student one species from the *FireWorks Encyclopedia*. He/she reads the essay and then acts out the species (without sound). After classmates correctly guess the species, the actor tells the class which community the species lives in and one thing about its relationship with fire.

Standards:		6th	7th	8th
Common Core ELA	Reading Informational Texts	1, 4,10	1,10	1,10
	Writing	2,3,4,7,10	2,3,4,7,10	2,3,4,7,10
	Speaking and Listening	1,2,4,5,6	1,2,4,5,6	1,4,5,6
	Science/Technology	1,4,9,10		
NGSS	Matter and Energy in Organisms and Ecosystems	LS2.A, LS2.B, LS2.C		
	Interdependent Relationships in Ecosystems	LS2.A, LS2.C, LS4.D		
	Growth, Development, and Reproduction of Organisms	LS1.B		
	Natural Selection and Adaptations	LS4.C		
EEEGL	Strand 1	C,E,G		
	Strand 2.2	A,C		

Teacher background: Different kinds of plants and animals have different needs. For example, some plants grow well only in sunny openings, while others grow well in shade and still others require special soil conditions or large amounts of water. Some animals are good runners, some are good fliers, and some are good at hiding underground.

Different species that live in forests of the northern Rockies and North Cascades have different ways to survive fire and thrive afterward. These traits are sometimes specific to a certain kind of fire, so changes in the kinds of fire that occur in their habitat – or the frequency of fires - may make life difficult for the organism.

In this activity, students teach each other about some of the species that live in forests of the northern Rocky Mountains and the North Cascades that are dominated by ponderosa, lodgepole, and ponderosa pine. Each student "adopts" a plant, animal, or fungus, prepares an art work that depicts it, and presents the organism to the class. Students' main source of information is the set of 2-page essays in the *FireWorks Encyclopedia* (**Middle_FireWorksEncyclopedia_NRM-NC.pdf**). They can seek information from other sources If you want them to do additional research, but that is not essential. Each student presentation should address organism's needs, the kind(s) of fire typical in its habitat, and how the organism deals with fire. Students will need that information not only for this activity but also when they create a drama that illustrates the relationships of these 3 forest ecosystems to fire (**Activity M21**).

The *FireWorks Encyclopedia* contains essays on more than 30 species (**Table M11**). (Additional species are occasionally added if they pertain to one or more of the ecosystems featured here.) If you do not need all of the species for your class, be sure to **assign those shown in bold print (and shaded in blue)** first. This subset of species includes the dominant tree species in each forest type, plus another important tree that is shade-tolerant; it also includes at least 1 herb, shrub, bird, and mammal from each forest type. Students will need these species to dramatize forest succession when they do **Activity M21.**

If you have a small class or a very limited time for Activity M21, you may decide to study just 1 of the 3 forest types in depth. In that case, select the species for students to adopt based on the description of their "Preferred forest type" in **Table M11.**

Materials and Preparation:

- Decide how to assign species to students. Make a copy of **Table M11** for recording assignments.
- Find the *FireWorks Encyclopedia* (**Middle_FireWorksEncyclopedia_NRM-NC.pdf**) in the trunk or provide students with computer access.
- Provide art supplies, if necessary.

Procedure:

1. Explain: Now that you know about the physics and chemistry of fire, it's time to learn how wildland fire, which seems very destructive, can help some of the species that live in forest ecosystems of the northern Rocky Mountains and the North Cascades. We'll learn about just a few species. This is a tiny fraction of the number of species present in forest ecosystems of the region – that is, the biodiversity in forests. In Glacier National Park, for example, there are more than 1,100 species of plants, 276 species of birds, and 71 species of mammals. Think how many kinds of insects, worms, and fungi there must be!
2. Explain the assignment: You will each "adopt" an organism that lives in forests of the northern Rockies and North Cascades. You will:
    - Learn about the organism from the essay in the *FireWorks Encyclopedia* (and other sources, if assigned).
    - Prepare a mask, costume, puppet, other art piece, or computer presentation that illustrates the organism and some aspects of its life history or relationship to fire.
    - Give a 3- to 4-minute presentation on the organism using the art piece. Include a basic description of the organism and its needs, the kind(s) of forest where it lives (ponderosa pine, lodgepole pine, and/or whitebark pine), the kind(s) of fire that occur there, and how the organism deals with fire.
3. Have a few students give their presentations during each class until all are done. Tell them to keep their costumes because they will be needed for another activity (**M21, Drama in the Forest: Fire and Succession, a Class Production**).

Assessment:

1. Have students give their 3- to 4-minute presentations. Have the rest of the students take notes, especially on the kind(s) of fire typical in that organism's habitat and how the organism deals with fire.
2. After all presentations, write the names of the organisms on strips of paper (or print them from the first column of **Table M11**) and put them in a hat.
3. Have each student pick out 3 organism names, write them down, and put them back into the hat.
4. Explain: Take out sheet of paper. Divide it into 3 sections. For each of the 3 organisms you selected from the hat, write:
    - The organism's name
    - 1 sentence about the ecosystem(s) where it is common (forests dominated by ponderosa, lodgepole, and/or whitebark pine)
    - 1 sentence about the kind(s) of fire that are typical in each organism's habitat
    - 1 sentence about ways in which each organism can survive fire and/or reproduce afterwards

Evaluation:	Excellent	Good	Fair	Poor
Presentation format	-Presentation was 3-4 minutes long. -Student used a creative, informative visual component.	-Presentation was substantially under or over 3-4 minutes. -Student used a visual component.	-Presentation was substantially over or under 3-4 minutes. -Visual component contained inaccuracies or was not used well in presentation.	-Presentation was greatly over or under 3-4 minutes. -Student did not prepare visual component.
Presentation content: • Organism's needs • Forest ecosystem(s) used • Typical kinds of fire in that forest • How organism deals with fire	-Student provided accurate information on all 4 criteria at left.	-Student provided accurate information on 3 of the criteria at left.	-Student provided accurate information on 2 of the criteria at left.	-Student provided accurate information on 0-1 of the criteria at left.
Writing Component (selecting 3 names from a hat). For each organism: • Forest ecosystem(s) • Typical kind(s) of fire • How it deals with fire	-For all 3 organisms, student clearly described all 3 criteria at left.	-For all 3 organisms, student described 2-3 criteria at left, or descriptions contained minor inaccuracies.	-Student described only 2 organisms, and description was incomplete or contained minor inaccuracies.	-Student described only 1 organism, and description contained major inaccuracies.

Table M11. Species in the *FireWorks Encyclopedia*

This table lists the species that can be "adopted" by students and presented to the class. If you do not need that many, **FIRST select the species shown in bold print and shaded in blue**. This shorter list of species will provide good coverage of the 3 forest types and will enable students to create effective dramatizations of forest succession if/when they do **Activity M21.**

Organism	Preferred forest type*	Responses to fire	Student assigned
American black bear	All	Can escape any kind of fire.	
American marten	All moist, old forests. Especially likes fir trees	OK with surface fire, prefers no fire.	
American three-toed woodpecker	All, especially LP because of tendency toward crown fire	Prefers forests after crown fire/severe fire.	
Armillaria root fungus	PP, in fir trees	Survives most fires underground but grows best in old forests.	
Arrowleaf balsamroot	PP	Sprouts after any fire from thick underground stem.	
Beargrass	Mainly LP	Grows back after fire from thick rhizomes.	
Black cottonwood	PP or moist ravines at higher elevations	Thick bark protects from some surface fires. Sprouts from base & roots after severe fire.	
Black fire beetle	Any forest that has just burned, even if it's still smoldering	Flies to trees that still may be hot, lays eggs under the bark.	
Black-backed woodpecker	All, especially LP because of tendency toward crown fire	Prefers severely burned forests	
Blue huckleberry	Mainly LP	Sprouts after most fires, grows well in openings created by severe fires.	
Clark's nutcracker	All, but especially adapted to WB	Escapes fires. Caches seeds in fire-created openings.	
Douglas-fir mistletoe	Mainly PP, also LP	Survives surface fires because they do not kill host tree.	
Douglas-fir	Mainly PP, also LP	Old trees survive surface fire because of thick bark.	

Elk	Uses all forest types, depending on season and food.	Can escape any kind of fire. Thrives on abundant food after fire.	
Engelmann spruce	Mainly LP, but also moist ravines at lower and higher elevations	Does not usually survive any kind of fire.	
Fireweed	Mainly LP but also PP and some WB forests	Sprouts from rhizomes after fire. Produces abundant seedlings in openings created by crown fire.	
Flammulated owl	PP	Prefers a mix of thickets and openings created by occasional surface fires	
Glacier lily	LP, WB, some PP	Sprouts from deep corm after any fire.	
Grizzly bear	All, but especially loves WB because of its seeds	Can escape any kind of fire.	
Grouse whortleberry	WB, some LP	Sprouts from rhizomes unless fire burned off the duff layer.	
Heartleaf arnica	Mainly PP and LP	Sprouts from rhizomes after most fires. Produces abundant seedlings after fire.	
Lodgepole pine	LP. Also occurs mixed with PP & WB.	Can survive some surface fires. Usually reproduces very well after crown fires.	
Mountain pine beetle	LP & PP. Thrives especially in dense LP forests that develop after crown fire.	Can survive surface fire and ground fire but not crown fire. Pine regeneration after crown fire provides optimum habitat.	
Northern flicker	All	Escapes fires. Thrives in any forest that has a lot of beetles.	
Pileated woodpecker	PP	Escapes fires. Needs large trees in mature forest for nesting. Can nest in stands that burn in surface fire.	
Pinegrass	Mainly PP	Sprouts from rhizomes after most fires.	
Ponderosa pine	Mainly PP, also some LP	Has thick bark. Thrives where occasional surface fires kill competitors.	

Quaking aspen	LP, also moist spots in PP	Has thin bark so is top-killed by most fires. Usually sprouts from roots after fire.	
Red squirrel	All. Really likes WB cones.	Avoids habitat with big openings created by large, severe fires.	
Red-backed vole	All habitat that is shady and moist	Can hide in burrow from fires but finds little food in burned environment.	
Saskatoon serviceberry	PP, also some LP	Sprouts from rhizomes after most fires.	
Smooth woodrush	Mainly WB, also in LP if enough moisture is available.	Sprouts from rhizomes after fire, thrives in fire-created openings.	
Snowbrush ceanothus	LP and PP	Crown fires produce heat that opens seeds. Plants can also sprout from roots.	
Subalpine fir	LP & WB	Does not usually survive any kind of fire.	
Western larch	PP & LP	Has thick bark so survives surface fires and sometimes crown fires. Reproduces well in fire-created openings.	
Western redcedar	PP, mainly in deep, moist valleys	Habitat rarely burns. Can survive some surface fires because of thick bark.	
White pine blister rust	WB	Dies if host tree (WB) is killed by fire, but always available to infest other, living WB trees.	
Whitebark pine	WB, some LP	Habitat does not burn often. When it does, fires are usually patchy. Can survive some surface fires.	
Wild onion	All	Can sprout after any fire that does not kill its bulb.	

***** PP=ponderosa pine/Douglas-fir forest community; LP=lodgepole pine/subalpine fir community; WB=whitebark pine/subalpine fir community.

12. Tree Parts and Fire: "Working Trees" Jeopardy-style Game

Lesson Overview: In this activity, students learn to name the parts of a tree, describe their functions, and describe how some of these parts can help a tree survive fire, avoid the effects of severe fire, or reproduce after fire.

Lesson Goal: Increase students' understanding of how trees function and how they are affected by different kinds of wildland fires.

Objectives: Given a list of tree parts and other terms, students can:

Subjects: Science, Reading, Speaking and Listening

Duration: Two half-hour sessions – but see the gray box below.

Group size: Whole class, working in teams (10 teams maximum)

Setting: Classroom

Vocabulary: *see terms in Handout M12-1.*

- Describe a tree part, a part of the tree's environment, and/or a type of fire to the class.
- Apply the correct term to a definition of a tree part or adaptation to fire in a Jeopardy-style game.
- Describe how specific tree parts and characteristics enable some trees to avoid, survive, or thrive after surface fire, crown fire, and ground fire.

IF TIME IS LIMITED, you can do the jeopardy game in one session rather than 2. To do that, skip **Part I** and just have students study **Handout M12-1: Tree Parts and Kinds of Fire** as homework in preparation for the game.

Standards:		6th	7th	8th
CCSS	Reading: Informational Texts	4,10	4,10	4,10
	Speaking and Listening	1,4,6	1,4,6	1,4,6
	Language	1,2,3,4	1,2,3,4	1,2,3,4
	Reading: Science and Technology	4,7,8,9,10		
NGSS	Matter and Energy in Organisms and Ecosystems	LS2.A, LS2.B,LS2.C		
	Natural Selection and Adaptation	LS4.C		
	Growth, Development, Reproduction of Organisms	LS1.B		
EEEGL	Strand 2	B,C		

Teacher Background: To understand how fire affects organisms in the forest ecosystems, students need to know a few terms. This activity challenges them to master 23 terms, many of which (such as leaf and branch) they already know. The activity consists of two parts. In **Part I**, students teach their classmates the terms – some about tree morphology, some about the forest environment (litter, duff, and mineral soil), and some about types of fire (surface, crown, and ground fire). In **Part II**, they participate in a Jeopardy-style game that contains 25 definitions plus a bonus question (***M12_Jeopardy_FireWorks1.pptx***). **Use the directions on Slide 1 and work with the game (Slide 2) ahead of time** to become familiar with the game, the process of moving/deleting boxes, and the scoring algorithm.

Different characteristics enable trees (and other plants) to avoid specific kinds of fire, survive fire, or reproduce and thrive after fire. For example:

- 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, fires are less likely to climb from the forest floor 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 mineral soil are protected from the heat of surface and ground fires. However, deep roots don't prevent damage to the cambium from surface fires or damage to the leaves and buds from crown fires.
- If a tree can protect its seeds from fire, new trees can become established afterwards. Tightly sealed cones protect the seeds of some trees from crown fire. Burial protects seeds from all kinds of fire – unless they are in duff or organic soil, which can burn if it dries out.
- If a tree can sprout from the roots after its top is killed, it can survive surface and crown fire. Its ability to survive ground fire depends on soil properties and how deeply its roots are buried.

Materials and preparation:

- Download the Jeopardy game (***M12_Jeopardy_FireWorks1.pptx***) and **make a backup copy** on your computer. BE SURE TO READ THE DIRECTIONS on Slide 1 ahead of time and practice working with the game on Slides 2-3 before you play it with the class. The answer key is on Slides 4-5 and also reproduced below. **IMPORTANT:** Minimize the left margin when you display the presentation, so students can't read the answers!
- Download ***M12_WorkingTreeDiagram_Blank.pptx*** so you can project it on the board during the student presentations in **Part I**. Each presenter will sketch where each term occurs on this diagram. If a particular term isn't shown in the diagram, have the student sketch it in.

- Print 1 copy/student: **Handout M12-1: Tree Parts and Kinds of Fire** and **Handout M12-2: Working Trees**.
- At least 1 day before doing this activity, give each student a copy of **Handout M12-1: Tree Parts and Kinds of Fire**. Explain that they will play a Jeopardy-style game and compete for "dollars" based on their understanding of these terms and how trees "deal with" fire - that is, how they avoid damage from fire, survive fire, or reproduce or regrow after fire. Tell them whether or not they will be allowed to use the definition sheet during the game.
- Decide on prize(s) or awards for the winning team.

Procedure - Part I (OPTIONAL. See grey box on first page):

1. Explain: Look up 1-2 term(s), as assigned, using **Handout M12-1: Tree Parts and Kinds of Fire** and at least 1 other source. Develop a 1-2 minute presentation to teach the class about the term(s). Your presentation must include a visual component such as a sample from a real tree, a photograph, a drawing, or another medium (short video, PowerPoint slide, etc.).
2. Assign each student 1-2 terms from **Handout M12-1.** There are 23 terms in all.
3. Have students teach their terms to the class. Have each student sketch and label his/her terms on the board/projection (***M12_WorkingTreeDiagram_Blank.pptx***). A few terms (snag, sprouter, and the 3 kinds of fire), are NOT on the projection; have students sketch them separately. **It is best to have <u>branches</u> presented before leaves, buds, cones, and catkins; <u>cones and catkins</u> presented before seeds; and <u>roots</u> presented before sprouts.** If the students "teach" errors or miss an important point, correct them gently.
4. Have students take their handouts and notes home to study for the Jeopardy game.

Procedure - Part II:

5. Explain: You will compete in a Jeopardy-style game to show your understanding of the information on the handout. Before beginning, are there any questions about the handout, any terms or concepts that you don't understand? Answer questions…
6. Set up teams.
7. Explain:
   - Explain the procedure. (**See the directions on Slide 1 of the game.)**
   - Tell students whether they are or are not allowed to use the handout during the game.
   - Play the game (***M12_Jeopardy_FireWorks1.pptx***). Check answers with the **FireWorks Jeopardy: answer key** below.
   - Present awards to the winning team.

Assessment: Give each student a copy of **Handout M12-2: Tree Parts and Kinds of Fire**. Go through directions as needed. Have students complete the handout.

Evaluation: Refer to **Teacher's Answer Key for Handout M12-2: Working Trees** below.

	Full Credit	Partial Credit	Less than Partial Credit
Part I. Presentation	-Student presented accurate information in a clear and concise way. -The visual component was relevant and helpful.	-Student presented information that contained some misinformation (*which the teacher corrected*). -Visual component was present but only slightly relevant.	-Student presented incomplete or incorrect information. -Visual component was distracting or missing.
Part II. Jeopardy Game	-Student participated consistently by contributing to group discussion, listening, giving answer for the group, and/or giving other group members a chance to answer.	-Student participated sporadically in game by listening, occasionally contributing to group discussion, and/or presenting answer for the group.	-Student did not participate by listening to or engaging in group discussion or presenting group's answer.
Written component (Handout M12-2)	-Student correctly labeled 9-10 parts on diagram. -Student correctly described 3 adaptations that can help the tree survive or grow after ground, surface, and crown fire.	-Student correctly labeled 5-8 parts on diagram. -Student correctly described 1-2 adaptations that can help the tree survive or grow after different types of fire.	-Student correctly labeled less than 5 parts on diagram. -Student did not describe any adaptations that can help the tree survive or grow after fire.

FireWorks Jeopardy: answer key

	Growth	Transport	Support	Protection & Habitat	Helps deal with what kind of fire?
$10	Makes food Leaf	Absorbs water from soil Root	Treetop Crown	Tree skin Bark	Resin-sealed cones Crown fire
$20	Holds baby tree Seed	Pumps water up from roots Xylem or sapwood	Connects leaves to trunk Branch	Holds conifer seeds Cone	Thick bark Surface fire
$30	Makes new xylem & phloem Cambium	Helps conifer seed float from tree Seed wing	Supports crown, connects roots to crown Trunk	Fallen leaves Litter	Deep roots in mineral soil Ground fire
$40	Holds next year’s leaves Bud	Delivers nutrients from leaves Phloem	Inner wood Heartwood	Dead tree with broken top Snag	Seedlings grow fast Surface fire
$50	Can regrow its top if killed Sprouter	Helps seeds fly miles on wind Catkin	Anchors trunk in soil Root	Layers of rotting leaves Duff	Low branches drop off Crown fire

FireWorks Final Question: answer key

Wager your winnings:

Deep duff can protect a tree from fire or make it more vulnerable. How?

Deep duff can protect a tree's cambium and roots until it dries out. After the duff dries, it burns slowly but hot. That kills the tree's shallow roots and the cambium around the tree's base.

Handout M12-1: Tree Parts and Kinds of Fire

Bark: the outside covering on a tree's trunk and branches, the tree's "skin." Thick bark can protect the tree from surface fire.

Branch: a limb of a tree or shrub that grows out from the trunk and holds the leaves up in the light. Some trees drop their low branches as they age, which helps keep surface fires from climbing up into the crowns. This way the tree can avoid crown fire.

Bud: The cells that will grow next year's leaves and branches. Located at the tree's top and the tips of branches. Similar cells occur at the tips of roots.

Cambium: the layer of living cells under a tree's bark that produces the xylem and phloem layers of cells.

Catkin: a kind of flower produced by some trees and shrubs. This lightweight, fluffy package hangs down from the plant's branches. It contains many tiny flowers, which can mature into tiny seeds. The "fluff" helps the seeds float a long way on the wind, sometimes many miles.

Cone: the package in which a conifer stores its seeds. If cones are sealed tight with resin, the seeds inside may survive crown fire and be released soon afterward.

Crown: a tree's top, which holds most of its leaves and buds.

Crown fire: a fire that spreads through the crowns of trees and tall shrubs. Crown fires are usually ignited from surface fires. They are common in some conifer forests and chaparral-type shrublands.

Duff: the layer of soil that is made up of dead, rotting plant parts. Duff is below litter and above mineral soil. Sometimes it is mixed with mineral soil.

Ground fire: a fire that burns in the duff and other organic material in the soil. Ground fires usually burn slowly, with lots of smoldering instead of long flames. Even without flames, ground fires can burn hot enough to kill things living in the duff, including roots and other underground plant parts.

Heartwood: inner wood of a tree, which helps it stand strong and resist decay.

Leaf: the green part of a plant that uses sunlight, water, and carbon dioxide to make "food". Needles are a special kind of leaf.

Litter: the layer of dead leaves and other plant matter, not yet decayed, lying at the top of the forest floor.

Mineral soil: soil that contains no plant or animal parts, so it cannot burn.

Phloem: the layer of living cells under a tree's bark that moves nutrients from one place to another, especially from the leaves to other parts of the tree.

Root: the part of a plant that lives underground, collects water and minerals from the soil, and keeps it firmly planted in the soil. If the roots are buried deep in mineral soil, they may be able to survive a ground fire.

Seed: a very tiny, living plant—just waiting to grow—plus a package of nutrients and a protective covering. If seeds are sealed tight inside a cone, they may survive crown fire. If they're embedded in moist duff, they may survive surface fire. If they're buried in mineral soil, they may survive ground fire.

Seed wing: part of a conifer seed that helps it float away from the parent tree when it falls.

Snag: a dead tree, often with a broken top.

Sprouter: a kind of plant that can grow from underground parts if its top is killed off.

Surface fire: a fire that burns the litter, grasses, shrubs, and wildflowers on the forest floor but does not burn the crowns of trees or the duff.

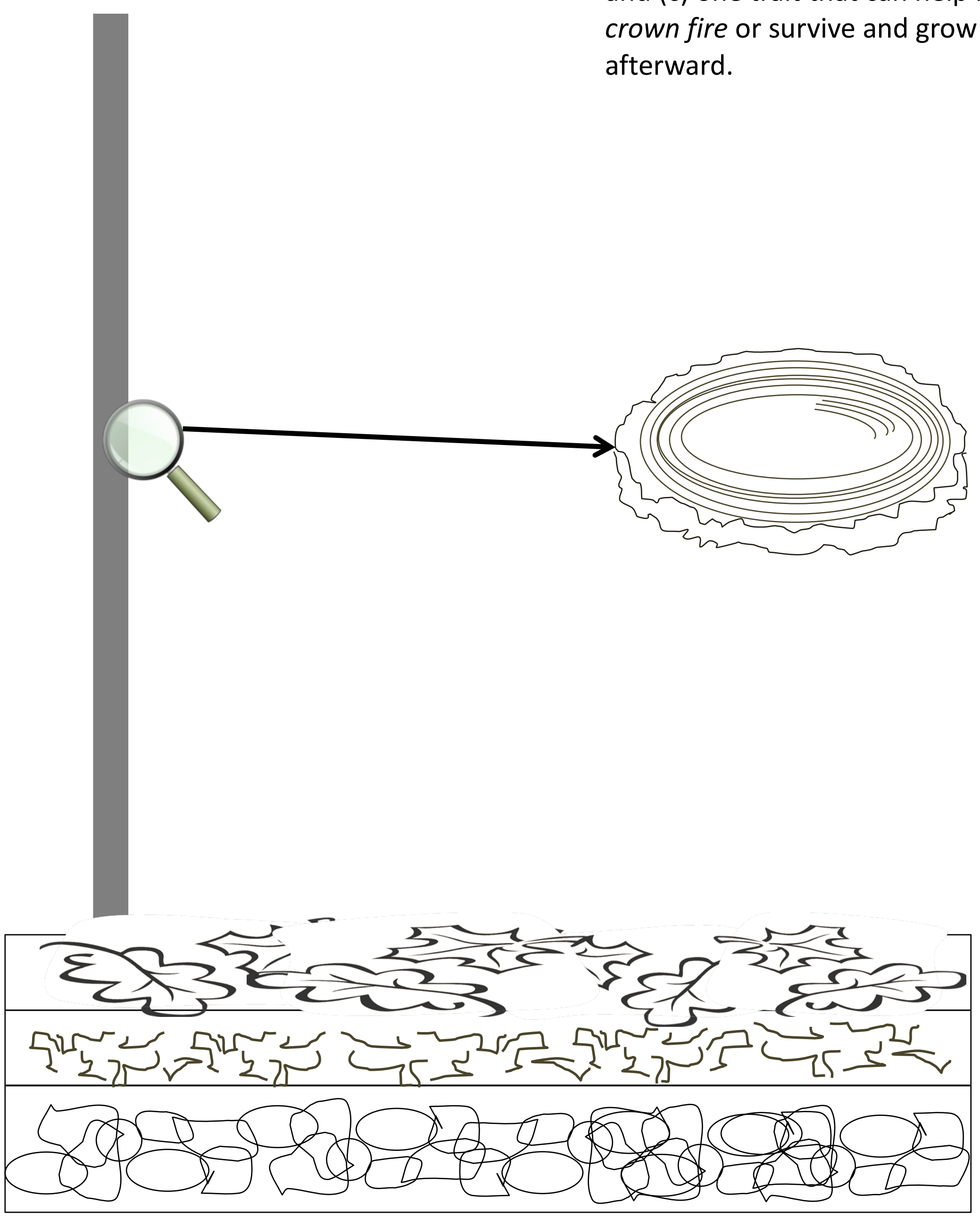
Trunk: the stem of a tree. The faster the trunk grows, the sooner its crown will be out of reach of surface fires.

Xylem: the layer of wood cells inside the cambium that pump water from roots to leaves. Also called sapwood. As a tree grows, older xylem cells become inactive and die, forming heartwood.

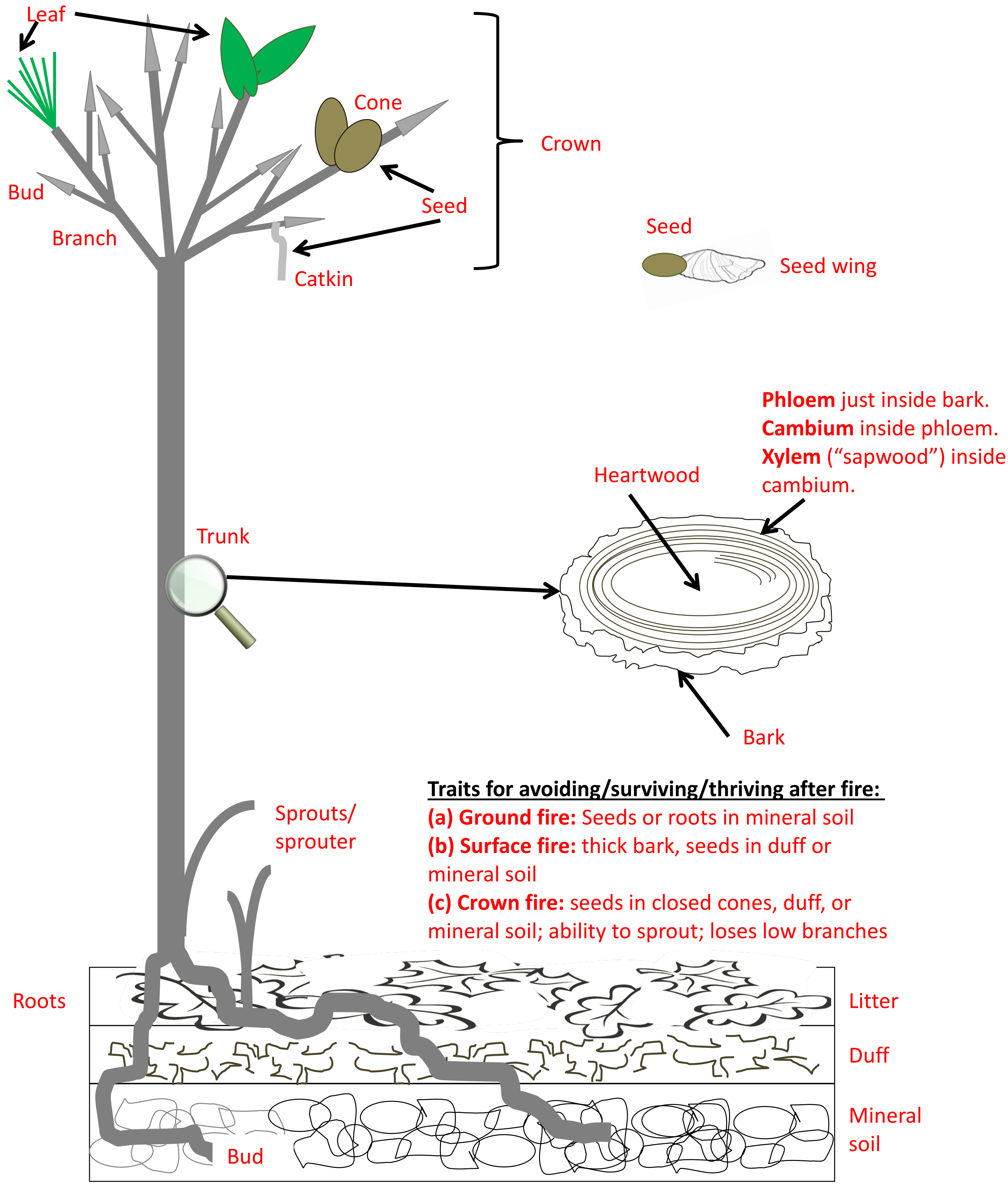
Handout M12-2: Working Trees

Name ______________

1. Sketch ten parts of this tree and/or its environment. Use terms from **Handout M12-1**. Label each part.
2. Name (a) one trait that can help the tree survive *ground fire*, (b) one trait that can help it survive *surface fire*, and (c) one trait that can help it avoid *crown fire* or survive and grow well afterward.



Answer Key for Handout M12-2: Working Trees



Traits for avoiding/surviving/thriving after fire:

(a) Ground fire: Seeds or roots in mineral soil

(b) Surface fire: thick bark, seeds in duff or mineral soil

(c) Crown fire: seeds in closed cones, duff, or mineral soil; ability to sprout; loses low branches

13. Tree Identification: Figure out the "Mystery Trees"

Lesson Overview: In this activity, students observe and record information on botanical specimens, then use each other's observations to identify 10 tree species of the northern Rocky Mountains and North Cascade range.

Lesson Goals: To increase students' understanding that trees have characteristics unique to each species and these can be used to identify them.

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

Duration: Two half-hour sessions

Group size: Whole class, working in 10 teams

Setting: Classroom

Vocabulary: *field guide, species names*

Objective: Given descriptions of individual tree species, a dichotomous key, and plant samples, students can use sets of photos and botanical specimens to identify 10 species.

Standards:		6th	7th	8th
Common Core ELA	Reading Informational Texts	4,7,10	4,10	4,10
	Writing Standards	10	10	10
	Speaking/Listening	1,4,6	1,4,6	1,4,6
	Language Standards	1,2,3,4	1,2,3,4	1,2,3,4
	Science/Technology	3,4,7,9,10		
NGSS	Matter and Energy in Organisms and Ecosystems	LS2.A,		
	Growth, Development, Reproduction of Organisms	LS1.B		
	Natural Selection and Adaptation	LS4.C		
EEEGL	Strand 1	A,B,C,E,F,G		

Teacher Background: To understand the complexity of fire's role in forests, students must be able to distinguish among tree species. In this activity, they use their observation skills to describe and identify 10 important trees in the northern Rocky Mountains and North Cascade range. They work in 10 teams, since there are 10 species represented in the "Mystery Trees" materials.

This activity has 2 steps, done in 2 class periods; in between, you'll need to copy some materials for the next class. In **STEP 1 – "KNOWN SPECIES,"** each of the 10 teams describes a "known" species and records their observations on a handout. In **STEP 2 – "UNKNOWN SPECIES,"** which is the **Assessment** for the activity, students use the "Mystery Trees Booklet" (assembled from the completed handouts on all 10 species) to identify all of the tree species – their own plus 9 others. Thus they are using each other's observations to distinguish among the tree species.

If you can visit a forest with the class, have students use their "Mystery Trees Booklets" to identify trees in the field.
Note: A quicker version of Mystery Trees, which uses a dichotomous key, is available in the elementary curriculum: **E10. Tree Identification: Using a Key to Identify "Mystery Trees".**

Materials and preparation:

- Print 10 copies of **Handout M13-1. Tree Species** (1 for each student team).
- Obtain some field guides from a library for students to examine.
- Assemble 10 stations, 1 for each species. Each station should display with the following items from the trunk:
    - Ruler
    - Tree Bark/trunk specimen
    - Cone or flower specimen
    - Foliage specimen
    - Set of four photos of the species (also available in ***Tree_ID_photos.pdf***)
    - Species name label (also available in ***Tree_spp_labels.pdf***)

Procedure:

STEP 1 – FIRST CLASS PERIOD – "KNOWN SPECIES"

1. Explain: Each team will describe a tree species using the specimens at their station and will record their observations on **Handout M13-1. Tree Species**.
2. Explain: In this step, you will work with "known" species, but in the next class session, you will work with "unknowns." You'll use the observations of the other teams to identify all of the "mystery" trees.
3. Explain: Only 10 species are included in this activity, but there are many more native trees in the forests of the northern Rocky Mountains and North Cascades. Thus you can use your descriptions to identify trees in the field, but you'll probably find some that you can't identify. That's what local field guides are for.
4. Pass around some field guides so students can see how they might be used.
5. Assign a team of students to each station. Explain: Complete **Handout M13-1** for your species. You must write neatly so other students will be able to read your observations. When you have completed the handout, let the teacher check your work.

6. As each team completes the handout, visit their station. **REMOVE THE SPECIES NAME LABEL.** Check the handout for completeness and accuracy. Ask the team to revise it, if necessary, so it will be useful for other students in identifying mystery trees.
7. After you approve the team's handout, collect it for copying. Unless you plan to do STEP 2 right away, have students place their specimens back in the grocery bag, leaving the species name label out. (You collected these in the last step.)

BEFORE THE NEXT CLASS: Make a booklet containing all 10 handouts. Use the "Mystery Trees Booklet" page shown at the end of this activity as a cover. Make a copy of the booklet for each team.

Assessment:

STEP 2 – SECOND CLASS PERIOD – "UNKNOWN SPECIES"

8. Set up the stations again – THIS TIME WITHOUT THE SPECIES NAME LABELS.
9. Give a copy of the "Mystery Trees Booklet" to each team.
10. Explain: DON'T SHARE INFORMATION WITH THE OTHER TEAMS DURING THIS STEP.
11. Explain: Each station contains a "mystery tree." You should recognize the one that your team described, but the others are "unknowns." Circulate from station to station and use the observations in your Mystery Trees Booklet to identify each tree. Then write the tree's one-letter code in the upper right corner of the page and circle it.

Evaluation: Here are the correct code letters for the tree species:

Black cottonwood	B
Douglas-fir	V
Engelmann spruce	H
Lodgepole pine	E
Ponderosa pine	O
Quaking aspen	L
Subalpine fir	C
Western larch	T
Western redcedar	D
Whitebark pine	J

Fully successful	Moderately successful	Unsuccessful
-Student team correctly identified 8-10 species	-Student team correctly identified 5-7 species	-Student team correctly identified <5 species

Handout M13-1. Tree Species: ___________________________

Team Members: ____

1. Are the leaves *broad and flat* (more than 1 centimeter wide)… or *narrow and needle-shaped…* or *a long series of tiny, overlapping scales*? ______________

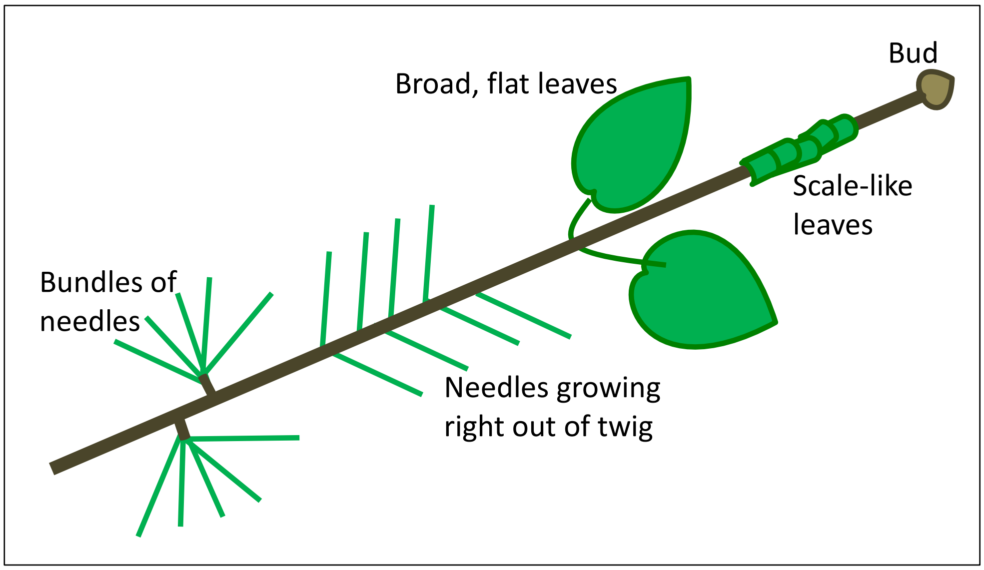
2. How big are the leaves? ______ centimeter(s) long by ______ centimeter(s) wide

3. If the leaves are NOT scales, do they grow in bundles or right out of the twig?

   ____

4. Find the biggest bud. This is at the tip of the twigs. How big is it?

   ______ centimeter(s) long by ______ centimeter(s) wide



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

6. Does the tree put its seeds in flowers or cones? ______________________

7. Describe the flowers, seeds, or cones — size, color, shape, other features:

8. How thick is the bark? _______________________ centimeter(s)
   Describe the bark:

9. Do the branches reach all the way from the treetop to the ground? _________________

10. Describe two other characteristics that would help someone identify this tree:

Mystery Trees Booklet for the Northern Rockies and North Cascades

Team Names:

____

1. Use the descriptions in this booklet to identify the tree species at each station.
2. Write the correct code letter for that species in the upper right corner of the page.
3. Circle the code letter so it's easy to see.

14. Who Lives Here and Why? Modeling Forest Communities

Lesson overview: In this activity, the class assembles a graphic model of forest communities in the northern Rocky Mountains and the North Cascades. They use feltboard materials from the trunk to show illustrate the optimal environmental conditions for each species and show how individual tree species are associated with each other in ecological communities. Then they use the model to predict the effects of changing climate conditions on the distribution of species.

Subjects: Science, Mathematics, Reading, Speaking and Listening

Duration: one half-hour class session, possibly followed by a station activity

Group size: Whole class

Setting: Classroom

Vocabulary: *aspect, climate change, community, elevation, environmental condition, gradient, habitat, moisture*

Goals:

1. To increase students' understanding that forest communities develop under specific environmental conditions because species with similar or complementary needs are likely to occur together.
2. To increase students' ability to interpret data displayed on a map and apply the information to make predictions.

Objectives:

Given information on the environmental conditions in which various tree species live, students can:

- Describe a forest community in terms of tree species that are likely to occur together.
- Use information from maps to predict the effects of climate change.

Standards:		6th	7th	8th
Common Core ELA	Science/Technology	3,7,10		
NGSS	Interdependent Relationships in Ecosystems	LS2.A		
	Weather and Climate	ESS2.D, ESS3.D		
	Natural Selection and Adaptation	LS4.B, LS4.C		
	Growth, Development, Reproduction of Organisms	LS1.B, LS4.B		
EEEGL	Strand 1	A,C,E,F,G		

Teacher background: Every species needs certain environmental conditions to survive, grow, and reproduce. Trees, for example, need a certain amount of sunlight and moisture and certain temperature conditions. They may also need a specific day length to begin growing, specific soils to provide nutrients, specific fungi to associate with their roots, and many other particular conditions. This activity focuses on their needs for specific moisture and temperature conditions.

Tree species with similar environmental needs are likely to occur together, forming unique forest communities. This version of FireWorks covers 10 tree species and focuses on the fire ecology of 3 communities: forests dominated by ponderosa pine and Douglas-fir, forests dominated by lodgepole pine and subalpine fir, and forests dominated by whitebark pine and subalpine fir. Students learned about the ecology of the 10 tree species in **Activity M11 (Who Lives Here? Adopting a Plant, Animal, or Fungus)** and how to identify the trees in **Activity M13 (Tree Identification: Figure out the "Mystery Trees")**.

In this activity, students use the information in **Handout M14-1. Optimum habitat conditions** to assemble a graphical model of forest communities on a feltboard. **Handout M14-1** describes the range of elevations and moisture conditions that is best for each tree species on a fictitious mountain called Sasquatch Peak. The table shows each species' requirements relative to those of the other species, but it may not show the exact range of those species in your particular location, and individuals of each species are likely to occur outside the ranges of conditions shown. Thus one of the shortcomings of the model is that it is specific to a particular location.

Once students have assembled the graphical model on the feltboard, they can see that trees with similar habitat needs tend to occur together, thus forming distinct forest communities – including the 3 communities featured in this version of FireWorks. They can also see that the forests of the northern Rocky Mountains and North Cascades actually include much more variety than occurs in the 3 community types featured here.

Students interpret data on climate change as shown in 2 maps (see **Handout M14-2**) and then use the feltboard model to predict how current conditions (warmer and drier than most of the

20th century) might change the optimum habitat for a species and influence the species present in forest communities.

Handout M14-1 and the feltboard model in this activity simplify the factors that constitute optimum habitat. They use distance from running water as a surrogate for moisture. Moisture conditions are represented as "moist" along a stream to "dry" along a ridge far from the water. In reality, of course, the moisture available to trees is influenced not only by distance from running water but also by soil properties, aspect, steepness, stand structure, and cover of litter and duff. For example, north-facing hillsides tend to be shadier and thus more moist than south-facing ones (in the northern hemisphere); and sites with extensive forest cover and deep duff tend to be more moist than sites with a lot of bare ground.

Handout M14-1 and the feltboard model use elevation as a surrogate for temperature, assuming that temperatures at low elevations are higher than temperatures at high elevations. In reality, this relationship is more complicated; temperature is influenced by slope, aspect, and topography. For example, north-facing hillsides tend to be cooler than south-facing ones; and if frost pools in a valley bottom overnight, temperatures may go from cool at low elevation to warm at middle elevation and then to cool again at high elevation.

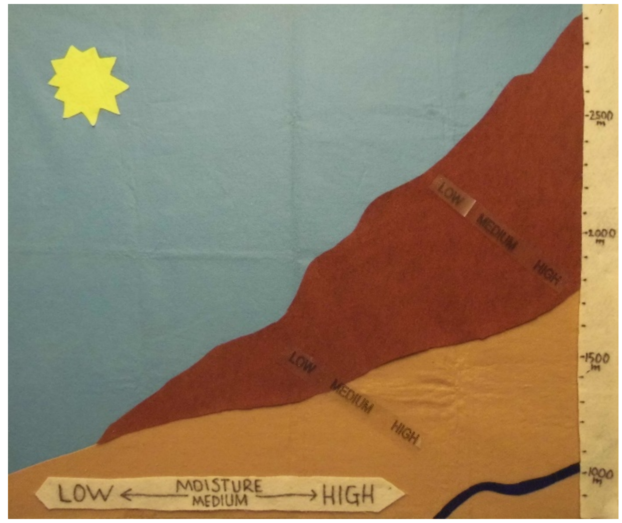
This activity also provides a simplified model of what may happen to tree distributions as climate changes. The only variables considered here are temperature and moisture. In reality, tree distributions respond to many other factors, including seed dispersal, species interactions, insects and diseases, connectivity of habitat, and changes in fire frequency, severity, and size.

Materials/Preparation:

1. Locate the following in the trunk:
    - Feltboard for the Ponderosa Pine forest community
    - Feltboard Kit (may be individual kit, or in the Mystery Trees Box)
    - Straight pins
2. Make 5 copies of **Handout M14-1. Optimum habitat conditions.** Cut them in half so you'll have 10 copies of the table. (You need one for each of the 10 tree species.)
3. Decide how you want to use the assessment tool, **Handout M14-2. Trees in a Changing Environment.** See the 3 options described below in **Assessment:**
    A. completing the handout together as a class
    B. completing it in teams at a station
    C. completing it individually

    Make the number of copies needed.
4. Display the felt background for the Ponderosa Pine community – on a bulletin board, if possible, so pins can be used to secure the pieces.
5. Take out the pieces of the Feltboard Kit.
    - Attach the dark brown piece representing Sasquatch Peak to the feltboard.

- Attach the "elevation bar" along the right-hand edge of the feltboard.
- Attach the "moisture bar" along the bottom.
- Attach the two transparent labels that indicate site moisture diagonally between the creek and the horizon.
- Secure the pieces with pins. See photo at right.



Procedure

1. Explain/ask: We're studying fire in 3 forest **ecosystems** of the northern Rocky Mountains and North Cascades. The **living things** in an ecosystem are called the **community**. What are some of the living things in a forest ecosystem? Trees, insects, mammals, fungi, plants… What are some of the **nonliving things** in a forest ecosystem? Air, water, mineral soil… In this activity, we'll focus on the tree species in forests on a steep mountainside.

2. Ask: What are some of the important tree species in communities of the northern Rocky Mountains and the North Cascades? Students could name any of the "mystery tree" species from **Activity M13**. They could mention other species as well.

3. Ask/discuss: What environmental conditions make a tree species thrive in some places and not others? What conditions help some species occur together and others occur in very different places? Why do these conditions matter so much? Draw out the following:

   - Elevation matters because it influences the temperature, length of summer vs. winter, exposure to wind, etc.
   - Slope, aspect and steepness matter because they control how much direct sunlight the plants receive (and thus temperature), how much wind they are exposed to, how rain and snow are deposited, and how moisture is retained in the soil.
   - Soil matters because it influences the nutrients available to the plant and how well water is retained.
   - Amount of moisture – precipitation and storage in the soil - matters because it influences how much water is available to plant roots.

   Note that this discussion addresses only <u>environmental</u> conditions that plants need. Every plant species also requires certain <u>biological</u> conditions, such as abundant pollinators or fungi that help roots absorb moisture and sparseness of competing vegetation. This activity doesn't focus on biological requirements.

4. Explain: Let's build a model that shows the "best" environmental conditions for each of our mystery tree species – that is, the conditions where trees of each species are most likely to grow and reproduce well. Then we will use the model to learn more about forest **communities** and how they might change as our climate changes.

5. Give each team a color-coded felt tree outline and the matching felt bar marked for that species[1]. You may want to give the species to the team that described it in **Activity M13.**

6. Give each team a copy of the half-page **Handout M14-1. Trees in a Changing Environment.**

7. Explain: We're going to use information in the handout to place the felt pieces for each species on the felt background of a fictitious mountain named Sasquatch Peak. (The specific elevation ranges for species vary throughout the northern Rockies and North Cascades, so the ones in this table are just one example; in our area, they could be higher or lower.) The feltboard shows two gradients in environmental conditions: elevation and moisture.
   - The elevation gradient represents temperature, from hot conditions in the valley bottom to cool conditions near the mountain top. What else might influence temperature? Aspect, shade, drainage patterns – especially for cold air… see **Teacher Background** above.
   - The moisture gradient goes from a creek bed (high moisture) to an exposed ridge (dry). This makes it look like moisture depends only on how near you are to a creek, but really it represents all of the things that influence moisture availability to plants. What are some of these? Nearness to water, aspect, soil properties, plant cover, litter/duff cover… see **Teacher Background**.

8. One at a time, have the student teams use **Handout M14-1** to place their species' colored bar in the appropriate location on the feltboard. A little chaos and some criss-crossing colored bars are no problem. When completed, the feltboard should look something like this, though perhaps less tidy:
   - Start by finding the species' maximum elevation on the vertical axis, then go across the mountainside to a point that represents its optimum moisture conditions. Place one end of the colored felt bar there.
   - Then go "downhill," diagonally and to the left, and place the other end of the bar near the species' minimum elevation and in the same moisture range. If it's too long, fold it under a little. If it's too short, change the angle a little.

[1] If your materials include a felt bar labeled GRAND FIR, turn it over and use a black marker to label it WESTERN REDCEDAR.

- Secure the felt bar with pins and place the tree's silhouette somewhere along the line.

9. Explain: This curriculum focuses mostly on the ecology of three communities: forests dominated by ponderosa pine with Douglas-fir, lodgepole pine with subalpine fir, and whitebark pine with subalpine fir. Where are those communities located in this model? Have students place the three felt labels for these forest communities on the feltboard.

10. Discuss: While we've named our 3 forest communities for the species most common there, you can see that other species are likely to occur.

    What is one species that you might find in low-elevation ponderosa pine/Douglas-fir communities? Western larch. Remind students to look at "low elevations" (near the bottom of the graph). Western larch is probably just to the right of Douglas-fir, since it needs slightly more moisture. Quaking aspen and black cottonwood should be even further to the right.

    What is one species that might show up on moist spots – perhaps next to creeks - in whitebark pine communities at high elevations – say, above 2000 m? Engelmann spruce. Show how to look to the right of whitebark pine and subalpine fir for more moist conditions.

11. Discuss: What happens to forest communities if the temperature and moisture conditions change? If you are in a moist area with a lot of subalpine fir, but the climate becomes hotter and drier, what species might become more common? Lodgepole pine, Douglas-fir, and ponderosa pine. Show how to look at lower elevations for species that thrive in hotter conditions and how to look to the left for species that thrive in drier conditions.

12. Ask: Why does it matter if the higher-elevation species (whitebark pine and subalpine fir, for example) fail to thrive and species that currently live on dry sites at lower elevations (ponderosa pine and Douglas-fir, for example) replace them? Loss of the high-elevation species will reduce the diversity of tree species across the landscape. It will reduce food and other habitat features needed by birds, mammals, and insects that currently rely on high-elevation forest communities; these include Clark's nutcrackers, red squirrels, and bears. With reduced habitat, the diversity of animal species may decline. Loss of the high-elevation species may lead to new combinations of species – new communities – in which there are fewer trees and more invasive ("weedy") species.

13. Take a photo of the completed feltboard. That way, if you or students want to change the pieces around to show the effects of climate change or removal/addition of species, you can always restore it to the original arrangement. This will be especially helpful if students use the display as a station for completing **Handout M14-2.**

Assessment: You can use **Handout M14-2. Trees in a Changing Environment** in any of these ways:

A. Do part or all of the handout together, as a class; you can project the maps needed for Questions 1 and 2 from ***2ClimateChangeMaps.pptx***.
B. Set up the feltboard display as a station and have groups of students complete their handouts together, one or two teams at a time. If you use this option, students can touch and manipulate the felt pieces as they answer the handout questions – as long as they return the pieces to their original positions when they are done.
C. Turn the students loose with the handout and have them complete it on their own.

INSTRUCTIONS:

1. Give each student a copy of **Handout M14-2. Trees in a Changing Environment**. Explain: The first page of the handout contains data about how the climate throughout the United States has changed over the past 50 to 100 years. We are going to focus on the information about our region, the northern Rocky Mountains and the North Cascades. The second page of the handout asks you to use information from the feltboard model to make predictions about how our forest communities might respond to climate change.

2. Have students complete the handout.

Evaluation:

	Excellent	Good	Fair	Poor
Questions 1 and 2: • 1 point for circling region on map • 1 point for correct verbal answer Questions 3-8: • 1 point each	9-10 points	7-8 points	5-6 points	Less than 5 points

Handout M14-1. Optimum habitat conditions for 10 tree species on Sasquatch Peak, which is somewhere in the northern Rocky Mountains or the North Cascades. The valley bottom is at 900 m elevation. The summit of Sasquatch Peak is at 3000 m.

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

Handout M14-1. Optimum habitat conditions for 10 tree species on Sasquatch Peak, which is somewhere in the northern Rocky Mountains or North Cascades. The valley bottom is at 900 m elevation. The summit of Sasquatch Peak is at 3000 m.

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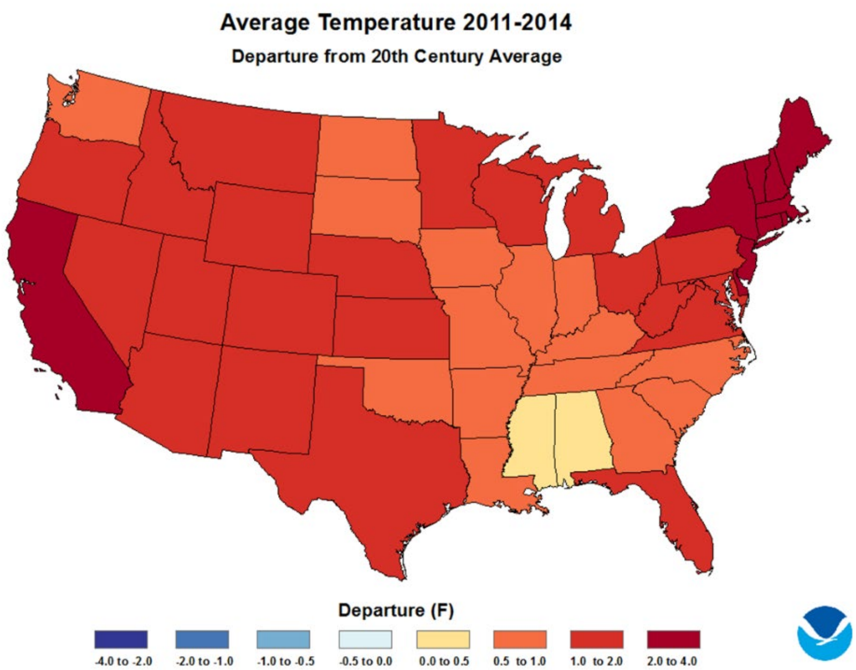
Lodgepole pine	1500-2300	low to medium
Quaking aspen	900-1900	medium to high
Ponderosa pine	900-1700	low
Subalpine fir	1400-2500	medium
Western larch	900-2000	medium
Western redcedar	900-1700	high
Whitebark pine	1800-2600	low

Handout M14-2. Trees in a Changing Environment

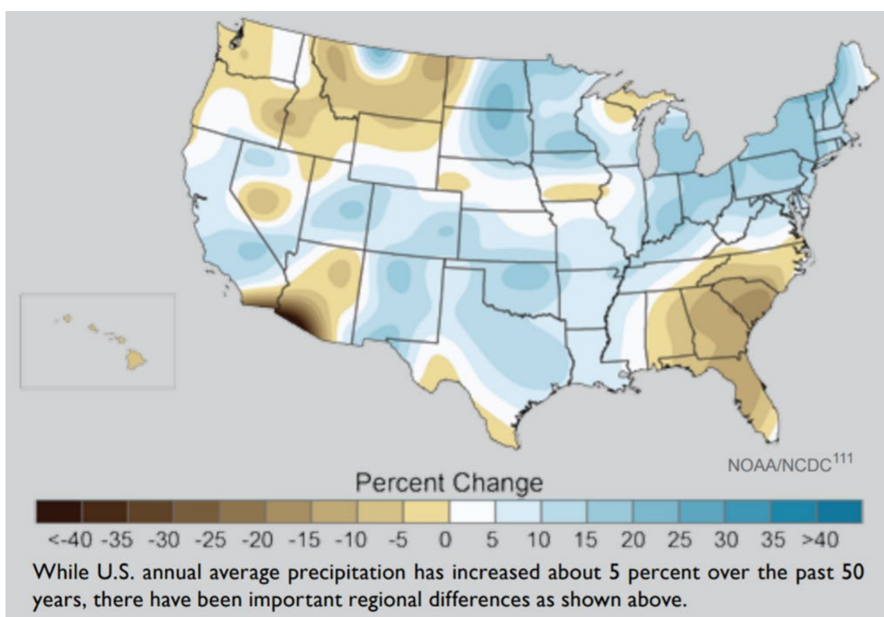
Name: ________________

Figure 1. AVERAGE TEMPERATURE MAP. Negative values indicate that the years 2011-2014 were cooler than the 20th century average. Positive values indicate that the years 2011-2014 were warmer than the 20th century average.



Source: https://www.ncdc.noaa.gov/cag/statewide/time-series/. This is an interactive web page with a huge amount of climatological information, both current and historical. The map shown here was obtained in February 2018. Consult the website to find information on more climate variables and on specific states or regions.

Figure 2. CHANGE IN ANNUAL PRECIPITATION, 1958 TO 2008. While precipitation over the United States as a whole has increased, there have been important regional and seasonal differences. In the Northwest, decreases have occurred in all seasons except spring.



While U.S. annual average precipitation has increased about 5 percent over the past 50 years, there have been important regional differences as shown above.

Source: Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009. https://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf (p. 30).

Use the maps on the previous page to answer these questions:

1. Figure 1 compares average temperatures in recent years with those of the 20th century. Circle the region that extends from the northern Rocky Mountains in the east across the North Cascades in the west. Does the map suggest that the climate in this region is getting hotter or colder? _____________

2. Figure 2 shows the trends in average precipitation over the past 50 years or so. Circle the area from the northern Rocky Mountains to the North Cascades. Does the map suggest that the climate in this region is getting wetter or drier? _____________

Use the half-page handout or the feltboard model of forest communities to answer these questions:

3. Suppose you are a western larch living at 1400 m elevation, and your home gets a lot drier. Name one tree species that will probably thrive in your community over the next 100 years:

   ____

4. Suppose you are a whitebark pine living at 1900 m elevation and your home gets a lot hotter. Name one tree species that may become part of your community:

   ____

5. Is whitebark pine likely to survive and reproduce better or worse in a hotter environment at 1900 m? Explain:

   ____

   ____

6. Suppose you are a subalpine fir living at 1500 m elevation, and your home gets drier and hotter. Name one tree species that will probably join your community – or will grow better, if it is already there.

   ____

7. Suppose you are an Engelmann spruce growing at 1600 m elevation, and your home gets both drier and hotter. Name one tree species that will probably be unable to persist in your community: ______________________________

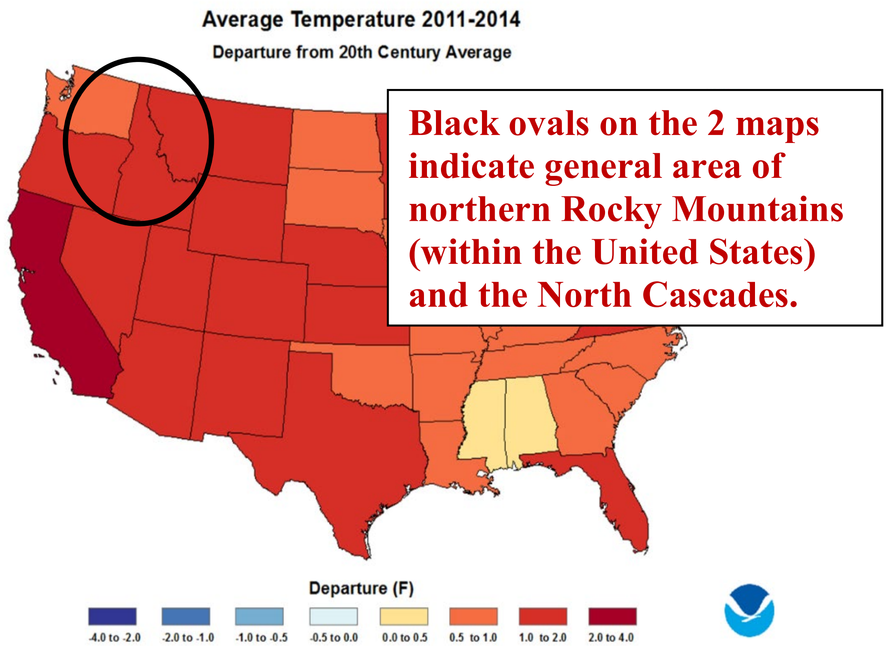
8. Is Engelmann spruce likely to survive and reproduce better or worse in a drier, hotter environment at 1600 m? Explain:

   ____

   ____

Answer Key to Handout M14-2. Trees in a Changing Environment

Figure 1. AVERAGE TEMPERATURE MAP. Negative values indicate that the years 2011-2014 were cooler than the 20th century average. Positive values indicate that the years 2011-2014 were warmer than the 20th century average.



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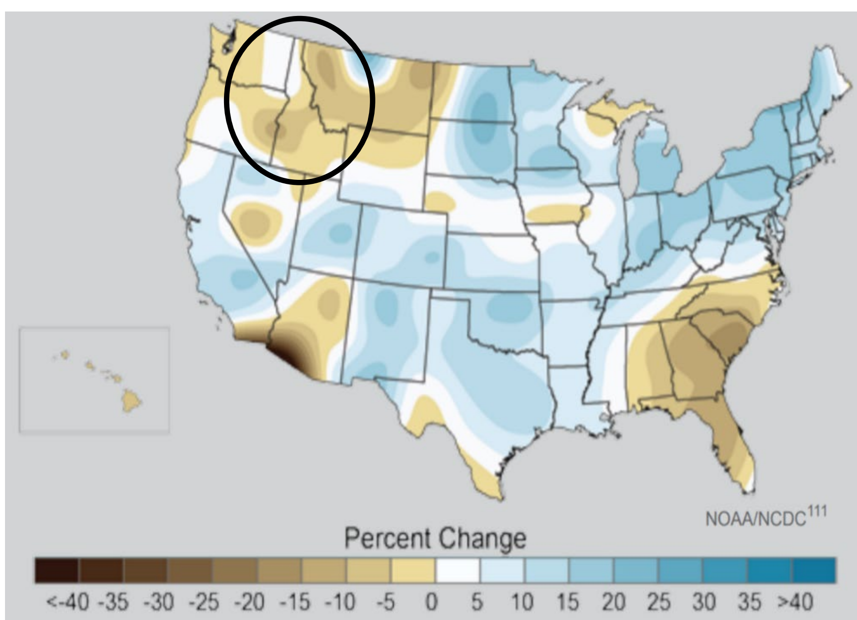

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Use the maps on the previous page to answer these questions:

1. Figure 1 compares average temperatures in recent years with those of the 20th century. Circle the region that extends from the northern Rocky Mountains in the east across the North Cascades in the west. Does the map suggest that the climate in this region is getting hotter or colder? Hotter

2. Figure 2 shows the trends in average precipitation over the past 50 years or so. Circle the area from the northern Rocky Mountains to the North Cascades. Does the map suggest that the climate in this region is getting wetter or drier? Drier – although this is not uniform throughout the region, and the caption says that spring is NOT drier in this region.

Use the feltboard model of forest communities to answer these questions:

3. Suppose you are a western larch living at 1400 m elevation, and your home gets a lot drier. Name one tree species that will probably thrive in your community over the next 100 years: Ponderosa pine and Douglas-fir are both correct.

4. Suppose you are a whitebark pine living at 1900 m elevation and your home gets a lot hotter. Name one tree species that may become part of your community: Ponderosa pine

5. Is whitebark pine likely to survive and reproduce better or worse in a hotter environment at 1900 m? Explain: Whitebark pine will probably fare worse. 1900 m is near the low end of its current distribution. If the climate gets a lot hotter, the environment could become more like current conditions at 1600 m, where whitebark cannot grow. If ponderosa pines become established, they could use much of the water on the site, making conditions even worse for whitebark pines.

6. Suppose you are a subalpine fir living at 1500 m elevation, and your home gets drier and hotter. Name one tree species that will probably join your community – or will grow better, if it is already there. Douglas-fir, lodgepole pine, and ponderosa pine are all correct.

7. Suppose you are an Engelmann spruce growing at 1600 m elevation, and your home gets both drier and hotter. Name one tree species that will probably be unable to persist in your community: Western redcedar and quaking aspen are both correct.

8. Is Engelmann spruce at 1600 m likely to survive and reproduce better or worse if the site gets drier and hotter? Explain: Engelmann spruce is likely to fare worse in the new environment. There are many species at 1600 m and lower elevations that do better on dry sites than Engelmann spruce. These include western larch, Douglas-fir, and ponderosa pine. If these species become established, they are likely to use much of the water on the site, making conditions harder for Engelmann spruce.

15. Bark and Soil: Nature's Insulators

Lesson Overview: This activity explores the use of insulation to slow the transfer of heat through materials. Bark (on stems of trees and shrubs) and soil are two kinds of materials that insulate living things from the heat of fires.

The trunk has only 1 set of materials for this experiment, so you can do it either as a <u>demonstration</u> or a <u>station</u> where students will work in groups of 2-4.

Subjects: Science, Mathematics

Duration: Two half-hour sessions <u>or</u> one half-hour session for demonstration, then 15-minute sessions for teams

Group size: Whole class for demonstration, teams of 3-4 for followup

Setting: Indoors

Vocabulary: *insulation*

Lesson Goal: Increase students' understanding of heat transfer and the usefulness of insulation to slow the process of heat transfer.

Objectives:

- Students can describe how insulation affects the flow of heat through a substance.
- Students can explain how tree bark and soil can protect living tissues from the heat of fires.

ABOUT STUDENT PRESENTATIONS: If you did **Activity M11. Who Lives Here? Adopting a Plant, Animal, or Fungus**, this would be a great time for student presentations on all of the tree species. That way they can connect the concept of bark thickness to traits of particular species that they've been studying.

Standards:		6th	7th	8th
CCSS--ELA	Writing	4,7,10	4,7,10	4,7,10
	Speaking and Listening	1,4,6	1,4,6	1,4,6
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	4,7,10	4,7,10	4,7,10
CCSS--Math	Geometry	6.G		
NGSS	Structures/Properties of Matter	PS3.A		
	Energy	PS3.B		
	Engineering Design	ETS1.A,B,C		
	Natural Selection and Adaptation	LS4.C		
EEEGL	Strand 1	A,C,E,F,G		

Teacher Background: This activity shows how insulation slows the transfer of heat through materials. The insulation in a home keeps it from heating up rapidly on a hot summer day and from cooling off rapidly on a cold winter night. Insulation may also slow the house's cooling after a hot summer day, which is why we might open the windows and use fans to bring cooler air inside.

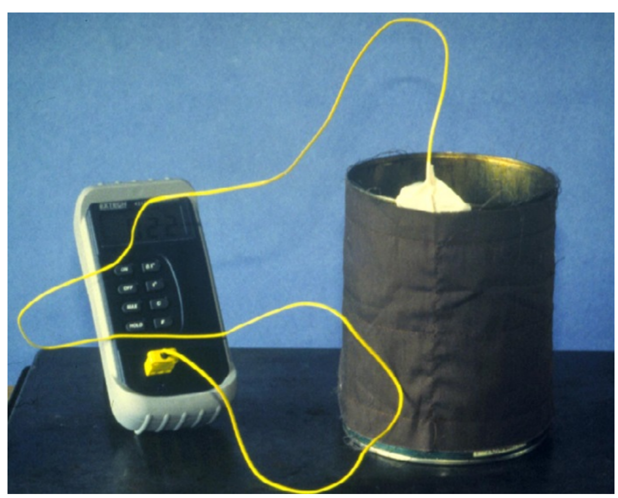
Nature has ways to insulate living things from the heat of wildland fires. Many trees have thick bark, which slows the transfer of heat from fire to the cambium cells beneath the bark. Since these are the living cells that make new xylem and phloem (and therefore enable the tree to move water and nutrients), they are crucial to its survival. Soil is another of nature's insulators. Soil protects small animals that stay in their underground burrows during fires. It also protects roots, buried seeds, and other underground plant parts.

In this activity, we assume that bark and soil will not burn. However, that assumption is not completely accurate. Bark can burn if it gets dried out and is exposed to enough heat. Some materials in the soil can burn, too. Soil is composed of tiny particles of rock (minerals), which are not burnable, plus partly decomposed particles of vegetation and animal matter, which are burnable. When the dead, rotting organic matter is in a distinct layer on top of the mineral soil, we call it duff. Also see **Activity M10. Fire, Soil, and Water Interactions**, which explores the effects of fire on soils.

In this activity, students "model" nature's insulation by covering a surface (a model tree or model soil) with quilting materials. They use a hair dryer to simulate the heat of a fire. They heat the surface for a short time and record the temperature pattern beneath the insulation as it heats up and cools off. They may be surprised to find that, while thick insulation prevents the temperature from rising rapidly, it also prolongs heating and slows cooling more than thin insulation does.

One limitation of the models used for this activity (an empty can representing a tree trunk and a table top representing soil): Heat may reach the thermocouple and then dissipate into the air beneath it – inside the can or beneath the table. In real trees and real soils, the material beneath the thermocouple would be dense and possibly moist, with a tremendous capacity to absorb heat and little ability to dissipate it.

Materials and preparation:



- **Decide** how to do the activity. The trunk has only 1 set of materials. Unless you have additional materials, you will need to do the experiment either as a class demonstration or as a station to be used by 2-4 students at a time. We describe the "station" approach in the steps below. We suggest that you do the first iteration (0 layers of insulation) as a demonstration, then have the student teams do the second (5 layers of insulation) and third (10 layers) iterations at the station.

- **Decide** whether to model the insulating properties of tree bark or those of soil. You can discuss which one to do with the class (Step 4 below). The only difference is where you place the insulation: around a coffee can (model of a tree trunk) or on a table (model of the soil surface). After you have studied heat transfer through one material (either bark or soil), the students should be able to discuss heat transfer through the other material. This is the last question on the handout.
- **Decide** whether to have students graph their data by hand on page 2 of the handout or use computer software such as Excel. **Note** that they must sketch hypotheses as well as observations on the graph, and that could complicate the use of a computer spreadsheet.

The photo above and the directions here explain how to do the tree bark model and demonstrate the first iteration of the experiment together with the class.

Set up a table so it can be used for demonstration. Use these materials from the trunk:

- Hair dryer
- Ruler
- Digital thermometer (make sure it has a working battery and you have a spare)
- 1.5-pound coffee can/paint can/round oatmeal box (if simulating tree bark). Cover the outside with newspaper. Tape the thermocouple to the outside of the newspaper, about a hand's width down from the top edge.
- 3 pieces of fabric (1 piece with no quilt batting, 1 with 5 layers of quilt batting, and 1 with 10 layers of batting)

Provide these materials yourself:

- Tape to secure thermocouple to table or "tree".
- Tape or large paper clips or clamps or clothesline pins to secure fabric to "tree"
- Stopwatch or clock (must show seconds)
- 1 copy/student or team of **Handout M15-1: Insulating Power**. Copy it 1-sided, because students will graph the data from the first page onto the graph on the second page.

Download and project (or sketch on the board) the empty data table and graph on **Handout M15-1** (***M15_EmptyGraph.pptx***).

Procedures:

1. Ask: How do you protect yourself and your home from freezing in winter and from getting too hot in summer? We use insulation – as well as heat from wood, fossil fuels, and other sources of energy.
2. Ask: How do wildland animals, plants, and fungi protect themselves from freezing and over-heating? Their main mechanism is insulation – either something they grow themselves, like fur and tree bark, or something in the environment, like soil. If you have done **Activity M11.**

Who Lives Here? Adopting a Plant, Animal, or Fungus, the students can refer to adaptations of specific organisms.

3. Explain: In this activity, we'll get a better understanding of how insulation works so we can understand some of the ways in which plants and animals are protected from the heat of fires. What you learn here is not just about living things in wildlands; it applies just as much to the insulation in your home and the way you dress for outdoor activities.

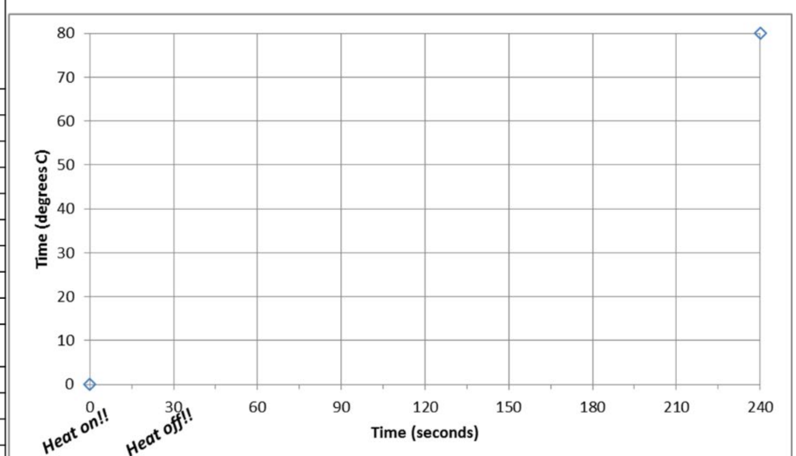
4. Give each student or team a copy **Handout M15-1: Insulating Power.** Read the experimental questions together with the class. Decide – or tell them - which question to investigate – the insulating effects of tree bark or soil. (Or split the class up and have different teams do the 2 different questions.)

5. **Demonstration:**

   a) Get 4 students to take on the roles described in the handout. Have them practice the timing of "Heat on" and "Heat off" before actually collecting data.

   b) Project or sketch the empty data table and graph (***M15_EmptyGraph.pptx***). Explain: This table and graph are on your handouts. We'll do the first trial of the experiment together, filling in the first column of the table and graphing our data. Write our results down on your handout as we go along. Then you'll do the 2nd and 3rd trials independently.

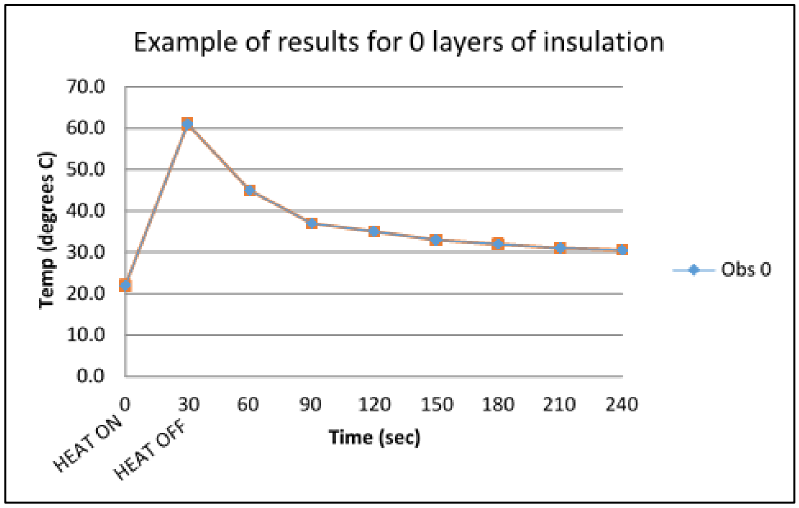
Time (seconds)	Temperature (°C)		
	0 layers (Obs 0)	5 layers (Obs 5)	10 layers (Obs 10)
0 – HEAT ON			
15			
30 – HEAT OFF			
45			
60			
75			
90			
105			
120			
135			
150			
165			
180			
195			
210			
225			
240			



   c) Ask: Can you hypothesize – make a guess - at what the temperature pattern will be if we do the experiment with just a thin piece of cloth insulating the thermocouple from the heat of the hair dryer? Try to get 2-3 hypotheses and sketch them on the graph. Mark each one with "Hyp 0" for "hypothesized pattern with 0 layers of insulation." Be sure to tell them that there is ABSOLUTELY NOTHING WRONG IF YOUR HYPOTHESIS TURNS OUT TO BE INCORRECT. The point of the experiment is to learn stuff, not to prove ourselves right or wrong.

d) Set up the experiment and follow steps 1-7 on the handout. Have students record the data on their handouts under the "Obs 0" column (for "observed pattern with 0 layers of insulation").

e) Have your student helpers graph the data on the board. Then have all the students graph it on their handouts. Label the line "Obs 0." It may look like the graph here.



6. Explain: Now you'll work in teams at a station. You'll do 2 more trials – one with 5 sets of insulation and one with 10. Follow the directions on the handout carefully, INCLUDING THE PART WHERE YOU PENCIL IN YOUR HYPOTHESIS ABOUT EACH TRIAL (Steps 9 and 12).

7. Set up the station, arrange the teams, and complete the experiment.

Assessment: Base assessment on completion of the handout. See the **Answer Key for Handout M15-1: Insulating Power**.

Evaluation:

	Excellent/Complete	Good	Fair	Poor/Incomplete
Question #11	-The student clearly compared/contrasted the observed and predicted results. -The student cited specific examples from the data.	-The student contrasted the observed and predicted results. -The student did not cite specific examples from the data.	-The student wrote that the predictions were (or were not) accurate. -The student did not explain why.	-The student did not address the question.
Question #14	-The student clearly compared/contrasted the observed and predicted results. -The student cited specific examples from the data.	-The student contrasted the observed and predicted results. -The student did not cite specific examples from the data.	-The student wrote that the predictions were (or were not) accurate. -The student did not explain why.	-The student did not address the question.
Question #15	-The student wrote separate responses for the 2 parts of the question (insulating properties of bark and of soil). -The student recognized the importance of bark for protecting cambium from surface fire and soil for protecting buried roots and seeds from surface and ground fire.	-The student responded to only 1 of the 2 parts of the question OR -The student did not specify the kind of fire that thick bark/deep soil protect against.	-The student responded to only 1 of the 2 parts of the question AND -The student did not specify the kind of fire that thick bark/deep soil protect against.	-The student did not answer the question directly.

Handout M15-1: Insulating Power

Names: ______________________________________

Here are two experimental questions:

- Can thick bark insulate the phloem, cambium, and xylem of a tree from fire's heat?
- Can soil insulate seeds and roots from fire's heat?

Find out by measuring and graphing the pattern of temperature change beneath different amounts of insulation.

Get organized:

- TIMER calls time at 15-second intervals and also calls out "Heat on!" and "Heat off!" at correct times.
- HEATER runs hair dryer.
- OBSERVER watches thermometer, calls out temperature at 15-second intervals.
- RECORDER writes down temperature observations.

Set up the experiment:

Set up the thermometer so the OBSERVER can see it.

For a soil model: Tape the thermocouple wire to a table top.

For a tree trunk model: Tape the thermocouple wire to the surface of an empty coffee can (covered with paper) or oatmeal box.

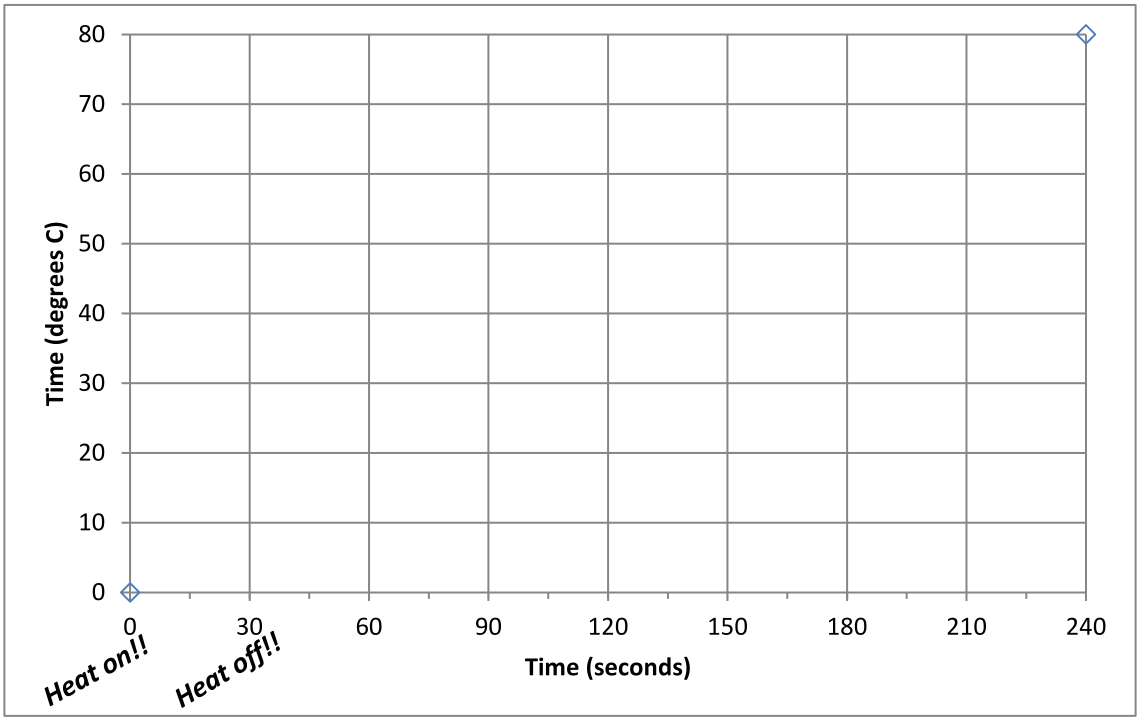
Do the first trial with just a thin piece of fabric covering the thermocouple. (Tape or clip the fabric in place.) Do the next trials with 5 layers of insulation (Steps 9-11 below) and then 10 layers of insulation (Steps 12-14).

Time (seconds)	**Temperature (°C)**		
	0 layers (Obs 0)	**5 layers (Obs 5)**	**10 layers (Obs 10)**
0 – HEAT ON			
15			
30 – HEAT OFF			
45			
60			
75			
90			
105			
120			
135			
150			
165			
180			
195			
210			
225			
240			

Procedure:

1. HEATER, position the hair dryer about 20 centimeters from the table or coffee can, pointing at the thermocouple tip (which you can't actually see now because it's under cloth).
2. OBSERVER, turn the thermometer on. Set it to degrees Celsius. Report the temperature.
3. RECORDER, write down the temperature at "0" seconds using the appropriate column in the table for the layers of insulation being tested (0, 5, or 10).
4. TIMER, call out "Zero, heat on!" HEATER, turn the hair dryer to "high."
5. TIMER, call out "Fifteen." OBSERVER, report the temperature. RECORDER, write it down.
6. TIMER, call out "Thirty. **Heat off**!" **HEATER, turn the hair dryer off**. OBSERVER, call out the temperature. RECORDER, write it down.
7. Every 15 seconds until 4 minutes have passed: TIMER, call out the time in seconds. OBSERVER, report the temperature. RECORDER, write it down.

8. Graph your results here. Connect the points. Label the line "Obs 0," meaning "observed with 0 layers of insulation."



9. What do you think will happen if you add 5 layers of insulation? Draw a line on the graph to show the temperature pattern you expect. This line shows your **hypothesis**. Label the line "Hyp 5" to indicate "hypothesized pattern with 5 layers."

10. Use the set of insulation with 5 layers and do another trial (steps 1-7). On the graph above, plot your data and label the line "Obs 5" to indicate "observed pattern with 5 layers."

11. Compare the line of observed results with your hypothesized line (Step 9). Use specific examples from your data and use complete sentences to describe how accurate your predictions were.

12. What if you add 5 <u>more</u> layers of insulation, for a total of 10 layers? Draw a line on the graph to show the temperature pattern you expect (your second hypothesis) and label it "Hyp 10."

13. Use the thickest set of insulation (10 layers). Repeat steps 1-7. On the graph above, plot your data and label the line "Obs 10."

14. Compare the line of observed results with your hypothesized line (Step 12). Use specific examples from your data and use complete sentences to describe how accurate your predictions were.

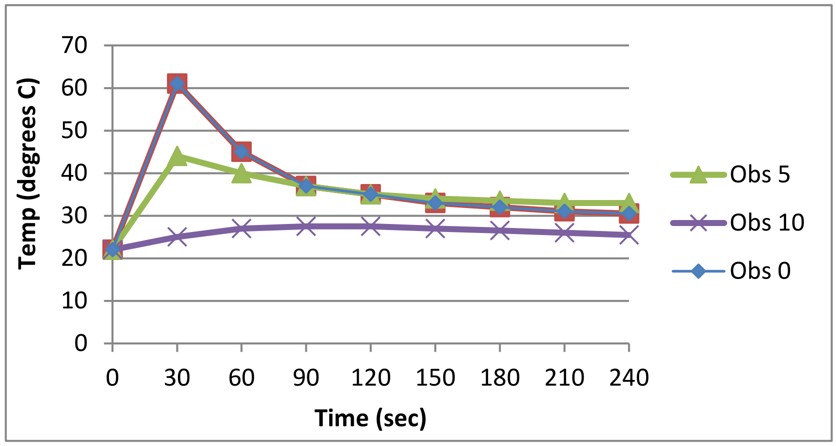
15. On a separate page, answer the 2 questions below, regardless of which question you tested. For each question, use complete sentences to explain your reasoning.

    A. Can thick bark really protect a tree?
    B. Can soil really protect underground seeds and roots?

Answer Key for Handout M15-1: Insulating Power

A completed data table and graph might look like this – except we did not insert hypothesized lines.

		Temperature (° C)		
		0 layers	5 layers	10 layers
Time (sec)		Obs 0	Obs 5	Obs 10
0	HEAT ON	22.0	22.0	22.0
30	HEAT OFF	61.0	44.0	25.0
60		45.0	40.0	27.0
90		37.0	37.0	27.5
120		35.0	35.0	27.5
150		33.0	34.0	27.0
180		32.0	33.5	26.5
210		31.0	33.0	26.0
240		30.5	33.0	25.5



15. On a separate page, answer the 2 questions below, regardless of which question you tested. For each question, use complete sentences to explain your reasoning.

A. Can thick bark really protect a tree?

Thick bark can protect a tree from surface fires because it can keep the cambium layer from heating up to lethal temperatures. Of course, the longer the fire burns, the deeper the heat will penetrate into the bark, phloem, cambium, and xylem. **Student graphs may even show that the "Obs10" temperature continues rising for quite awhile after the hair dryer is turned off.** Thick bark does not insulate leaves or the buds at the tips of branches, so it cannot protect a tree from the heat of crown fire. Thick bark cannot protect a tree from ground fire either. If a fire smolders in the duff around the base of the tree, it can kill the tree's roots, and it can kill the cambium at ground level.

A. Can soil really protect underground seeds and roots?

Thick soil can protect underground seeds and roots from surface fire because it can keep them from heating up to lethal temperatures. Of course, the longer the fire burns, the deeper the heat will penetrate. But if there is a lot of burnable material (like duff) on top of the soil or mixed in with it, and if that material burns, the resulting ground fire can kill buried seeds and roots – and even burn them up. So thick soil may not protect buried seeds and roots from ground fires, and it does not offer any protection against crown fires.

16. Buried Treasures: Identifying Plants by their Underground Parts

Lesson Overview: Students examine specimens of grasses, wildflowers, and shrubs and use a dichotomous key to identify them based on their "buried treasures" – that is, their underground parts that can sprout after fire and grow new plants.

Lesson Goal: To increase students' understanding that plants have many ways to survive wildland fire and/or reproduce successfully after fire, including by sprouting from underground structures.

Subjects: Science, Mathematics (logic), Reading

Duration: One to two half-hour sessions

Group size: Whole class, possibly working in teams

Setting: Classroom

Vocabulary: *bulb, caudex, corm, dichotomous key, fire dependent, rhizome, top-kill*

Objectives:

- Students can recognize different kinds of underground plant parts that can sprout new plants (bulb, rhizome, root crown, caudex) after fire.
- Students can use a dichotomous key based mainly on underground parts to identify 8 plant specimens.

ABOUT STUDENT PRESENTATIONS: If you did **Activity M11. 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 species they've been studying.

Standards		**Sixth**	**Seventh**	**Eighth**
CCSS	Speaking and Listening	1,2,6	1,2,6	1,2,6
NGSS	Structure, Function and Information Processing	LS1.A		
	Growth, Development and Reproduction of Organisms	LS1.B		
	Engineering Design	ETS1.B,C		
	Natural Selection and Adaptations	LS4.B, LS4.C		
EEEGL	Strand 1	A, C, E, G		

Teacher Background: People are generally familiar with the above-ground appearance of plants, and they know that most plants have roots underground, but they don't think much about plants' other underground parts (unless it is in terms of food). Yet plants have many kinds of "buried treasures" that enable them to survive fire and thrive afterward. This activity covers only a few species of plants with buried treasures; we selected these species because they are important members of northern Rocky Mountain and North Cascades plant communities. They all regenerate from underground parts after fire, and some of them require fire to regenerate. We say these species are “fire dependent.”

Seeds are one kind of buried treasure. If they are located deep enough in the soil that they do not burn up, they can grow new plants after fire. Some plants have seed coats so hard that they require heat to break open. For example, the seeds of snowbrush ceanothus (plant 8 in this lesson) can only germinate if they are heated up. In this activity, the specimen of snowbrush ceanothus is used to introduce the idea of buried treasures. Then the students use a dichotomous key to identify 8 additional plant species that thrive after fire in the wildlands of the northern Rocky Mountains and North Cascades. Most keys rely on plants’ above-ground characteristics as criteria for identification, but this key is based mainly on plants’ underground parts. The activity covers 5 kinds of buried treasures: seeds, bulbs, corms, caudices, and rhizomes. Other buried treasures, not covered in this activity, include root crowns, lignotubers, and taproots.

While snowbrush ceanothus grows new plants from seed after fire, the other species featured in this activity sprout new growth from surviving underground parts such as roots and specialized leaves and stems. These parts are what make plants perennial – that is, able to re-grow after cold winters, grazing, fire, and other forces have removed or killed their aboveground parts (called “top-kill”). Perennating structures work because they contain tiny buds with undifferentiated cells (“meristem tissue,” which is like stem cells in animals). Meristem cells can develop into new stem and leaf tissues, but they are usually suppressed by hormones produced in the plant’s above-ground parts. When the above-ground parts are removed, the buds are no longer suppressed, so they begin to grow and develop.

Buried treasures are plant adaptations to fire. Other plant adaptations to fire in the northern Rocky Mountains and North Cascades include the thick bark of mature ponderosa pines, western larches, and Douglas-firs (explored more fully in **Activity M15: Bark and Soil: Nature’s Insulators**) and the serotinous cones produced by many lodgepole pines. Students may have learned about serotiny from the student presentation on lodgepole pine in **Activity M11.** If you would like to explore the topic in more detail, use **Activity E11: Recipe for a lodgepole pine forest** from the Elementary curriculum.

Materials and preparation:

- Download for projection: ***M16_BuriedTreasure.pptx***.
- Print 1/student or team:
    - **Handout M16-1: Underground Plant Parts**
    - **Handout M16-2: Dichotomous Key**.
- Find the 9 plant specimens in the trunk. Each species’ buried treasure is noted in parentheses here:
    1. arrowleaf balsamroot (caudex)
    2. beargrass (rhizome)

3. fireweed (rhizome)
4. glacier lily (corm)
5. pinegrass (rhizome)
6. serviceberry (rhizome)
7. smooth woodrush (rhizome)
8. snowbrush ceanothus (seed)
9. wild onion (bulb)

- Keep Plant 8 (snowbrush ceanothus) out to introduce the activity and show a species with seeds that require fire.
- Set up the other 8 specimens at stations around the room so students can circulate to identify them.

Procedure:

1. Give students five minutes to sketch a plant that they have seen near their house, school, or outside of their town. After students are finished, have a few of them show their sketches. Did anyone sketch underground parts? If they did, give them kudos!
2. Write **"Buried Treasures"** on the board. Ask: What parts of plants are found underground? List them on the board. Students will name roots and perhaps seeds. Encourage them to recall underground "vegetable" parts, such as onions, radishes, and potatoes. We think of them as foods, but for the plant they are ways to store energy and regenerate. Although students may not know the technical names for these plant parts, they may be surprised at how familiar they are with plants' buried treasures.
3. Explain: Most kinds of plants reproduce from seed, and some have seeds that require heat to begin developing. Show the specimen of Plant 8, snowbrush ceanothus. Its seeds have very hard coats, which will not open – and cannot begin to grow - until they are cracked open by heat. If a plant or animal needs fire, we call it a fire dependent species.
4. Explain: Some plants can also sprout new growth from their roots. Quaking aspen and black cottonwood are examples. (Students already identified these trees if they did **Activity M13: Tree Identification: Figure out the "Mystery Trees."**)
5. Explain: In today's class we'll look at several kinds of "buried treasures" – plant parts that can generate new growth and even whole new plants after their above-ground parts have been removed or killed – that is, top-killed – by fire, grazing, winter's cold, and other disturbances. You'll need to know about these plant parts to identify the plant specimens that are set up at stations around the room.
6. Give each student a copy of **Handout M16-1: Underground Plant Parts.**

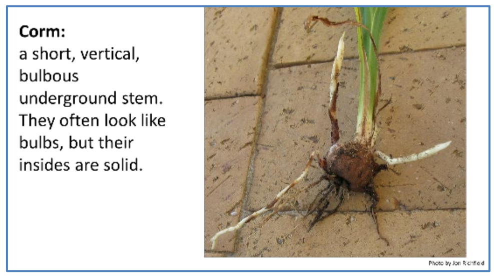
Project ***M16_BuriedTreasure.pptx,*** which shows 4 kinds of buried treasures. Stop at each slide and have students write the term on the handout, sketch what it looks like, and define it.

Slide 1

https://commons.wikimedia.org/wiki/File%3AOnionBulbRoots.jpg

By Jonathunder (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons

Slide 2



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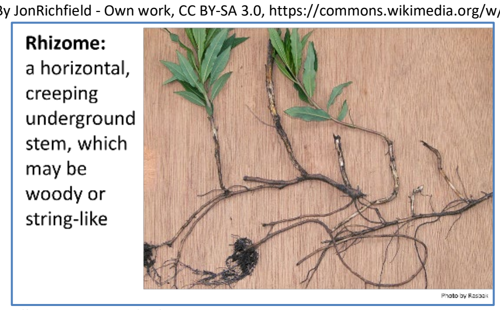
Slide 3



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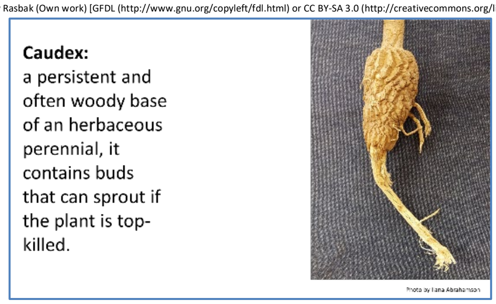
Slide 4



7. Review/Explain: Fires top-kill many plants, yet many of them can grow back from buried treasures – and they often grow larger and produce more seeds than before the fire because they get more sunshine, moisture, and possibly nutrients in the postfire environment. Furthermore, they may produce completely new plants from the same underground parts.
8. Explain: Now that you know more about plants buried treasures, you'll use a dichotomous key to identify some of the shrubs, wildflowers, and other plants that grow in the northern

Rocky Mountains and North Cascades. You'll identify them mainly based on the buried treasures that enable them survive and even thrive after fire.

Assessment:

- Give a copy of **Handout M16-2: Dichotomous Key** to each student or team.
- Explain: All of these wildland plants are champions at surviving and sprouting from their buried treasures after fire. You will use their buried treasures to identify the species of each sample.
- Explain these concepts for how to use the key:
  - For every plant specimen, start at the beginning (left side) of the key. If you start in the middle, you can't be certain that you got the identification correct.
  - When you think you have identified the specimen, write its number in the appropriate box in pencil.
  - Finalize your numbers only after you have identified all of the specimens.
  - Identify each species, write the correct number in the box with that plant's name, and move on to the next specimen. You may re-examine any specimen and change your mind until we finish the activity.

Have a few students start at each station.

Evaluation:	Excellent	Good	Fair	Poor
	Student identified all 8 species correctly	Student identified 6-7 species correctly	Student identified 5 species correctly	Student identified <5 species correctly

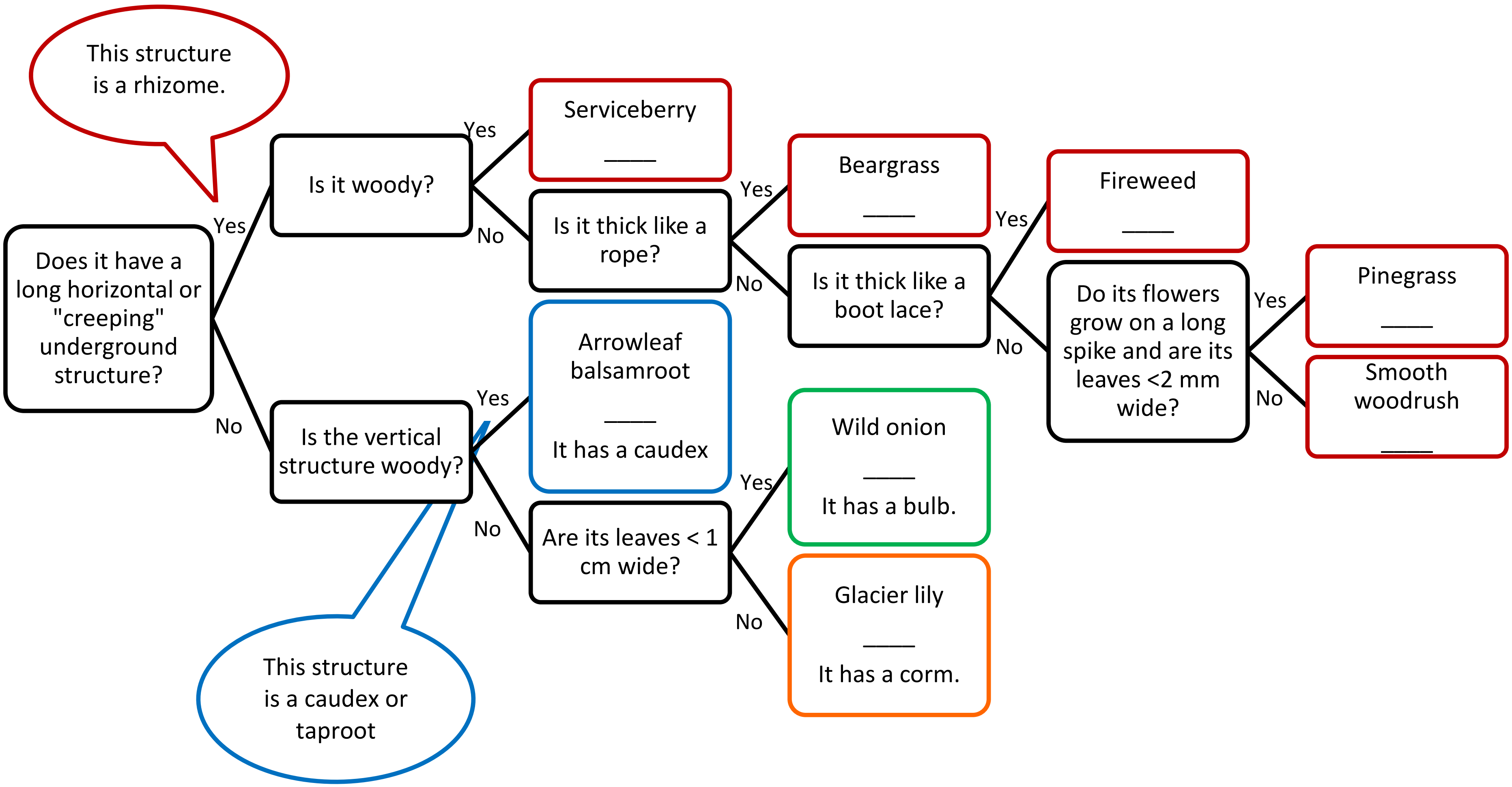
Handout M16-1: Underground Plant Parts

Name: _______________________________

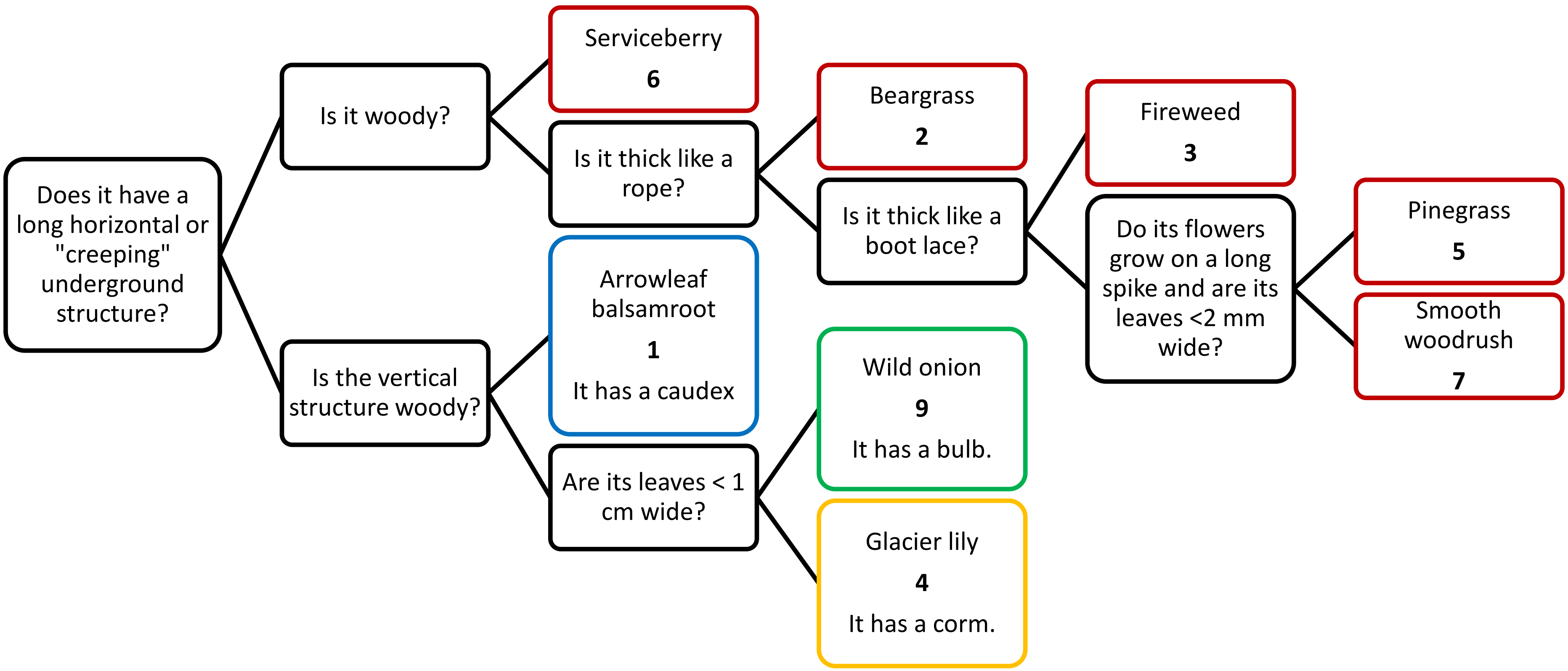
Term	Draw	Define

Handout M16-2: Dichotomous Key

Name____________________



Handout M16-2: Dichotomous Key Answer Key



Unit VI.
Fire History and Succession

M17 & H16. Dating Fires Using Dendrochronology

Lesson Overview: Students discuss the current prevalence of wildfires in their region and ways to find out if those fires are typical for the 3 forest types they have been studying – forests historically dominated by ponderosa, lodgepole, and whitebark pine. Then they either view a presentation or complete an electronic tutorial covering 10 terms that are important for understanding fire history.

Subjects: Science, Technical reading, Technical writing

Duration: One 30-40-minute session

Group size: Entire class

Setting: Classroom or computer lab

Vocabulary: *annual ring, catface, cohort, dendrochronology, fire scar, increment core, low-severity fire, pith, stand-replacing fire, tree cookie*

Lesson Goal: Ensure that students have a working understanding of dendrochronology and fire history methods so they can interpret the fire history of individual trees and forests in subsequent activities.

Objectives: Students understand all of the new FireWorks vocabulary (see list above and in Step 3 of **Materials and preparation**) well enough to use them in a paragraph about how to use trees' annual growth rings to learn about fire history.

Middle School Standards:		**6th**	**7th**	**8th**
CCSS	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Writing	1,4,10	1,4,10	1,4,10
	Writing: Science and Technology	3,4,7,9,10		
NGSS	Structure, Function, and Information Processing	LS1.A		
	Natural Selection and Adaptation	LS4.C		
	History of Earth	ESS2.C		
EEEGL	Strand 1	A,B,C,E,F,G		
	Strand 2.2	A		

High School Standards:		9th	10th	11th	12th
Common Core ELA	Reading Science/Technical Subjects	3,5,7,10		3,5,7,10	
	Writing Science/Technical Subjects	7,10		7,10	
	Science/Technical Subjects	2,4,5,6,7,8,9,10		2,4,5,6,7,8,9,10	
NGSS	Structure and Function	LS1.A			
	Interdependent Relationships in Ecosystems	LS2.A, LS2.C,LS2.D, LS4.C			
	Natural Selection and Evolution	LS4.B, LS4.C			
	History of Earth	ESS1.C, ESS1.A			
	Earth's Systems	ESS2.A			
EEEGL	Strand 1	C,E,F,G			

Teacher Background: Fire has been a part of the history of most forests in North America for thousands of years. A forest's fire history is evident in its tree-ring record. The study of trees' annual growth rings is called dendrochronology. For more information on that field of science, use the presentation/tutorial ***M17andH16_UsingDendroForFireHistory.pdf***. The slides from that tutorial are reproduced in Step 6 below.

Fire ecologists classify the severity of fires on standing forests into 3 categories:

- *Stand-replacing fires* kill most of the trees on a site, creating conditions that favor the establishment of a new forest where most of the trees are about the same age – a new cohort.
- *Low-severity fires* kill some trees (especially young ones and older ones of species with thin bark) and burn around others. They often leave scars on some of the surviving trees. Low-severity fire is not exactly the same as surface fire: Many surface fires are of low severity, but some are severe enough to kill most of the trees in a stand and are thus stand-replacing.
- *Mixed-severity fires* cause some stand replacement and some low-severity within a single burn or alternate between low-severity and stand-replacing fires over time.

You'll notice that these categories are based on tree mortality rather than changes in the soil, which were studied in **Activity M10 or H12.**

This activity begins with a question – "Are our forests OK, or are today's wildfires destroying them?" This question leads to brainstorming for ways to learn about past patterns of fire – the fire history in which native species have managed to survive and even thrive for thousands of years. After brainstorming, students work through a presentation/electronic tutorial on ways to learn about fire history. (If you use this as a tutorial, you can download the pdf file to individual computers and provide students with an Internet connection.)

If students would like to learn more about how trees respond to injuries on a metabolic and cellular level, encourage them to look at the following article, available at: https://www.fs.usda.gov/nrs/pubs/jrnl/2016/nrs_2016_smith-k_002.pdf. The article includes beautiful photos that show changes in tree cells and how they grow after a tree has been injured by fire.

> Smith, Kevin T.; Arbellay, Estelle; Falk, Donald A.; Sutherland, Elaine Kennedy. 2016. **Macroanatomy and compartmentalization of recent fire scars in three North American conifers.** Canadian journal of forest research. 46: 535-542.

If students would like to learn more about the potential for fire-scar sampling to injure or kill trees, encourage them to read the following (at https://firelab.org/project/condition-live-fire-scarred-ponderosa-pine-twenty-one-years-after-removing-partial-cross):

> Heyerdahl, Emily K.; McKay, Steven J. 2017. Research report: Condition of live fire-scarred ponderosa pine twenty-one years after removing partial cross-sections. Tree-ring research. 73(2): 149-153.

Materials and Preparation:

1. Download ***M17andH16_UsingDendroForFireHistory.pdf*** to EITHER present in class OR have the class use it as a tutorial to be accessed digitally.

2. If you choose to use the matching exercise for assessment, make 1 copy/student of **Handout M17 & H16-1**. **Vocabulary for Fire Historians**.

3. Write this list of terms on the board:
    - Annual ring
    - Cambium
    - Catface
    - Cohort
    - Dendrochronology
    - Fire scar
    - Increment core
    - Low-severity fire
    - Pith
    - Stand-replacing fire
    - Tree cookie

4. Find in the trunk: Actual fire-scarred tree cookies (not essential for this lesson, but very helpful in making the photos of fire-scarred cookies seem more real)

Procedures:

1. **Hook:** Explain: We've been studying how fires behave and how plants and animals deal with fires. Now we want to ask "Are our forests OK, or are today's wildfires destroying them?" Other ways to put it: Are today's wildfires too big or too small? Are they too severe? Are the forests we've been studying (ponderosa pine, lodgepole pine, and whitebark pine) threatened because of fire or lack of fire? Just as important is this question: How could we answer these questions?

2. Provide some information on the extent of recent wildfires in your area and have students discuss them in relation to the questions above. There are many ways to provide such information. A few are listed here. **Students are most likely to identify with information from their local area.**

   a. Go to the Incident Information System website (https://inciweb.nwcg.gov/) and obtain recent data on wildland fires in your area. You can do this ahead of time or with the students. If students all have computers, they can do this themselves.

   b. Go to the National Interagency Fire Center's homepage (https://www.nifc.gov/fireInfo/fireInfo_statistics.html) - or have students do so - and obtain information on historical fire statistics.

   c. Go to the "Historically Significant Wildfires" page (https://www.nifc.gov/fireInfo/fireInfo_stats_histSigFires.html) and examine information on a few of the wildfires that have caused deaths or destroyed homes from 1804 to recent years.

   d. Display the table below, which contains data from a single 365-day period in the area from the northern Rocky Mountains to the North Cascades. Or just quote a few numbers from the table, such as the number and area of wildfires just in your state over this 365-day period.

Major wildfires during 365 days, 18 July 2016 to 17 July 2017

Data from the United States Incident Information System:

https://inciweb.nwcg.gov/

State	Number of fires	Area (acres)	Area (square miles)	Area (square kilometers)
Idaho	18	276,224	432	1,118
Montana	23	92,881	145	376
Oregon	13	114,319	179	463
Washington	20	321,306	502	1,300
Wyoming	24	200,538	313	812
Total:	98	1,005,268	1,571	4,068

3. Explain: One way to answer the question "Are our forests OK?" is to compare current patterns of wildland fire with the historical patterns, since native plants and animals are adapted to historical patterns. How many fires? How big? How severe? We need to become FIRE HISTORIANS.

4. Ask: How can we get information about the history of fire in a forest? Open discussion. Here are some methods used by scientists: Analyze annual rings in trees (increment cores and cross sections); analyze charcoal in peat cores from bogs, lakes, etc.; refer to Native American traditions; refer to journals, letters, maps, and other records from historical explorations; refer to records of the trees that marked section corners in early surveys.

5. Explain: We'll become fire historians by studying data from trees' annual rings. Before we can do this, we need to understand some basic information about tree growth, fire effects, and sampling methods. That's what we'll do with the presentation/tutorial in this activity. By the end of the activity, you need to understand the terms listed on the board and know how to use the science of dendrochronology to learn about fire history.

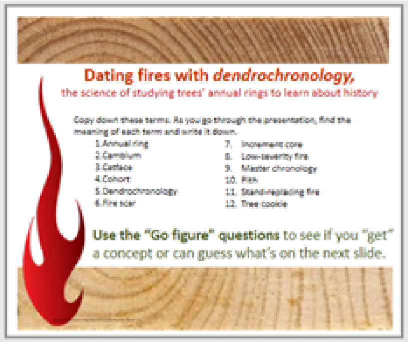
6. We suggest 3 different ways to use ***M17andH16_UsingDendroForFireHistory.pdf***.

    a) Have students go through the slides on their own, treating it as a scavenger hunt to find the terms listed on the board and figure out what they mean.

    b) Have students go through the slides as a tutorial (in class or as homework).

    c) Go through the slides as a presentation/discussion with the class.

A note about the blue information boxes in the slides and notes in the PowerPoint version of the slides: These contain interesting information that supplements slide content and answers questions sometimes asked by students, but this information is not essential for completing the activity.



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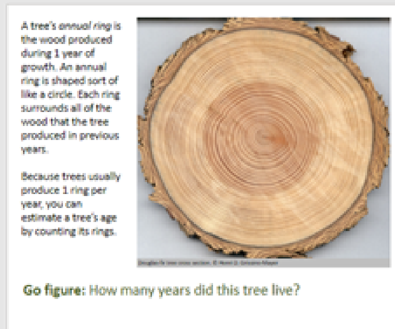

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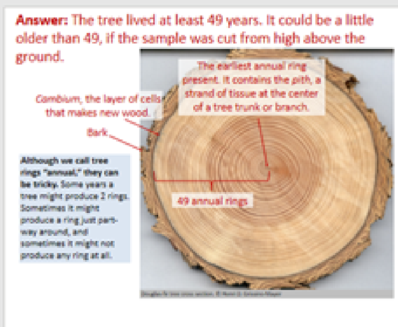

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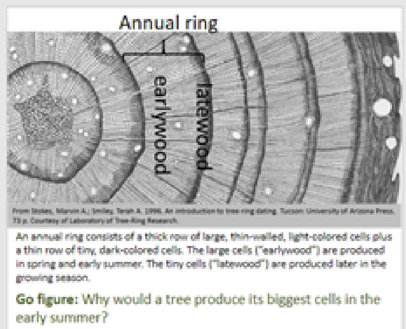

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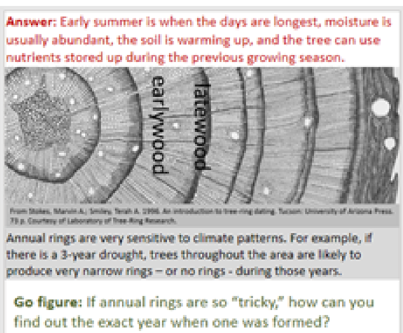

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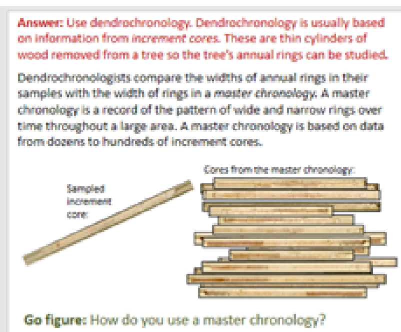

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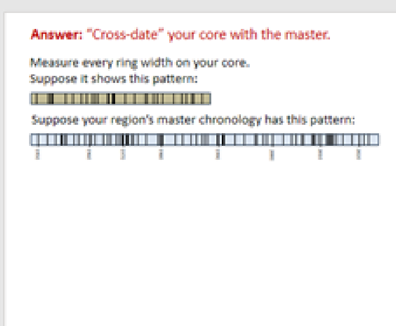

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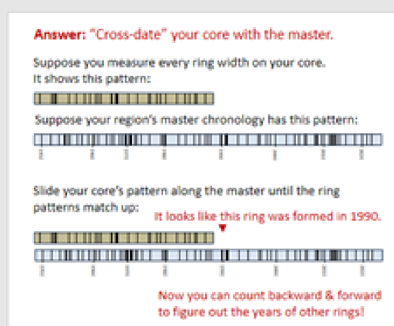

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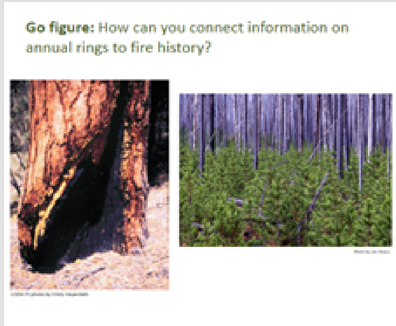

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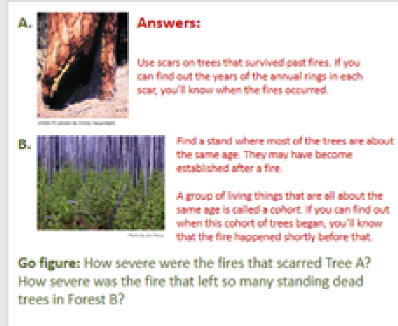

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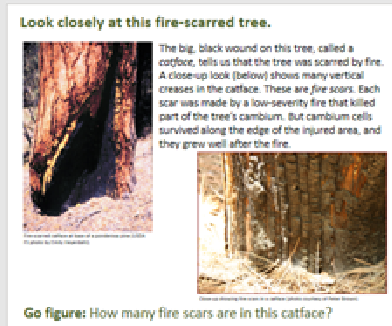

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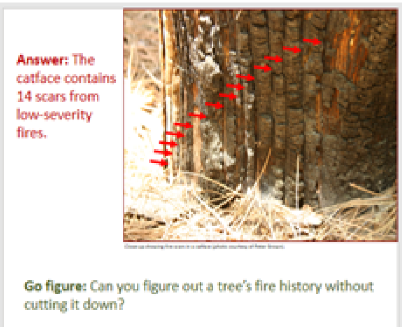

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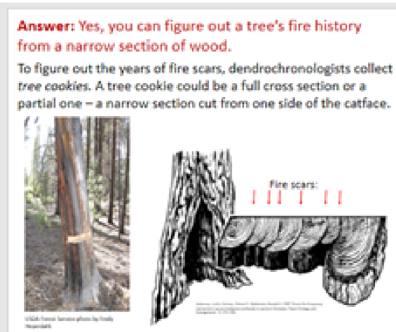

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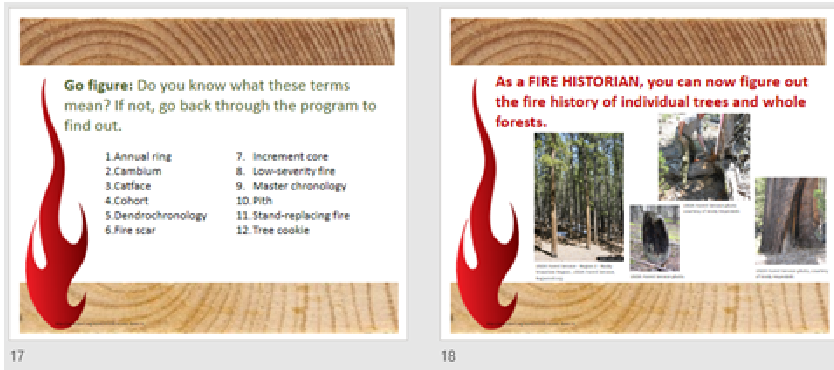


Assessment: Use one of these 2 assessments:

OPTION 1: Matching (**Handout M17 & H16-1**)

OPTION 2: Writing assignment. Refer to the list of terms on the board:

- Annual ring
- Cambium
- Catface
- Cohort
- Dendrochronology
- Fire scar
- Increment core
- Low-severity fire
- Pith
- Stand-replacing fire
- Tree cookie

Have students write a paragraph that explains to a classmate how he/she could use trees' annual rings to learn about fire history. In the paragraph, they should use at least 8 of the terms listed.

Evaluation:

	Excellent	Acceptable	Poor
OPTION 1: Matching (Handout M17 & H16-1)	10-11 answers correct	7-9 answers correct	Fewer than 7 answers correct
OPTION 2: Writing assignment	Paragraph uses 8-11 terms correctly.	Paragraph uses 6-7 terms correctly.	Paragraph uses fewer than 6 terms correctly.
	Paragraph accurately describes use of dendrochronology to study fire history.	Paragraph describes use of dendrochronology to study fire history with moderate accuracy.	Paragraph contains numerous inaccuracies or omits important concepts.
	Paragraph contains an appropriate topic sentence.	Paragraph contains an appropriate topic sentence.	Paragraph does not contain an appropriate topic sentence.
	Paragraph uses complete sentences.	Paragraph uses complete sentences.	Paragraph does not use complete sentences.
	Paragraph is clear and coherent.	Paragraph is clear.	Paragraph is not clear.

Handout M17 & H16-1. Vocabulary for Fire Historians

Name: ______________________________

Next to each term, write the letter of the correct definition.

A.	Annual ring	____ A fire that has does not change the soil very much and kills very few of the mature trees.
B.	Catface	____ The science of learning about the past by dating annual rings in living and dead trees.
C.	Cohort	____ A large wound on a tree trunk or branch, where living wood is gradually growing from the edges over the dead wood in the injured area.
D.	Dendrochronology	____ A layer of wood produced during 1 year of tree growth. This layer encircles all of the wood that the tree produced in previous years.
E.	Fire scar	____ A fire that kills all or most of the mature trees and provides good conditions for growing a new generation of trees.
F.	Increment core	____ A thin cylinder of wood that is removed from a tree so the tree's annual rings can be studied.
G.	Low-severity fire	____ A cross section or narrow sample of wood taken from a tree trunk so the tree's annual rings can be studied.
H.	Pith	____ A mark on a tree trunk where a fire killed the tree's cambium part-way around. When you look at one of these marks on the outside of a tree, it looks like a vertical crease or fold in the wood.
I.	Stand-replacing fire	____ A group of living things that are similar in age.
J.	Tree cookie	____ A strand of spongy tissue that runs through the center of a tree trunk or branch.
K.	Cambium	____ The layer of living cells under a tree's bark that produces the annual rings

Teachers' Key to Matching, Handout M17 & H16-1:

G, D, B, A, I, F, J, E, C, H, K

Teachers' Glossary for Evaluation of Writing assignment:

This is a list of definitions of the terms that students should use in the assigned paragraph. All of the terms are defined, illustrated, and used in the presentation/tutorial ***M17andH16_UsingDendroForFireHistory.pdf***. The definitions are adapted from the Merriam-Webster Dictionary (https://www.merriam-webster.com/), the "FireWords" Glossary of Fire Science Terminology (http://www.firewords.net/), and/or the FireWorks program (https://www.firelab.org/project/fireworks-educational-program).

1. **Annual ring:** A ring of wood produced during 1 year of a tree's growth. Annual rings are nearly circular in shape (unless the tree has a catface). Each annual ring surrounds all of the wood that the tree produced in previous years.
2. **Cambium:** the layer of living cells under a tree's bark that produces the annual rings. If the entire cambium is killed, the tree will die. If only a portion of the cambium is killed, it can still produce new cells including annual rings.
3. **Catface:** A large wound on a tree trunk or branch, where living wood is gradually growing from the edges over the dead wood in the injured area.
4. **Cohort:** A group of living things that are similar in age. A group of students who are all in a particular grade-level in school is a cohort. A group of trees that all began growing after a severe fire is a cohort.
5. **Dendrochronology:** The science of learning about the past by dating annual rings in living and dead trees.
6. **Fire scar:** A mark on a tree trunk where a fire killed the tree's cambium part-way around. When you look at a fire scar from the outside, it looks like a vertical crease or fold in the wood.
7. **Increment core:** A thin cylinder of wood that is removed from a tree so the tree's annual rings can be studied.
8. **Low-severity fire:** A fire that has does not change the soil very much and kills few of the mature trees. Low-severity fires often leave fire scars on the trunks of mature trees.
9. **Pith:** A strand of spongy tissue that runs through the center of a tree trunk or branch. In an increment core or tree cookie, the pith shows the earliest year of growth.
10. **Stand-replacing fire:** A fire that kills all or most of the mature trees and provides good conditions for growing a new generation of trees. The young trees then "replace" the trees killed by fire.
11. **Tree cookie:** A sample of wood taken from a tree trunk so the tree's annual rings can be studied. The sample may be a full cross section – that is, a piece cut all the way across the tree trunk, so it looks a little like a cookie; or it may be a partial cross section – that is, a narrow piece cut from the side of a catface.

M18 & H17. History of Stand-replacing Fire

Lesson Overview: Students use information from 11 cross-dated increment cores to figure out the approximate age of a forest stand that originated after stand-replacing fire.

Lesson Goals: Understand how scientists can estimate the time when a stand-replacing fire occurred. Be able to assemble and interpret a *stand history diagram* and discuss evidence for a stand-replacement *fire regime*.

Subjects: Reading, Writing, Speaking and Listening, Math, Science

Duration: one 30- 40-minute session

Group size: Whole class

Setting: Classroom

Vocabulary: *fire regime, stand history diagram*

Objectives:

- Students can follow technical directions to record observations and contribute their information to a class diagram that shows the history of a forest stand.
- Students can describe the fire history shown by a stand history diagram that contains cohorts of trees.

ABOUT STUDENT PRESENTATIONS: If you did **Activity M11 or H14**, this would be a great time for the presentation **on a species with serotinous cones, such as lodgepole pine**.

Middle School Standards:		6th	7th	8th
CCSS	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Writing	1,4,10	1,4,10	1,4,10
	Writing: Science and Technology	3,4,7,9,10		
NGSS	Structure, Function, and Information Processing	LS1.A		
	Natural Selection and Adaptation	LS4.C		
	History of Earth	ESS2.C		
EEEGL	Strand 1	A,B,C,E,F,G		
	Strand 2.2	A		

High School Standards:		9th	10th	11th	12th
Common Core ELA	Reading Science/Technical Subjects	3,5,7,10		3,5,7,10	
	Writing Science/Technical Subjects	7,10		7,10	
	Science/Technical Subjects	2,4,5,6,7,8,9,10		2,4,5,6,7,8,9,10	
NGSS	Structure and Function	LS1.A			
	Interdependent Relationships in Ecosystems	LS2.A, LS2.C,LS2.D, LS4.C			
	Natural Selection and Evolution	LS4.B, LS4.C			
	History of Earth	ESS1.C, ESS1.A			
	Earth's Systems	ESS2.A			
EEEGL	Strand 1	C,E,F,G			

Teacher Background: In this activity, students continue to build their skill in using trees' annual rings to figure out a forest's fire history. They use increment cores collected for the following study:

> Heyerdahl, Emily K.; Loehman, Rachel A.; Falk, Donald A. 2014. Mixed-severity fire in lodgepole pine dominated forests: are historical regimes sustainable on Oregon's Pumice Plateau, USA? Canadian journal of forest research. 44(6): 593-603.

Each team determines the years of the earliest and final annual rings on a photo of an increment core. Then the class compiles the information from 11 cores into a stand history diagram. This is a vivid quantitative way to depict the history of a forest. Stand history diagrams will be used in the next two activities; by the end of **Activity M20 & H19,** students will be able to use a stand history diagram to describe the historical fire regime of a forest.

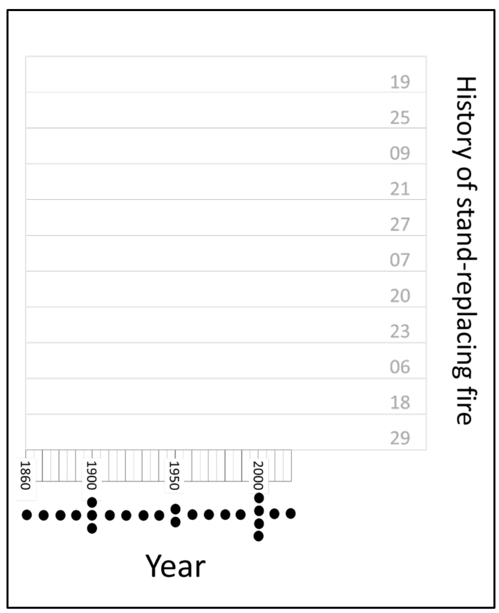
Scientists use dendrochronology to learn about the historical pattern of stand-replacing fire by analyzing the ages of all of the mature trees in a stand. If most of the trees originated within a few years of each other, they are generally considered a cohort. However, not all cohorts are initiated by fire. To figure out what disturbance allowed so many trees to establish in such a short time, scientists look for additional evidence: For example, cut stumps suggest logging; the presence of large numbers of old logs (without scorched wood) suggests windthrow; the presence of scorched wood and charcoal in the soil suggests fire.

Materials and preparation:

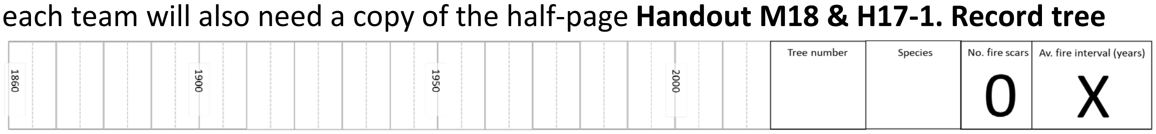
1. Find in the trunk and display in classroom: the poster that shows a map and photos of the area where the increment cores and tree cookies used in FireWorks were collected. You can also project the poster from this file: ***PotholesStudyArea.pptx.***

2. Find in the trunk: 11 photos of increment cores. (These are about 20-40 cm long and quite narrow. They are usually bundled into an envelope or a roll. An example is shown below.) The core photos can also be printed from ***IncrementCorePhotos.pptx.***

3. Find in the trunk and display the background poster for the stand-replacing stand history diagram, shown on right. It is also available for download from ***FireHistBackground_stand-replacing.pptx*** (right-hand side). Students will attach their timelines (next step) to this background poster. We suggest laying the background poster on a large table or on the floor for assembly. Have tape available for attaching the students' timelines that represent individual cores.



4. Prepare timelines for students to use in constructing the stand history diagram by doing one of the following:
   - OPTION 1. Use 11 of the laminated timeline strips provided in the trunk (shown below – they are actually about half a meter long). Provide 1/team. These can also be printed from the left-hand side of ***FireHistBackground_stand-replacing.pptx***. If you use this option, each team will also need a copy of the half-page **Handout M18 & H17-1. Record tree**



history on a timeline and a dry-erase marker, preferably the same color for every team. To clean the strips after they are used, you will also need a cloth, an eraser, and cleaning fluid.

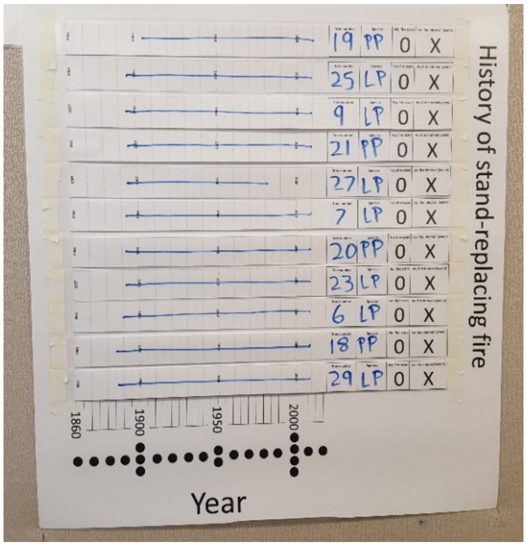
- OPTION 2. Make 11 copies (1/team) of ***FireHistTemplate_stand-replacing.pptx***, one for each team. Each team will also need scissors and tape.

5. Make 1 copy/student of **Handout M18 & H17-2. You find an older cohort!**

Procedure:

1. Explain: In the last activity, we learned how fire historians use dendrochronology to learn how many fires have occurred in past centuries and how severe the fires were. In this activity, we'll use dendrochronology to figure out the history of STAND-REPLACING FIRE in a forest in central Oregon. Refer to the poster or projection of ***PotholesStudyArea.pptx.***
2. Explain: Once we figure out the historical fire regimes for forests in this particular area – that is, the frequency, severity, and spatial uniformity of past fires - we'll be able to understand fire regimes of the ecosystem(s) that we've been studying. We can use what we learn to address one of the most important questions about today's forests, the question that we asked at the start of the last activity: "Are our forests OK, or are today's wildfires destroying them?"
3. Hand out to each team: a photo of an increment core, plus EITHER (1) a dry-erase marker, a blank timeline, and a half-page handout with instructions **(Handout M18 & H17-1. Record tree history on a timeline)** or (2)a copy of ***FireHistTemplate_stand-replacing.pptx***.
4. Have the students place the rings so they can read the print from left to right. Have them examine their cores as you explain:
   a) Dendrochronologists have already dated each of these increment cores. They used small dots to mark the ring at the start of every decade. They also marked the earliest ring on the core – usually the pith – with a short black line. Find this line near the left end of your core.
   b) The most recent ring is at the right end of your core. Find this ring. Ignore any bark that lies outside (to the right of) the annual rings.
   c) Count rings to the left of the earliest dot to figure out the earliest year shown on your core. Count rings to the right of the most recent dot to figure out the most recent year.
   d) Transfer that information to your timeline, as instructed on your half-page handout, and place the timeline on the class's stand history diagram background.

5. Have students follow the instructions on the handout and add their completed timeline to the background. When all are completed, it should look something like this. Data are on the right.



Species	Tree number	Earliest date	Final date
Lodgepole pine	6	1890	2009
Lodgepole pine	7	1902	2009
Lodgepole pine	9	1895	2009
Ponderosa pine	18	1887	2009
Ponderosa pine	19	1906	2009
Ponderosa pine	20	1893	2009
Ponderosa pine	21	1895	2009
Lodgepole pine	23	1893	2009
Lodgepole pine	25	1896	2009
Lodgepole pine	27	1894	1982
Lodgepole pine	29	1887	2009

6. Review/Ask: What is a cohort? Give an example. A cohort is a group of living things that are all about the same age. Our class is a cohort.

7. Explain: Dendrochronologists figure that a lot of trees that all got established in a short time constitute a cohort. Scientists decide what “a short time” is depending on the location and growing conditions. In the study we’re using, the scientists decided on about 20 years to define a cohort. Do the trees in our increment cores form a cohort? Yes, because all of the trees became established within a 20-year period (between 1887 and 1906).

8. Ask: How might a fire have gotten this cohort started? The cohort could have become established after the overstory trees were killed by a stand-replacing fire, perhaps a crown fire. That would have made excellent conditions for young pines to germinate and start growing. What other events could have started the cohort? Possibilities include a pine beetle epidemic, logging, or a severe wind storm…. How could we be certain that fire was the cause? Find other clues, like fire-scarred trees or charcoal in the soil or a nearby bog.

9. Summarize: Remember the name for the pattern of fire frequency and severity over a long time: a fire regime. Our increment cores suggest that the forest we’re studying had a STAND-REPLACING fire regime. How certain can we be about that? We should probably be cautious about that conclusion, since we only have 11 samples and only 1 cohort. It would be better if we could go deeper into the past and get more samples.

10. **DON’T TAKE THE STAND HISTORY DIAGRAM OR THE STUDY AREA POSTER DOWN YET. YOU’LL NEED THEM BOTH FOR THE NEXT 2 ACTIVITIES.**

Assessment:

1. Explain: Now we'll get a little more practice at discovering a history of stand-replacing fire.
2. Give each student a copy of **Handout M18 & H17-2. You find an older cohort!** and have them complete the assignment.

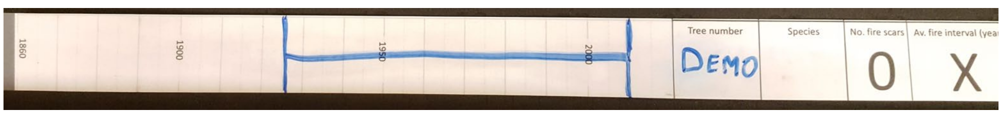
Evaluation:

	Excellent	Good	Poor
Format	Used correct business letter format	Used letter format	Did not use letter format
Writing	Writing is clear. Used full sentences. Used topic sentences for paragraphs.	Writing is clear. Used full sentences.	Writing is unclear or sentences are incomplete.
Content:			
Identified period when old cohort began growing	approximately 1770-1785	approximately 1770-1785	One or both dates inaccurate by more than 5 years.
Identified possible cause for beginning of old cohort	Old cohort could have started after fire, but we don't have charcoal evidence for a fire around 1770. Other possible explanations include wind storm and beetle epidemic.	Old cohort could have started after fire (or other cause). Did not discuss lack of evidence for fire.	Did not suggest a reasonable cause for beginning of old cohort.
Identified year of death for old cohort	Most of the trees died around 1877, although two of them died earlier.	Most of the trees died around 1877.	Date inaccurate by more than 5 years.
Gave explanation for death of old cohort	Fire was probably the cause, since so many of the logs in this cohort were black and charred.	Fire was probably the cause, since so many of the logs in this cohort were black and charred.	Did not identify a cause or did not explain evidence.
Connected death of old cohort to beginning of more recent (1887-1906) cohort	Old cohort was killed by stand-replacing fire around 1877, which is about 10 years before the earliest date in the cohort that we described in class. The fire that killed the trees in the old cohort may have cleared the way for establishment of the new cohort between 1887 and 1906.	Explained that old cohort died just before the more recent cohort began growing but did not explain the possible connection between the two.	Did not identify a reasonable explanation for the relationship between the two cohorts.

Handout M18 & H17-1. Record tree history on a timeline

Using a dry-erase marker, record the fire history of your tree core on your timeline:

1. Record your tree's number and species in the correct boxes at the right end of the timeline. Use "PP" for ponderosa pine and "LP" for lodgepole pine. Make the print large so people can see it from across the room.
2. Find the tiny pencil-marked dots on your increment core. Find the left-most dot and its year (written below the dot). Count the rings to the left to figure out your core's earliest year, but don't count rings to the left of the pith (marked with a vertical line).
    - On your timeline, draw a vertical bar to show that year.
3. Find the right-most dot on your increment core and its year. Count the rings to the right to figure out your core's final year.
    - On your timeline, draw a vertical bar to show that year.
4. Draw a dark horizontal line to connect the 2 vertical bars.



Attach your core's timeline to the poster that has information from all increment cores:

5. Find your core's number on the poster.
6. Attach your timeline to the poster right on top of your core's number and the box it is in. Carefully line up the edges of your timeline with edges of the box.

Handout M18 & H17-1. Record tree history on a timeline

Using a dry-erase marker, record the fire history of your tree core on your timeline:

1. Record your tree's number and species in the correct boxes at the right end of the timeline. Use "PP" for ponderosa pine and "LP" for lodgepole pine. Make the print large so people can see it from across the room.
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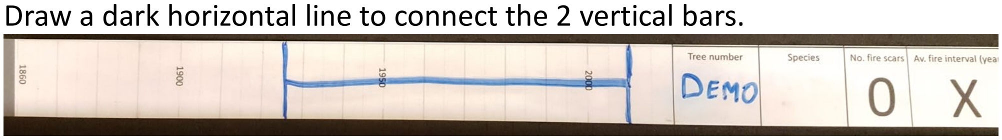
3. Find the right-most dot on your increment core and its year. Count the rings to the right to figure out your core's final year.
    - On your timeline, draw a vertical bar to show that year.
4. Draw a dark horizontal line to connect the 2 vertical bars.



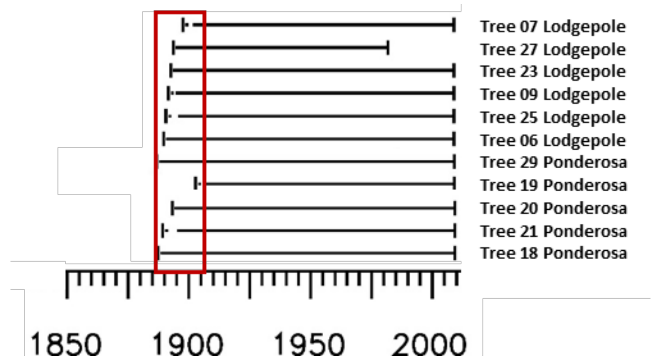
Attach your core's timeline to the poster that has information from all increment cores:

5. Find your core's number on the poster.
6. Attach your timeline to the poster right on top of your core's number and the box it is in. Carefully line up the edges of your timeline with edges of the box.

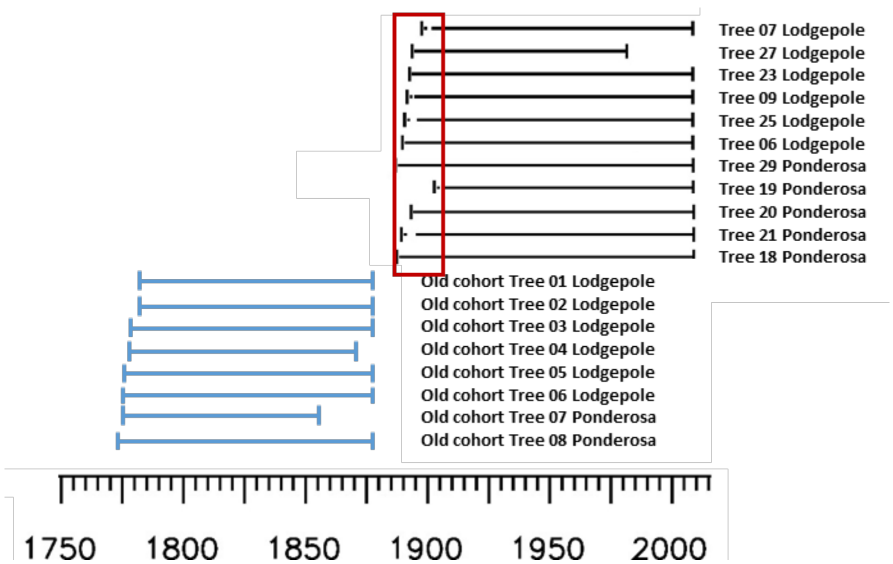
Handout M18 & H17-2. You find an older cohort!

Name: _______________________

At right is a copy of the stand history diagram that you completed in class. The trees are in a different order, but their timelines are the same. A red outline shows the cohort of trees that you identified in class.



Suppose you go back to the place in central Oregon where those 11 cores were collected and find 8 fallen logs buried in the ground. These were not sampled in the earlier study, so they provide new information. The logs look very old. Their bark is all gone, but they are not rotten. Many of them have black char on the outside of the wood. You collect increment cores from all of them. You return to the lab and cross-date them to find the years of their earliest and most recent annual rings. Then you add your new data to the class's stand history diagram. Now it looks like this:



You have found evidence that there was a cohort of trees that started back in the 1700s! Call it the "old cohort." Write a letter to the scientists who did the original research. In the letter, explain:

- When your "old cohort" started growing (give a range of dates)
- What may have caused the old cohort to start growing (do you have any evidence for that?)
- When the old cohort died
- What probably caused so many trees in the old cohort to die at one time (do you have any evidence for that?)
- How your discovery might explain what caused the 1887-1906 cohort of trees (the ones in the gray shaded box) to start growing.

M19 & H18. History of Low-severity Fire

Lesson Overview: Students create a living model to demonstrate how fire can leave scars on a living tree. They use dendrochronology to describe the history of low-severity fire for a single tree and then a whole forest. They assemble a stand history diagram and use it to identify years when low-severity fire occurred and to describe the spatial uniformity of past fires. Then they use information from the stand history diagram to discuss the historical policy of complete fire suppression.

Subjects: Science, Technical reading, Technical writing, Mathematics

Duration: One 30-40-minute session

Group size: Entire class

Setting: Classroom

Vocabulary: *fire interval*

Lesson Goals: Students understand that low-severity fires were common in some forests during the past. They understand that historical fires were sometimes patchy in their spread pattern and sometimes more uniform. Students understand that low-severity fires are less common now, at least partly due to the policy of suppressing all fires as soon as possible after they are detected. Students are able to express an informed opinion about fire policy and support their opinion with evidence.

Objectives: Students can

- identify annual rings on tree cookies and identify scars made by low-severity fire.
- describe the history of low-severity fire for a single tree and for a whole forest.
- express an informed opinion and support it with evidence.

WANT TO USE STUDENT PRESENTATIONS ON INDIVIDUAL SPECIES TO INTEGRATE CONCEPTS? If you did one of the activities in which students researched a specific organism and its relationship to fire (**Activity M11 or H14**), this would be a great time for student presentations on all of the tree species that haven't yet been covered.

Middle School Standards:		6th	7th	8th
CCSS	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Writing	1,4,10	1,4,10	1,4,10
	Writing: Science and Technology	3,4,7,9,10		
NGSS	Structure, Function, and Information Processing	LS1.A		
	Natural Selection and Adaptation	LS4.C		
	History of Earth	ESS2.C		
EEEGL	Strand 1	A,B,C,E,F,G		
	Strand 2.2	A		

High School Standards:		9th	10th	11th	12th
Common Core ELA	Reading Science/Technical Subjects	3,5,7,10		3,5,7,10	
	Writing Science/Technical Subjects	7,10		7,10	
	Science/Technical Subjects	2,4,5,6,7,8,9,10		2,4,5,6,7,8,9,10	
NGSS	Structure and Function	LS1.A			
	Interdependent Relationships in Ecosystems	LS2.A, LS2.C,LS2.D, LS4.C			
	Natural Selection and Evolution	LS4.B, LS4.C			
	History of Earth	ESS1.C, ESS1.A			
	Earth's Systems	ESS2.A			
EEEGL	Strand 1	C,E,F,G			

Teacher Background: In this activity and the next one, students continue to analyze samples and data from the following study:

Heyerdahl, Emily K.; Loehman, Rachel A.; Falk, Donald A. 2014. Mixed-severity fire in lodgepole pine dominated forests: are historical regimes sustainable on Oregon's Pumice Plateau, USA? Canadian journal of forest research. 44(6): 593-603.

Contrary to the impression created by news media during the height of wildfire season, wildland fires vary a lot in how frequently they occur, their spatial pattern of spread, and their severity. The variation is caused by all 3 of "sides" of the Fire Environment Triangle (weather, topography, and fuels), which students learned about in Activity **M05** or **H08**. See step 12 under **Procedures** for some discussion of things that might cause such variation.

In this activity, students examine tree-cookie photos that have scars from past fires. The following information on fire scars and wood may help you answer some questions that could arise:

- After a tree has one fire scar, it is more vulnerable to further scarring because the fire-killed bark has fallen off from the area where the cambium was damaged, so the scarred portion of the trunk dries out and has no insulating bark. Another reason for the tree's increased vulnerability is that the edge of the scar may contain a lot of pitch, which protects the sapwood from invading insects and fungi – but which is also easy to ignite.

- Trees do not "heal" in the same way animals do: Dead cambium does not recover to become functioning tissue again, as our skin and bones can do after an injury. However, the dead wood may gradually be covered by new cambium and bark that grow in from the edges of the injured area. "Trees do not HEAL, they CONCEAL."

- Fire scars form most often on the uphill side of tree trunks. Why? A hot vortex of flame forms on the leeward side of any obstacle in a fire's path. Since fires often spread uphill, the uphill side of the tree trunk tends to get more of this vortex heat than the other sides. Also, there is usually more debris on the uphill side of the tree since branches, cones, litter, and duff accumulate there as they roll downhill.

- Why is some of the wood in a tree cookie dark while other areas are very light? The outer wood (xylem, also called sapwood) is often lighter than the inner wood (heartwood) because it is filled with a sappy mixture of water and minerals. The heartwood and other wood in injured areas of the trunk is dark because it is filled with pitch rather than sap. Pitch can help tree survive after it is injured by keeping fungi and insects from invading the healthy wood – at least for a time. The pitch-filled cells do not transport water and nutrients throughout the tree, but they do provide important structural support for the tree.

- Other unusual marks in wood include patches of rot, holes made by wood-boring beetles, damage from fungi, checks (radial cracks where the wood has dried and split), and branch scars (where a branch originated or a broken branch stub was covered by later growth).

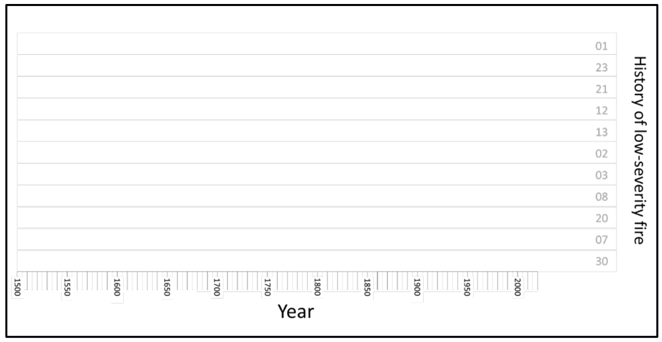
Materials and Preparation:

1. Note that the Stand History Diagram created in the previous activity and the poster of the study area from that activity (***PotholesStudyArea.pptx***) should still be on display.

2. Find a piece of black plastic or cloth about 25 cm wide and 0.5-1.0 m long. Plastic from a black garbage bag works well.

3. Find in the trunk:

   - a small whisk broom
   - actual fire-scarred cookies
   - the background poster for the low-severity stand history diagram (shown on right and available for download in ***FireHistBackground_low-severity.pptx***). Display it in the classroom. Have tape on hand for attaching timelines.



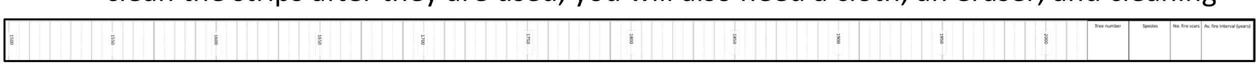
   - the set of 11 laminated photo posters of fire-scarred tree cookies. These are usually stored in a pillowcase or large envelope. They are also available for download and printing from ***CookiePostersNRM-Cascades.pptx.***
   - the FireWorks Cookie Book, also available in this file: ***CookieBookNRM-Cascades.pptx.***

4. Make 1 copy/student or team: **Handout M19 & H18-1. A Tree's Story.**

5. Make 1 copy/student of the short handout: **Handout M19 & H18-3. How well did the policy work?** (There are 3 copies on a page.) Also provide 1 copy/student of **Reading_ForestHistSociety_FireSuppression.docx.** You can print this from the file, copy it from the **Appendix** at the end of this lesson, OR provide computer access so students can read it. This reading is an excerpt from a longer article. If you want them to read the full article, find it online at https://foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/u-s-forest-service-fire-suppression/.

6. Prepare timelines for students to use in constructing the stand history diagram by doing one of the following:

   a) OPTION 1. Use 11 of the laminated timeline strips provided in the trunk (shown in miniature below – they are actually about 1.4 m long), one timeline/team. If you use this option, also provide each team with a copy of **Handout M19 & H18-2. Record fire history on a timeline.** Each team will also need 2 dry-erase markers, preferably in 2 contrasting colors. (Blue and black were used in the photo shown in Step 9 below.) To clean the strips after they are used, you will also need a cloth, an eraser, and cleaning



   fluid.

   b) OPTION 2. Make 11 copies (1/team) of ***FireHistTemplate_low-severity.pptx***. Print the pages 1-sided. Each team will also need 2 markers, preferably in contrasting colors, as well as scissors and tape.

Procedures:

1. Explain and refer to the poster of the study area (***PotholesStudyArea.pptx***): Now that we know how to construct a stand history diagram, we're going to figure out the history of low-severity fire for a single tree and then for a forest in the same study area we looked at before, in central Oregon.

2. **REVIEW: Human model of fire scar formation.** Explain: We're going to look at tree cookies with scars made by past fires. Some of them have a pretty complicated fire history. Before we start, let's review the way in which a fire scar is formed. We'll construct a living model of the process.

3. Follow these directions or see a demonstration online at: *www.youtube.com/watch?v=MyFBYQh_S_M*.

   a) One student holds his/her arms out in a circle, forming a ring that represents the tree's cambium – that is, the sheath of living cells right under the bark that form xylem and phloem – and are essential for continued growth.

   b) Ask the students to imagine that the "tree" is facing uphill and a low-severity surface fire is coming up from behind it, running uphill. Select a student to represent the surface fire, using the whisk broom to burn from the "downhill" side of the tree around it to the other side, then continuing "uphill" and away from the tree.

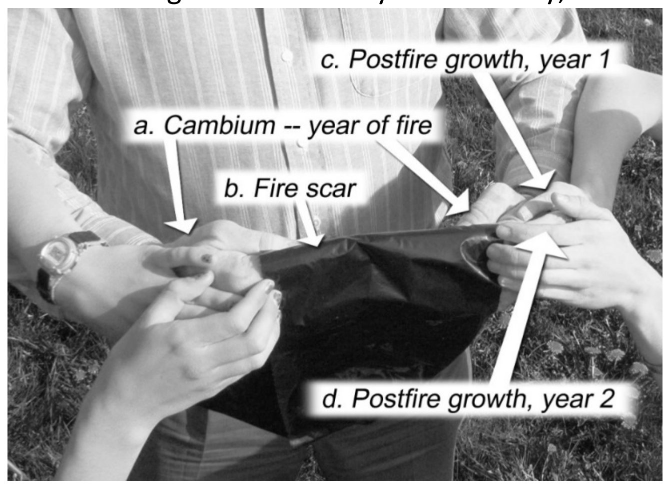
   c) Interview the "tree." Ask how the fire felt. Point out that the tree is still alive, since it is talking, so this must have been a low-severity fire!

   d) Tell the students that the fire was hot enough to kill the cambium part-way around the tree – in fact, right where the student's hands meet. 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 annual ring next year.

   e) Ask: Why is there more damage on the uphill side than the downhill side? Fires form a hot vortex of flame as they go around an obstacle and the flames come together from the two sides. Also, there is often more debris on the uphill side, since branches, cones, and litter accumulate there as they roll downhill. The duff is generally deeper on the uphill side as well.

   f) Get two more students to help, one standing on each side of the model tree. They are the next year's annual ring. Each places a hand against the arm of the "tree," right at the edge of the area "killed" by fire (which is now covered in black). New cells can't grow out of the black area because it has no living cambium.

g) Get two more students to represent the tree's growth in the second postfire year. 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 are dividing both outwardly and laterally, so they are beginning to grow over the scar. This is how the "bubble" or "curl" of growth forms at each edge of a fire scar.



Students build a living model of tree cambium and fire scar with their hands.

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

i) Explain: Sometimes the growing wood from the two sides of the fire scar comes together and bark forms over the scar, hiding it from everyone who doesn't know about fire scars. To those "in the know," like this class, that caved-in look on the uphill side of the tree suggests a history of low-severity fires.

4. Explain: Now we'll analyze fire history from 11 tree cookies collected in central Oregon. We'll analyze the first one together. Then we'll do the others in teams and build a stand history diagram with all of the data.

5. Give each student a copy of Handout **M19 & H18-1. A Tree's Story**.

6. Explain: The handout contains a photo of a cookie taken from a catface on a tree that survived many low-severity fires. Dendrochronologists have figured out the exact year of each fire scar. Your job is to figure out the years between fires – called *fire intervals* – and then calculate the average fire interval. Work through the handout, and then we'll discuss the results.

7. Have students complete the handout in class or as homework. Go through the answers in class so they can check their results and ask questions. (See the **Answer Key** below.) Then discuss:

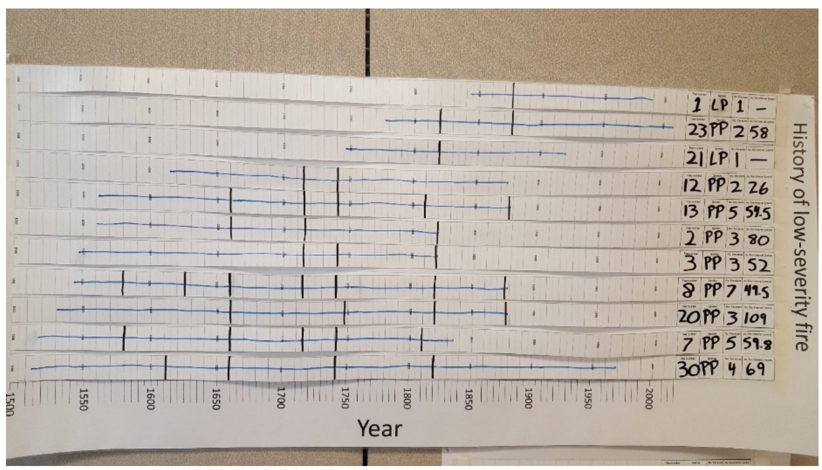
   a) Did this tree grow well or poorly in the years after fire? After the 1626 and 1659 fires, the tree grew well. After the 1580 and 1819 fires, the tree grew poorly. The 1741 fire did not seem to influence growth very much. The tree died a year after the 1877 fire.

   b) What might be some reasons for changes in the tree's growth after fire? Slow growth is likely to occur if the fire killed a lot of the tree's foliage or much of the cambium. Rapid growth after fire may occur if the fire killed nearby plants, thus reducing competition for moisture and nutrients, or if nutrients in the ash from burned vegetation enriched the soil.

c) Could a tree or forest be injured by lack of fire? Answers to this question vary from place to place and from one forest type to another. In forests that have experienced little or no fire in the past, lack of fire does not injure the forest. In forests that have a long history of low-severity fires, however, lack of fire can injure the forest. For example, when low-severity fire is excluded for a long time from a forest where it used to occur every decade or so, dense undergrowth and deep duff may develop. These conditions can make fires that are very severe and likely to kill even large, old trees. A dense understory can also weaken large, old trees by competing for moisture and nutrients. Lack of fire can also reduce diversity across the landscape, so a forest that used to have patches of different vegetation and ages becomes more and more uniform. Increased uniformity increases the potential for fires to spread across large areas when burning conditions are just right.

8. Hand out 10 of the cookie photo posters, one to each team. Do not use Tree 08, since you already analyzed it in class. However, have one team complete a timeline for Tree 08 – perhaps the team doing Tree 01 or Tree 21, since those both have just 1 fire scar. Give each team a timeline, instructions, and the other materials needed to complete their timeline (see Step 6 under **Materials and Preparation**).

9. Have each team follow the instructions (that is, do the calculations, plot the tree's history on their timeline, then attach the timeline to the background poster). The resulting stand history diagram should look something like this:



10. As a class:

a) List every year when at least one tree was scarred. (1580, 1612, 1626, 1659, 1715, 1741, 1819, 1877)

b) Count the number of years when a fire occurred – that is, at when least 1 tree was scarred. (8)

c) Calculate the intervals between years when a fire occurred (32, 14, 33, 56, 26, 78, and 58 years)

d) Calculate the average interval between years when a fire occurred. Explain: This is the fire interval for the whole forest. (42 years)

11. Ask/discuss: What was the historical fire regime for this forest? The data show a low-severity fire regime, at least before 1900. How does the stand history diagram give us more information than the data from a single tree, such as Tree 08 on the handout? In the stand history diagram, we can see how many years had low-severity fires over the whole area. We can see that the fire interval for the whole forest is shorter than the intervals for most of the individual trees. We can see that not every fire scarred every tree; this means that some of the fires were either small or patchy. We can see that some fires scarred most of the trees, so they must have been larger or more uniform. We can see that a lot of trees died shortly after the 1877 fire, suggesting that it was pretty severe.

12. Ask/discuss: What could cause fires to be patchy – to scar or kill some trees and not others? Refer back to the 3 of "sides" of the Fire Environment Triangle (weather, topography, and fuels), which students learned about in Activity **M05** or **H08**. You can display the poster from that activity, if you wish (***FireEnvironmentTrianglePoster.pdf***). Consider these possible sources of variation:

    - If the weather has been hot and dry for a long time, the surface fuels could be uniformly dry and the fire could burn uniformly. But if the fuels are patchy – a bare spot here, a grassy opening there, a pile of fallen trees somewhere else – the burn will probably be patchy too.
    - If the trees are close together on one hillside and far apart on another, the two sites will have different susceptibility to crown fire.
    - A fire that burns through a gently rolling landscape is likely to burn more uniformly than a fire in an area with deep gullies and steep slopes.
    - Variation in the species, size, and vigor of trees also influences the frequency of fire, its severity, and the footprint it leaves on the landscape. Ponderosa pines, for example, develop thick bark at an early age, so they can survive surface fires that kill young fir trees. As our climate grows warmer and fire seasons grow longer, the "weather" side of the Fire Environment Triangle is likely to alter fire regimes in many plant communities.

13. **DON'T TAKE THE STAND HISTORY DIAGRAMS OR THE STUDY AREA POSTER DOWN YET. YOU'LL NEED THEM FOR THE NEXT ACTIVITY.**

Assessment:

1. Give each student a copy of **Handout M19 & H18-3. How well did the policy work?**
2. Give each student a copy of – or computer access to – **Reading_ForestHistSociety_FireSuppression.docx. (**See Step 5 in **Materials and preparation** above for options on how to provide the reading.)
3. Explain: Read the instructions and the article and then complete the assignment.

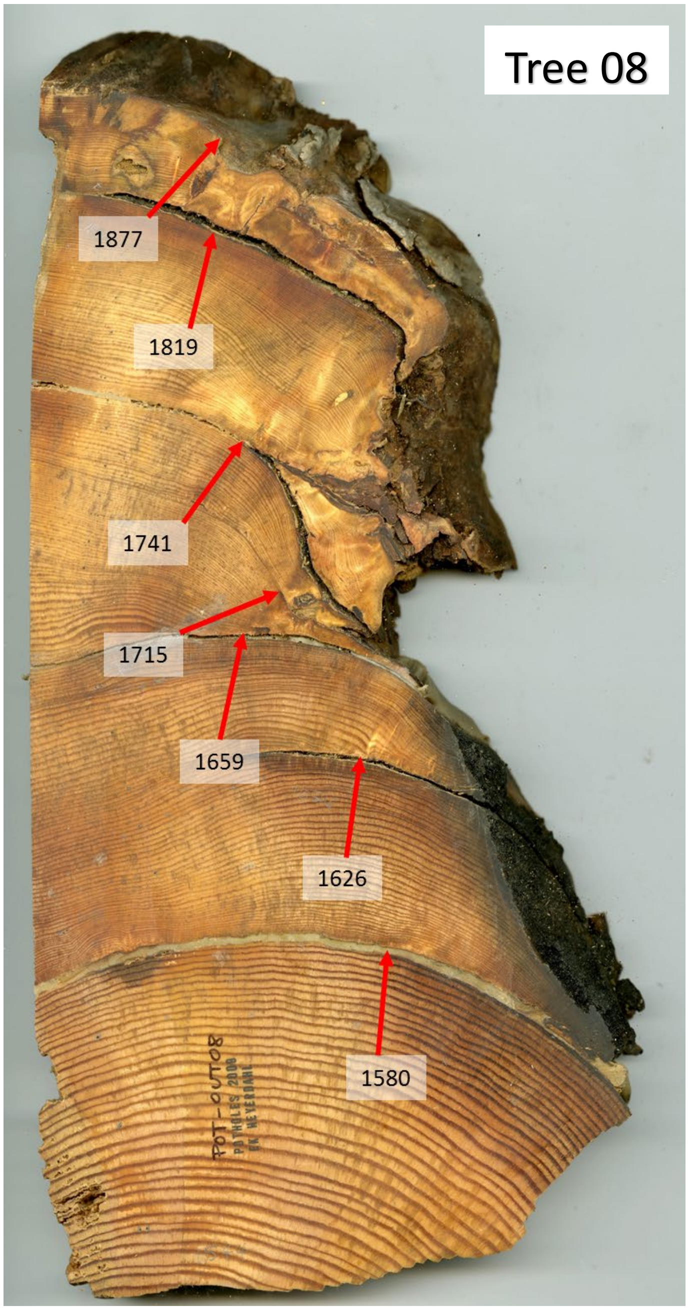
4. AN ALTERNATIVE ASSESSMENT: Have the students do the reading and then discuss the questions posed in the handout in small groups. This option will be harder to evaluate but may be more engaging for the students.

Evaluation:

	Excellent	**Good**	**Poor**
Following directions in handout	Student used 2 or 3 paragraphs.	Student used 2 or 3 paragraphs.	Student did not use multiple paragraphs.
Writing quality	Student used effective topic sentences, complete sentences throughout, and clear writing style.	Essay was lacking in 1 of these qualities.	Essay was lacking in 2 or more of these qualities.
Content:			
Do you think the policy was effective in the 1900s? Yes. The stand history diagram from tree cookies shows that no low-severity fires occurred in the 1900s. The diagram from increment cores shows that no stand-replacing fires occurred in the 1900s. Students may add other information from personal experience or their study of individual species.	Student answered the question and gave supporting information.	Student answered the question but support was weak or lacking.	Student did not answer the question.
Do you think the policy would be effective now? Either "yes" or "no" answer could be defended - "Yes" because full fire suppression would protect people, watersheds, and property… if it were successful. "No" because full suppression degrades habitat for many species and seems infeasible, especially in the face of fuel accumulation and climate change over the past century.	Student answered the question and gave supporting information.	Student answered the question but support was weak or lacking.	Student did not answer the question.

Handout M19 & H18-1. A Tree's Story

Name: ________________



Specimen furnished by Dr. Emily Heyerdahl.

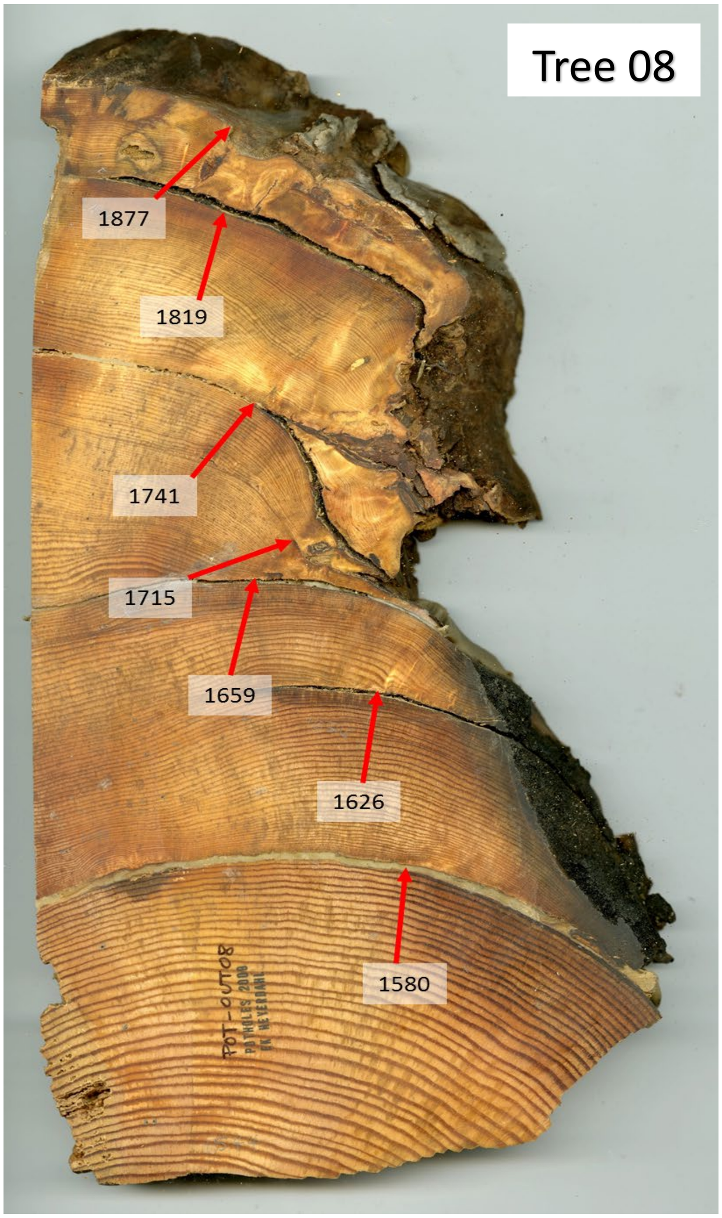
Here is a photo of a tree cookie from a forest in central Oregon. Each fire scar is marked with a red arrow and the year when the fire occurred.

1. In the table below, under "Fire year," write the date of every fire scar on the cookie. Write the dates in order, from most recent to oldest.

Fire year	Fire interval (years)

2. How many years occurred between each pair of fires? Record your answers above under "Fire interval."
3. What is the longest fire interval? ________ years
4. What is the shortest fire interval? ________ years
5. What is the average fire interval? ________ years

Answer key to Handout M19 & H18-1. A Tree's Story



Here is a photo of a tree cookie from a forest in central Oregon. Each fire scar is marked with a red arrow and the year when the fire occurred.

1. In the table below, under "Fire year," write the date of every fire scar on the cookie. Write the dates in order, from most recent to oldest.

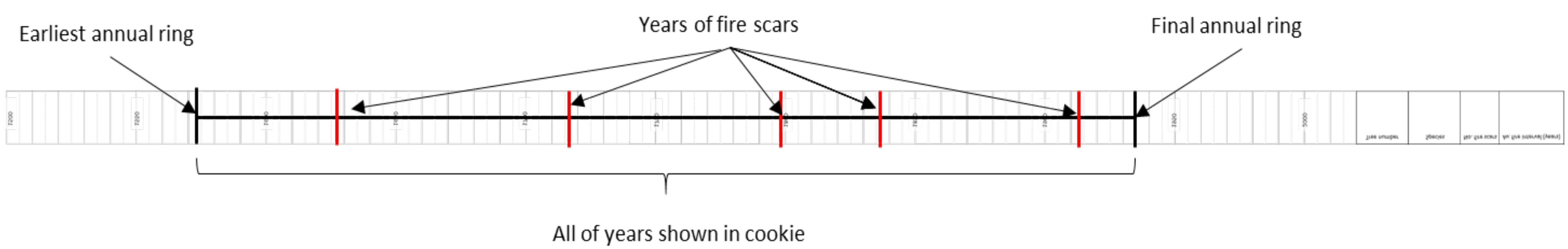
Fire year	Fire interval (years)
1877	
	58
1819	
	78
1741	
	26
1715	
	56
1659	
	33
1626	
	46
1580	

2. How many years occurred between each pair of fires? Record your answers above under "Fire interval."
3. What is the longest fire interval? 78 years
4. What is the shortest fire interval? 26 years
5. What is the average fire interval? 49.5 years

Handout M19 & H18-2. Record fire history on a timeline

Using dry-erase markers, record the fire history of your tree cookie on your timeline:

1. Record your tree's number and species in the correct boxes at the right end of your timeline. Use "PP" for ponderosa pine and "LP" for lodgepole pine. Make the print large so people can see it from across the room.
2. Count the number of fire scars on your cookie and record it in the correct box. If your cookie has scars that were NOT made by fire, ignore them.
3. Calculate the average fire interval for your tree and record it in the correct box. If your cookie has scars that were NOT made by fire, ignore them. If your cookie has only 1 fire scar, put an "X" in this box because you cannot calculate an average fire interval.
4. Draw a DARK vertical bar across your timeline to mark the year of your cookie's earliest annual ring. (See the example below.)
5. Draw another DARK vertical bar across the timeline to mark the year of your cookie's final annual ring.
6. Draw a DARK horizontal line across the middle of your timeline to connect the year of the earliest ring with the year of the final ring. Draw this line right across the dates printed on the timeline. This line spans all of the years shown in your cookie.
7. USING A CONTRASTING COLOR, draw a vertical bar across your timeline to mark the year of every fire scar on your tree cookie.
8. HAVE SOMEONE CHECK YOUR WORK. If you have errors, the class's pooled data will not make sense.



Attach your cookie's timeline to the stand history diagram for fire-scarred cookies:

1. Find your cookie's number on the poster.
2. Attach your timeline to the poster right on top of your cookie's number and the box it is in. Carefully line up the left edge of your timeline with the left edge of the box.

Handout M19 & H18-3. How well did the policy work?

Read the excerpt from "U.S. Forest Service Fire Suppression." This article was published by the Forest History Society. Here is a quote from the article:

> Three of the men who had fought the 1910 fires—William Greeley, Robert Stuart, and Ferdinand Silcox—served from 1920 to 1938 as Forest Service chief, which put them in a position to institute a policy of total fire suppression…. This policy had two goals: preventing fires, and suppressing a fire as quickly as possible once one started.

Write a 2- or 3-paragraph essay that answers these questions:

- Do you think the policy was effective in the 1900s?
- Do you think the policy would be effective now?

Explain. Use information from your class's 2 stand history diagrams and from your other knowledge about fire to support your answer.

Handout M19 & H18-3. How well did the policy work?

Read the excerpt from "U.S. Forest Service Fire Suppression." This article was published by the Forest History Society. Here is a quote from the article:

> Three of the men who had fought the 1910 fires—William Greeley, Robert Stuart, and Ferdinand Silcox—served from 1920 to 1938 as Forest Service chief, which put them in a position to institute a policy of total fire suppression…. This policy had two goals: preventing fires, and suppressing a fire as quickly as possible once one started.

Write a 2- or 3-paragraph essay that answers these questions:

- Do you think the policy was effective in the 1900s?
- Do you think the policy would be effective now?

Explain. Use information from your class's 2 stand history diagrams and from your other knowledge about fire to support your answer.

Handout M19 & H18-3. How well did the policy work?

Read the excerpt from "U.S. Forest Service Fire Suppression." This article was published by the Forest History Society. Here is a quote from the article:

> Three of the men who had fought the 1910 fires—William Greeley, Robert Stuart, and Ferdinand Silcox—served from 1920 to 1938 as Forest Service chief, which put them in a position to institute a policy of total fire suppression…. This policy had two goals: preventing fires, and suppressing a fire as quickly as possible once one started.

Write a 2- or 3-paragraph essay that answers these questions:

- Do you think the policy was effective in the 1900s?
- Do you think the policy would be effective now?

Explain. Use information from your class's 2 stand history diagrams and from your other knowledge about fire to support your answer.

Appendix. Reading on the history of Fire Suppression Policy

U.S. Forest Service History

U.S. Forest Service History > Policy & Law > Fire > Suppression

9:37 PM
8/13/2017

U.S. Forest Service Fire Suppression

Legendary forest fires in the late 1800s like the Peshtigo Fire of 1871 bolstered the argument by early conservationists like Franklin Hough and Bernhard Fernow that forest fires threatened future commercial timber supplies. Concern for protecting those supplies and also watersheds helped conservationists convince the U.S. government in 1891 to begin setting aside national forest reservations. When the U.S. Forest Service was established in 1905, it was given managerial control of these lands, soon renamed national forests. Forest management necessitated fire protection. After all, foresters argued, why create national forests if they were going to burn down.

Just five years later, in what has become known as the "Big Blowup," a series of forest fires burned 3 million acres in Montana, Idaho, and Washington in only two days. The 1910 fires had a profound effect on national fire policy. Local and national Forest Service administrators emerged from the incident convinced that the devastation could have been prevented if only they had had enough men and equipment on hand. They also convinced themselves, and members of Congress and the public, that only total fire suppression could prevent such an event from occurring again, and that the Forest Service was the only outfit capable of carrying out that mission. Three of the men who had fought the 1910 fires—William Greeley, Robert Stuart, and Ferdinand Silcox—served from 1920 to 1938 as Forest Service chief, which put them in a position to institute a policy of total fire suppression.

Fire fighters building a fire line, Gifford Pinchot National Forest, 1934.

The other goal the Forest Service had was to develop a systematic approach to fire protection. In the decades following the Big Blowup, this would involve building networks of roads, communications systems, lookout towers, and ranger stations.

This policy had two goals: preventing fires, and suppressing a fire as quickly as possible once one started. To prevent fires, the Forest Service came out in opposition to the practice of light burning, even though many ranchers, farmers, and timbermen favored because it improved land conditions. It must be remembered that at this time foresters had limited understanding of the ecological role of fire. Forest Service leaders simply argued that any and all fire in the woods was bad because it destroyed standing timber. Educating the public about the need for fire prevention became an important part of this goal. In 1944, the Forest Service introduced the character Smokey Bear to help deliver its fire prevention message.

Civilian Conservation Corps fire fighting crew, Clark National Forest, 1937.

Following several severe fire seasons in the early 1930s, fire suppression took on even greater urgency. In 1933, the federal government created the Civilian Conservation Corps, which put thousands of men to work building fire breaks and fighting fires. In 1935, the Forest Service established the so-called 10 a.m. policy, which decreed that every fire should be suppressed by 10 a.m. the day following its initial report. Other federal land management agencies quickly followed suit and joined the campaign to eliminate fire from the landscape. Fire suppression efforts were aided by the development of new technologies, such as airplanes, smokejumpers, and fire suppression chemicals. With such tools, fires could be fought anywhere—and were.

Until around 1970, federal land managers remained obsessed with controlling large fires. But during the 1960s, scientific research increasingly demonstrated the positive role fire played in forest ecology. This led in the early 1970s to a radical change in Forest Service policy—to let fires burn when and where appropriate. It began with allowing natural-caused fires to burn in designated wilderness areas. From this the "let-burn" policy evolved, though it suffered a setback in the wake of the 1988 Yellowstone fires. Since around 1990, fire suppression efforts and policy have had to take into account exurban sprawl in what is called the wildland-urban interface. Another issue the Forest Service now faces is that fires have grown in size and ferocity over the last 25 years. The fire-fighting budget has grown to about 50 percent of the agency’s entire budget, which limits funds available for land management activities such as land restoration and forest thinning that could aid in fire suppression.

Available at: https://foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/u-s-forest-service-fire-suppression/

M20. Fire History in Ponderosa, Lodgepole, and Whitebark Pine Forest Communities

Subjects: Reading, Writing, Speaking and Listening, Math, Science

Duration: One 30- to 40-minute session

Group size: Whole class

Setting: Classroom

Vocabulary: *mixed-severity fire*

Lesson Overview: Students use the stand history diagrams that they assembled in the 2 previous activities to learn about mixed-severity fire regimes. They apply this understanding as they learn about the historical fire regimes in 3 forest communities of the northern Rocky Mountains and North Cascades – forests dominated by ponderosa, lodgepole, and whitebark pines. In the Assessment, they read articles about fire regimes in these forest types and summarize an article in a news blog.

Lesson Goals: Understand the nature of low-severity, stand-replacing, and mixed-severity fire regimes. Recognize the most prevalent fire regime in 3 forest community types. From technical articles, learn how fire regimes may have changed over the past century and explain why changes in a fire regime matter.

Objectives:

- Students can recognize low-severity, mixed-severity, and stand-replacing fire regimes from stand history diagrams.
- Students can understand a 1-page technical article on a fire regime.
- Students can write a concise blog that summarizes information on a fire regime, how it may have changed over the past century, and why that matters.
- Students can identify strengths and weaknesses in blogs written by other students.

Middle School Standards:		6th	7th	8th
CCSS	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Writing	1,4,10	1,4,10	1,4,10
	Writing: Science and Technology	3,4,7,9,10		
NGSS	Structure, Function, and Information Processing	LS1.A		
	Natural Selection and Adaptation	LS4.C		
	History of Earth	ESS2.C		
EEEGL	Strand 1	A,B,C,E,F,G		
	Strand 2.2	A		

Teacher Background: In the 2 previous activities, students used data from a published research study to assemble stand history diagrams that showed low-severity and stand-replacing fire regimes. Both of these patterns were common historically in forests of the western United States. In this activity, they learn about a third common pattern, the mixed-severity fire regime.

A forest with a mixed-severity fire regime has some places where fires were severe enough to replace old stands with young ones… and other places where some of the big trees were killed but others survived (probably with fire scars)… and yet other places that have not burned at all in a long time. A forest with a mixed-severity fire regime may also experience low-severity fires that alternate over time with stand-replacing fires. In other words, its fire history is all mixed up – and that history produces very complex forests with a mixture of tree species and ages.

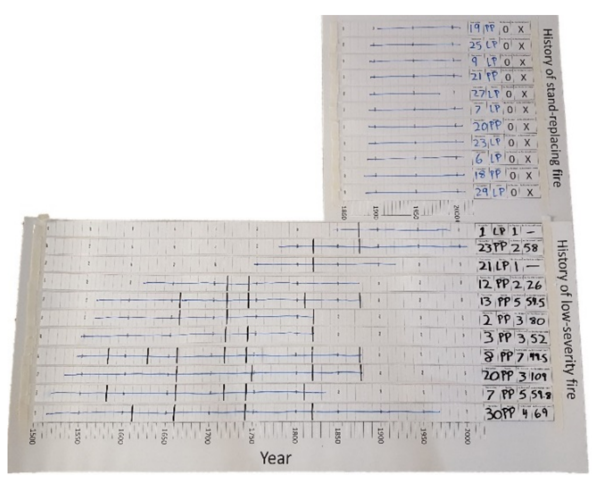
In this activity, students also learn about the fire regimes that were most prevalent historically in the 3 forest communities they have been studying:

- Most ponderosa pine/Douglas-fir forests from the northern Rocky Mountains to the North Cascades had fire regimes of frequent, low-severity fire in past centuries, but they also had occasional mixed-severity fires, and sometimes they also had stand-replacing fires.
- Most lodgepole pine/subalpine fir forests in the region had historical regimes of either stand-replacing or mixed-severity fire, depending on fuels, topography, and weather patterns.
- Most whitebark pine forests had mixed-severity fire regimes.

For more details on these forest types and their fire regimes, how they have changed in the past century, and why the changes are important, see the technical readings that students summarize in the **Assessment** for this activity (in the **Appendix** and available for download from **3FireRegimes_TechnicalReadings.docx**) and the related **Evaluation** section below.

Materials and preparation:

- Note that the ***PotholesStudyArea.pptx*** poster from **Activity M18andH17_High-sevFireHist** should still be on display.
- Take the stand history diagrams from the previous 2 activities and move them so the one showing stand-replacing fire is above the one showing low-severity fire. Tuck the "Dot Diagram" information on the stand-replacement diagram under the top of the low-severity diagram to make them look more continuous. IF YOU DON'T HAVE THESE DIAGRAMS, YOU CAN JUST START WITH THE PRESENTATION BELOW.



- Download ***M20_MixedSeverity&3ForestTypes.pptx.***
- Make 1 copy/student of **Handout M20-1. News blog.**

- Print 1 copy/3-student team of the technical readings in the **Appendix** or make them available electronically from **M17andH16_DendroForFireHist.docx.**

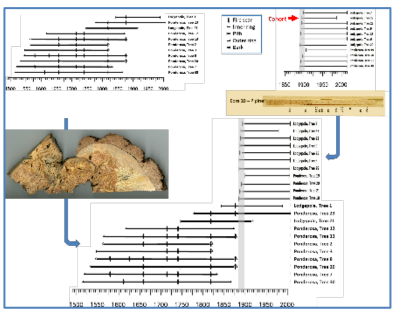
Procedure:

1. Explain: The increment cores and tree cookies that we've studied were sampled in different ways, but all of them came from the same research study in the same area of central Oregon. Let's combine the information from the two of them to see if we can learn more about the fire history of the area.
2. Look at the combined stand history diagram on display or **Slide 1** in ***M20_MixedSeverity&3ForestTypes.pptx***. Go through/discuss the rest of the slides:

Slide 1

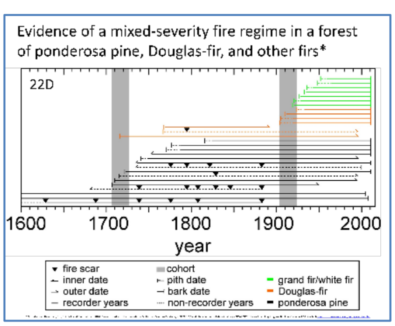
All of the increment cores and fire-scarred tree cookies that we've looked at came from the same study area in central Oregon. Let's see what happens when you have a mixture of low-severity and stand-replacing fire over time and space.

Slide 2



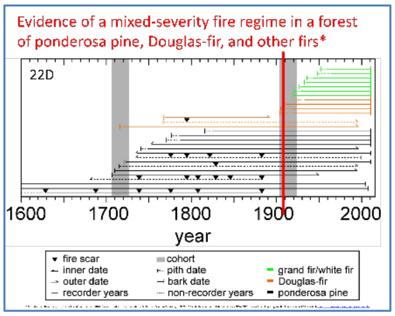
The top diagrams here are like the ones we constructed in class. The diagram based on fire scars – showing a history of low-severity fires - is on the left. The diagram based on increment cores – showing a history of stand-replacing fire - is on the right. When we combine them to describe the whole area and all of the variety it contains, what can we say about the history of the whole, big area? Over the past 500 years, the area has experienced both low-severity and stand-replacing fire. The cohort that started in the late 1800s (mostly lodgepole pine) probably started after the 1877 fire. This fire also scarred 5 ponderosa pines, and 3 of them died the next year. So the 1877 fire must have had some low-severity areas and some stand-replacing areas. When we put all of our data together – from fire scars and increment cores - what can we say about the area's fire regime? Perhaps the area has had a *mixed-severity* fire regime. Or perhaps the fire regime changed from low-severity to stand-replacing in the early 1900s.

Slide 3



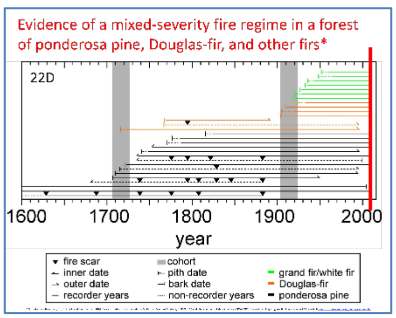
Let's look at more information about mixed-severity fire regimes. They are pretty common. Here's an example from a stand with ponderosa pines, Douglas-firs, and other firs. The design of this diagram is just a little different from the ones we put together: First, the fire scars in this diagram are shown with black triangles rather than straight lines… and second, the different tree species are shown with different colors. So… what is the story of this forest? The forest had a lot of low-severity fires until around 1900 but has had none since then. There was a stand-replacing fire in the early 1700s. It didn't scar any trees that we know of, but it led to establishment of the oldest Douglas-fir tree on the site. There was another stand-replacing fire around 1900, which led to the establishment of lots of Douglas-firs and other firs but no ponderosa pines.

Slide 4



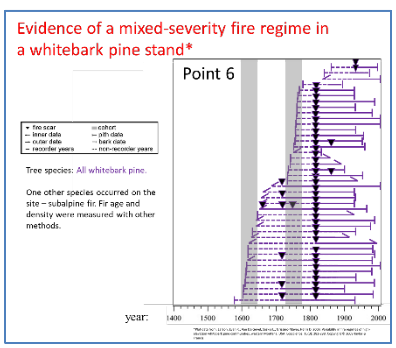
If we draw a line through the year 1910, can you picture what that forest probably looked like then? There were a lot of big old ponderosa pines and a couple of big Douglas-firs. There may have been a lot of dead Douglas-firs too, killed by a recent stand-replacing fire. There were probably also a lot of tiny Douglas-firs and other firs, the beginning of that new cohort.

Slide 5



If we draw a line through the year 2010, can you picture that forest? There were just a couple of big old ponderosa pines, and there were a lot of Douglas-firs and other firs. They were be grown-up but not nearly as big as the old pines. There would probably be a lot of smaller firs too, since they can reproduce well in shade – unlike ponderosa pines.

Slide 6

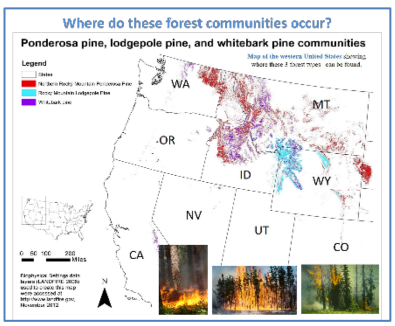


Here's another example of a forest with a history of mixed-severity fire. This diagram shows the history of a stand of whitebark pines in a high-elevation forest. What is the story of this forest? There are 2 cohorts – one from the early 1600s and one from the mid 1700s. There seem to be just 3 years with low-severity fire until around 1815, when a fire scarred nearly every tree on the site. That same fire may have helped the 3 youngest whitebark pines (at the top of the diagram) start growing. A few whitebarks died in the 1800s, and then mortality increased dramatically through the 1900s. By the year 2000, every whitebark pine was dead. Based on student presentations and other things we've learned, can you guess why they died? Many of the trees were probably killed by mountain pine beetles, and many others by white pine blister rust. In addition, the trees may have been too weak to resist beetles and rust because low-severity fire had not killed off the competing fir trees over the past 100 years or so.

Slide 7

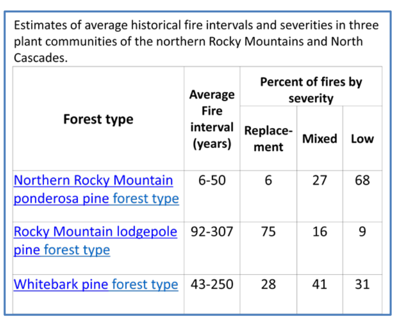
Now we know about 3 historical fire regimes: low-severity, mixed-severity, and stand replacement. Let's return to the 3 types of forest we've been studying and learn about their historical fire regimes – and the way they've changed through the past 100 years or so. First, a review: What are these 3 forest communities? Forests dominated by ponderosa pine (on the left), lodgepole pine (upper right), and whitebark pine (lower right). Keep in mind that we're talking about COMMUNITY TYPES, not individual tree species. The community types are named for the tree species that was most plentiful there in past centuries, but many other tree species can occur in each type. Review: What other tree species occur in the ponderosa pine type? Douglas-fir, other fir species, western larch, lodgepole pine…. What other tree species occur in the lodgepole pine type? Douglas-fir, subalpine fir, western larch, Engelmann spruce, whitebark pine…. What other tree species occur in the whitebark pine type? Subalpine fir, Engelmann spruce, lodgepole pine….

Slide 8



Where do the 3 forest types occur? Discuss locations of the communities on the map relative to your location. Note that all of the plants and animals we've been studying – and the fire weather we have studied and the smoke data we've studied – come from ponderosa pine, lodgepole pine, or whitebark pine communities in this region. What fire regime do you think was most prevalent in each of these types?

Slide 9



Estimates of average historical fire intervals and severities in three plant communities of the northern Rocky Mountains and North Cascades.

Forest type	Average Fire interval (years)	Percent of fires by severity		
		Replace-ment	Mixed	Low
Northern Rocky Mountain ponderosa pine forest type	6-50	6	27	68
Rocky Mountain lodgepole pine forest type	92-307	75	16	9
Whitebark pine forest type	43-250	28	41	31

This table summarizes information for our 3 forest types from dozens of research studies. Let's read it carefully. [Go through the caption at the top, then the row and column titles.] Let's answer some questions with this information. What is the most common fire severity for ponderosa pine forests? Low-severity, at 68% of fires. What is the most common fire severity for lodgepole pine forests? Stand replacement, at 75% of fires. What is the most common fire severity for whitebark pine forests? Mixed severity, since about 41% of fires were of mixed severity. But low-severity and stand-replacement fire occurred a lot too (31% and 28%). How would you describe the historical fire regime for the whitebark pine type? It looks like whitebark pine communities in general have a mixed severity fire regime… they're all mixed up!

3. Summarize: Now we'll read more about the fire regimes in our 3 forest communities (ponderosa pine, lodgepole pine, and whitebark pine), determine if the forests and fire regimes have changed in the last 100 years, and decide if the changes have important

consequences. In other words, we will answer the questions that we asked at the beginning of this unit (Activity **M17andH16_DendroForFireHist.docx**): Are our forests OK, or are today's wildfires destroying them? Are today's wildfires too big or too small? Are they too severe? Are the forests we've been studying threatened because of fire or lack of fire?

Assessment:

1. Divide the class into groups of 3. One member of each group will write a short blog about the historical fire regime in ponderosa pine communities, one about lodgepole pine communities, and one about whitebark pine communities.

2. Give a copy of the 3 technical readings to each group or arrange for them to do the readings electronically. The readings are printed in the **Appendix** below and available electronically in **3FireRegimes_TechnicalReadings.pdf**.

3. Assign – or have students choose – who in each group will write about each forest type. Each group must cover all 3 forest types.

4. Give each student a copy of **Handout M20-1. News blog.** Explain that news articles should get the reader's attention, be very clear, and be as short as possible while still getting the point across. An Illustration can be very helpful.

5. Go through the directions in the handout. When you get to 1(d), explain that the article will not give you much information on this issue. Here are a few sources you can use: what you learned about fuels and fire spread in the unit on fire behavior, what we learned about smoke, and what we learned from student presentations on individual species.

6. Have them do the assignment. When the writing is completed, post the blogs on a school website, if possible, and encourage students in other classes to read them.

Evaluation:

Excellent	Good	Poor
Headline is 8 words or less, accurate, and interesting.	Headline is accurate but more than 8 words or dull.	No headline is included, or headline is inaccurate.
Article is 150 words or less.	Article is too long.	Article is too long.
Article is accurate.	Article has minor inaccuracies.	Article has major inaccuracies.
Article accurately describes historical fire frequency and severity.	Article accurately describes historical fire frequency or severity but not both.	Article includes inaccurate information.
Article correctly describes 2 or more changes in last 100 years.	Article correctly describes 1 change in last 100 years.	Description of change is inaccurate or missing.
Article gives 1 or more valid reasons why change(s) matter.	Article gives 1 valid reason why change(s) matter.	Article gives no reason or incorrect reasons why change(s) matter.
Article includes appropriate illustration with accurate caption, credited appropriately.	Article includes illustration with caption.	Article includes irrelevant illustration or no illustration, or caption/credit is incorrect.

Suggested content for essays on each of the 3 forest types:

Forest type:	Northern Rocky Mountain ponderosa pine	Rocky Mountain lodgepole pine	Whitebark pine
General fire regime:	Mostly frequent, low- to moderate-severity surface fires. Fires often burned in a patchy/mosaic pattern.	Infrequent stand replacement or mixed-severity fires were most common. Sometimes low-severity fires occurred.	Mixed-severity fire regime, that is, fires of severities that varied in space and time, creating complex patterns of tree survival and mortality.
Fire intervals:	6-50 years… most studies report 6-15 years.	100-300 years, but with intervals as short as 25 years and as long as 400 years	60-300 years, sometimes as long as 500 years. Stand-replacing fires occurred at 250-year intervals or longer.

How vegetation and fire regime have changed:	Fuel loads, particularly ladder fuels, have increased. Forest patches have become denser. Fire exclusion may cause larger, more severe fires than what occurred historically.	Some studies indicate little change over the past century. However, fire exclusion could gradually make the landscape more uniform, since fewer new patches of burned forest are created by fire.	It is hard to say how fire suppression has affected these forests. It may lead to further loss of whitebark pine (in addition to loss from white pine blister rust) and replacement by fir and spruce.
Why changes matter: THIS INFORMATION IS NOT IN THE READINGS. (For possible information sources, see **Assessment, Step 5** above.)	Native plants and animals may not survive in the changed environment. Many people have homes and live in this forest type; increased fire severity increases risks to watersheds, people, and property.	Native plants and animals may not survive in the changed environment. Many people have homes and live in this forest type, often in areas remote from fire control resources. Increased uniformity of vegetation could increase the possibility of larger fires.	Native plants and animals may not survive in the changed environment. Establishment of rust-resistant whitebark pine may fail if fire has not prepared a seedbed. If rust-resistant whitebark pines do become established, they may be shaded out by already-established subalpine firs and spruces. Large, uncontrollable, more severe fires at lower elevations could spread into whitebark stands and kill the remaining rust-resistant trees.

Handout M20-1. News blog.

Name: ____________________________________

<u>My</u> forest community type: _______________________________________

1. Write a short blog about your forest community type and its fire regime for a high-school science website. It should be no more than 150 words long.
   a) Describe your forest community type (what are the most important trees?).
   b) Describe the forest type's historical fire regime (how often fires occurred and how severe they were).
   c) Describe 1 major change in your forest type's vegetation and fire regime during the past 100 years.
   d) Tell your readers why that change matters. Use information from other sources, such as student presentations and your ideas about smoke and people's safety.
   e) Write a headline no more than 8 words long. Make it catchy but also accurate.
   f) You may include 1 photo or other illustration. If you do, include a caption and credit the source.
2. Exchange papers with 2 students who wrote about the OTHER two forest community types. Have them write their suggestions for your article in the spaces below.
3. Read their papers and write your suggestions on their handouts, then give them back.
4. Use comments from your reviewers to improve your blog. Then hand it in with this handout.

Suggestions from student writing on ANOTHER forest type:

Name: ____

Write at least 1 strength and 1 way to improve the article. You may write on the back too.

Suggestions from student writing on YET ANOTHER forest type:

Name: ____

Write at least 1 strength and 1 way to improve the article. You may write on the back too.

Appendix. Technical readings on historical fire regimes in northern Rocky Mountain ponderosa pine, Rocky Mountain lodgepole pine, and whitebark pine forests.

Fire regimes of Northern Rocky Mountain ponderosa pine forests

USDA Forest Service photo.

Ponderosa pine dominates low-elevation forests and savannas from the northern Rocky Mountains to the North Cascades. Douglas-firs and other fir trees are also common among the large, old trees. Historically, ponderosa pine forests were a mosaic of open stands, dense patches of young trees, and areas without any trees at all. Frequent fires maintained ponderosa pines as the biggest, oldest trees, even in places where firs trees would probably take over without fire.

Before the time when fires were kept out of the forests (the early 1930s), there was plenty of litter and undergrowth in ponderosa pine forests, but there were not many young trees or woody fuels. Lightning fires occurred in summer, and American Indians set fires in spring and fall.

Most of the fires were surface fires of low to moderate severity that burned in a patchwork pattern. Stand-replacement fires were infrequent, but they were an important part of the fire regime.

Results from fire history studies show that average fire intervals in ponderosa pine forests of the northern Rocky Mountains ranged from 6 years to 50 years. Most studies report averages of 6 to 15 years. Fires were less frequent but more severe at higher elevations, in moist sites, and on north-facing slopes.

As fires have been kept out of ponderosa pine forests in the northern Rocky Mountains, fuel loads have increased - particularly ladder fuels. Many ponderosa pine forests have a lot of Douglas-firs and other fir species in the understory, and not many ponderosa pines. Many forests are denser than they were in the past. Cheatgrass has invaded some ponderosa pine forests, increasing the fine fuels.

Many ponderosa pine forests of the northern Rocky Mountains have changed over the past century. They now have longer fire intervals, but when fires occur they tend to be more severe and possibly larger than what occurred historically. The size and frequency of severe fires are likely to continue to increase with climate change. Large, severe fires threaten the integrity of ponderosa pine ecosystems.

Adapted from: Fryer, Janet L. 2016. Fire regimes of Northern Rocky Mountain ponderosa pine communities. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory (Producer). Available: https://www.fs.usda.gov/database/feis/fire_regimes/Northern_RM_ponderosa_pine/all.html [2017, April 24].

Fire Regimes in Rocky Mountain Lodgepole Pine/Subalpine Fir Forests

Wildland fires usually occurred at intervals from about 100 years to 300 years in lodgepole pine/ subalpine fir forests, although sometimes fires were more frequent. Most fires were either stand-replacing or mixed-severity, but low-severity fires occurred occasionally. Where there are a lot of ladder fuels, fallen logs and branches, and dense tree crowns, these forests are likely to have stand-replacing fires. They can be crown fires or severe surface fires – or a combination of crown and surface fire. In dry locations where fuels are sparse, fires are likely to be a patchwork of mixed severities.

Chris Schnepf, University of Idaho, Bugwood.org

In forests dominated by Rocky Mountain lodgepole pine, the amount of fuel is related to stand age. If a young stand is very dense, with interlocking crowns, sparse lower limbs, and few understory plants , it is unlikely to burn at all unless the wind is very strong; then it may burn in a crown fire. As the forest gets older, the trees may be killed by bark beetles or dwarf mistletoe, and youg fir trees may grow in, increasing the ladder fuels. Then the stand becomes likely to burn in either stand-replacing or mixed-severity fire.

Research from two national parks shows how fire regimes in lodgepole pine forests can vary:

- A study in forests containing western larch and Rocky Mountain lodgepole pine in Glacier National Park showed that forests with a dry climate and gentle topography experienced mixed-severity fires about every 25 to 75 years. Forests on wetter, steeper, sites experienced stand-replacing fires at longer average intervals, ranging from 140 to 340 years.
- A study in Yellowstone National Park showed that low-elevation lodgepole pine forests experienced mixed-severity fires about every 25-150 years; higher-elevation forests experienced stand-replacing fires at longer intervals, ranging from 300-400 years.

Because fire intervals are long in most Rocky Mountain lodgepole pine forests, it is hard to say for sure whether fire suppression efforts have changed these forests substantially. Where these forests had some low-severity fires in the past, they now have almost none. Lack of fire may be making forests more uniform and therefore more susceptible to epidemics of bark beetles. In addition, the uniform fuels could mean that future fires will be mostly stand-replacing; there will be little mixed-severity fire.

Adapted from: Anderson, Michelle D. 2003. Pinus contorta var. latifolia. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: https://www.fs.usda.gov/database/feis/plants/tree/pinconl/all.html [2017, April 26]. **and** Arno, Stephen F. 2000. Fire in western forest ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 97-120.

Fire Regimes in Whitebark Pine Forests

Whitebark pine fire regimes vary a lot in space and time. The most common kind of fire is of mixed-severity. A history of mixed-severity fire creates a complex pattern of tree survival and mortality on the landscape. Mixed severity fires occurred in the past at 60- to 300-year intervals; sometimes they occurred at intervals longer than 500 years!

Some fires in whitebark pine stands burn in sparse surface fuels and have low severity, killing only the smallest trees and the thinnest-barked overstory trees, such as subalpine fir. Fires are likely to be more severe if they burn in areas with heavy fuel loads or when the weather is especially dry and windy. These conditions help fire spread into the tree crowns and kill large patches of whitebark pines that may be hundreds of years old. Burned openings in whitebark pine stands provide good locations for Clark's nutcrackers to cache the heavy, nutrient-rich seeds of whitebark pine.

Many whitebark pine forests from the northern Rockies to the North Cascades have had occasional large, stand-replacing fires. These fires occurred at intervals of 250 years or even longer. The fires were usually driven by strong winds. They often originated in dense forests at lower elevations. Whitebark pines were often the first trees to become established on these large burns because their seeds were brought in by Clark's nutcrackers. Fir, spruce, and lodgepole pine trees seeded in more gradually from the edges, since they did not get any help from birds!

Because fire intervals are very long in whitebark pine forests, it is hard to say how fire suppression has changed them. In some areas, lack of fire could be leading to loss of whitebark pine and replacement by more shade-tolerant trees, such as spruce and fir. Even if whitebark pine seedlings are resistant to infection from white pine blister rust, they could have trouble getting a start on life if fire has not first cleared the soil and killed the small trees of competing species.

Adapted from: http://whitebarkfound.org/ecology-management/fire-regimes/, http://whitebarkfound.org/ecology-management/threats/ **and** Larson, Evan R.; Van De Gevel, Saskia L.; Grissino-Mayer, Henri D. 2009. Variability in fire regimes of high-elevation whitebark pine communities, western Montana, USA. Ecoscience. 16(3): 282-298.

21. Drama in the Forest: Fire and Succession, a Class Production

Lesson overview: Students prepare and produce three short plays (approximately 15 minutes each). Each play depicts the role of fire, succession, and other changes over time in one of 3 ecosystems: forests dominated by ponderosa pine and Douglas-fir; lodgepole pine and subalpine fir; and whitebark pine and subalpine fir.

Goals: Increase students' understanding of change in ecosystems over time—caused by fire, other disturbances, and succession without disturbance.

Objectives: Given reference materials on biology, ecology, and succession, students can produce a drama that illustrates succession, the role of fire, and other processes that change forest communities.

Subjects: Science, Reading, Writing, Speaking and Listening, Social Studies, Arts

Duration: 1-2 class periods for student preparation, about 15 minutes for each of three presentations

Group size: large groups

Setting: Classroom

Vocabulary: *succession*

ABOUT STUDENT PRESENTATIONS: All presentations from **Activity M11. Who Lives Here? Adopting a Plant, Animal, or Fungus** should be completed before you do this activity.

Standards:		6th	7th	8th
Common Core ELA	Writing	3,4,6,7	3,4,6,7	3,4,6,7
	Speaking and Listening	1,2,4	1,2,4	1,2,4
	Science/Technology	3,7,10		
NGSS	Interdependent Relationships in Ecosystems	LS2.A, LS2.C, LS4.D		
	Matter and Energy Flow in Organisms and Ecosystems	LS1.C		
	Earth's Systems: Processes that Shape the Earth	ESS2.A		
	Growth, Development, and Reproduction of Organisms	LS1.B		
EEEGL	Strand 1	A,C,E,F,G		

	Strand 2.2	A,C,D

Teacher Background: Forests change over time. One of the most dramatic forces of change in forests of the northern Rockies and North Cascades is fire. However, many other disturbances alter these ecosystems, including wind storms, floods, landslides, and epidemics of insects and fungi. Change also occurs without disturbance; this process is called succession.

What kind of changes occur during succession after fire? In the first years, more sunlight and water are available to understory plants, some soil nutrients have increased, and the soil is warmer. Plants that need sunny openings or abundant nutrients thrive in the first years after fire, and some animals thrive on these plants. Some trees reproduce prolifically. As the years go by, shrubs begin to shade out the smaller plants, and then trees begin to shade out the shrubs. Plants that need sunny openings decline, and those that can grow and reproduce in shade take over. Plants and animals that require cool, dark forests are present only in late succession.

This activity asks students to create and present 3 plays that depict fire and succession in 3 forest ecosystems over the past 300-400 years. **Table M21** (at the end of this lesson) lists organisms that might comprise the "cast" for each drama.

If you used **Activity M11**, in which students "adopted" organisms and gave presentations on them, have students play the roles of the same organisms in this activity. If you did not do **Activity M11**, assign each student an organism from the list in **Table M21.** Provide students with time to learn about their organisms from the *FireWorks Encyclopedia* (available in the trunk and in the **M11** folder).

Want to link this activity to physical science?

Explain: You can think of ecosystem as a huge reservoir of high-energy chemical bonds among carbon, oxygen, and hydrogen atoms.

- Trees and other plants add to the reservoir when they capture the sun's energy and store it in their tissues, but they can't keep the carbon to themselves.
- Fungi grab it from the plant tissues so they can grow and reproduce. Insects grab it from leaves, needles, tree cambium, and dead tissues.
- Mammals and birds grab it from leaves, stems, seeds, and even tree bark… and from other animal matter. Fish grab it from plant matter and other animals in the water.

This complex of interactions is often referred to as a food web, but it can also be viewed as a pool of carbon moving about, taking one form after another as the energy originally stored by plants is mined and the atoms are recycled. Fire is a much faster recycler than the food web, but ultimately it accomplishes the same thing – releasing the energy in the high-energy chemical bonds within plant tissues.

Materials and Preparation:

- Use **Table M21** (at the end of the activity) to plan the casts for the 3 plays. If you did **Activity M11. Who Lives Here? Adopting a Plant, Animal, or Fungus** as a class, refer back to **Table M11**, the list of species assigned to students**.** Students should use the same costumes, puppets, art, etc. from **M11** in their plays.
- Print 1 copy/student of the assignment**: Handout M21. Drama in a forest ecosystem**.
- Give each team a list of the cast for their drama; this could be a copy of your **Table M21** and a copy of your **Table M11** (species assignments for **Activity M11**).
- Provide access for students to the *FireWorks Encyclopedia* (in the trunk or ***Middle_FireWorksEncyclopedia_NRM-NC.pdf*** in the **M11** folder**.** Students may need to consult several essays to figure out how to portray fire and succession.
- If students need additional information or if you want them to do additional research, many resources are available, including:
    - the introduction to this curriculum
    - the 3 looseleaf notebooks in the trunk that are used for **Activity E14. Story Time: Feltboards Show Fire and Succession**
    - Many internet sources. Here are 3:
        - Essays on the ecology of whitebark pine forests (http://whitebarkfound.org/ecology-management/)
        - A summary of forest ecology in Yellowstone National Park, including lodgepole pine ecology (https://www.nps.gov/yell/learn/nature/forests.htm)
        - Ponderosa pine ecology (https://www.nps.gov/articles/wildland-fire-in-ponderosa-pine.htm)

Procedure

1. Explain: We've been studying individual members of forests in the northern Rocky Mountains and the North Cascades. How do all those pieces fit together? How do community members interact? How to the ecosystems change over time? This is the process called succession*.* We talked a little about succession when we were studying ladder fuels and "tinker trees" (**Activity M06**), but now we'll focus on it.
2. Explain: You will work in teams to present a drama that describes the role of fire and succession in 3 forest ecosystems (those dominated by ponderosa pine with Douglas-fir, lodgepole pine with subalpine fir, and whitebark pine with subalpine fir) over the past 300-400 years. Each team will produce a play about 15 minutes long that shows the relationships among various organisms, the kind of fire that was typical in this ecosystem,

the pattern of succession after a typical fire, and how the ecosystem has changed in the past 100 years or so, especially where fire has been absent. Each student will portray the organism that he or she adopted in **Activity 11. Who lives here? Adopting a plant, animal, or fungus,** or will be assigned a species from **Table M21.** Many students will be in just 1 play, but a few may need to participate in 2 or even 3 plays.

3. Give each student a copy of **Handout M21. Drama in a forest ecosystem.** Go through the directions together and answer questions, so everyone knows what is expected.
4. Have the students who represent the 3 pine trees (ponderosa, lodgepole, and whitebark pine) come up. Give each of them the species list for the play depicting that ecosystem. This could be an annotated copy of **Tables M21** and **M11**.
5. Have the students on each team gather and figure out how to portray fire and succession in their ecosystem. Some species must be "shared" among teams because they have important roles in more than one forest community; tell these students to visit each team that needs them and figure out how to participate.
6. Have students do additional research if necessary, plan their plays, and rehearse.

Assessment: Have students produce their plays for one another and, if possible, for another audience – perhaps a younger class or a parent group.

Evaluation	Full Credit	Partial Credit	Minimal credit
Group Contribution	Student made many contributions during group planning. Student allowed other teammates to participate.	Student made few contributions during group planning but was actively listening and supportive of others.	Student did not make contributions during group planning or took over the planning and did not allow others to participate.
Individual Contribution	Student was well prepared for the presentation.	Student was prepared for the presentation.	Student was not prepared for the presentation.
Content	Information was scientifically accurate. Many facts were used.	Information was accurate but could have used more facts.	Information was not scientifically accurate. Few or no facts were used.

Handout M21. Drama in a forest ecosystem

Produce a play that shows the audience about your forest ecosystem, how fire changes it, and how it changes without fire.

1. Get together with all of the students representing species in your ecosystem. This is the cast for your play. Some students will be in more than 1 play, so figure out how to "share" them.
2. Learn about succession by discussing the needs of each cast member, which you learned from student presentations based on the essays in the *FireWorks Encyclopedia*.
3. Select one person to narrate the presentation. That person will narrate and will also portray his or her character in the play.
4. Prepare your play. Make it about 15 minutes long.
5. **In your play, show:**
    a. **how the various organisms interact (who needs whom for food or shelter)**
    b. **at least 1 fire. Show the kind of fire that was typical in this kind of forest in the centuries before about 1900.**
    c. **how your forest ecosystem changes right after fire and then as years go by.**
    d. **how your forest community has changed over the past 100 years or so, especially if there have been no fires.**
6. Perform your play for your class or another audience.

Table M21. Species in succession dramas for 3 forest ecosystems

Use this table to plan the "casts" for the plays that students will create to show fire and succession. In the list below, each cast has 15 or 16 species, but this assumes that all species were assigned to students if/when you did **Activity M11** (see your copy of **Table M11**). They probably weren't, so delete any species not assigned and adjust the casts accordingly.

If you did **Activity M11,** use **Table M11** to see which species each student represented.

Species shown in **bold print** below with **blue** highlighting are the most important ones to include in the plays. Some species are listed in more than one ecosystem; you can let those students perform twice or choose which cast to perform in. Many other species could occur in more than 1 ecosystem, based on the "Preferred forest type" shown in **Table M11**; the only limit on casting is how complex you want the plays to be.

Note that the American marten and red-backed vole are listed below only in the whitebark pine ecosystem, but in reality they can occur in any moist, old forest.

Organism	PP*	LP	WP
American black bear		X	
American marten			X
American three-toed woodpecker	X		
Armillaria root fungus	X		
Arrowleaf balsamroot	X		
Beargrass		X	
Black cottonwood	X		
Black fire beetle	X	X	X
Black-backed woodpecker		X	
Blue huckleberry		X	
Clark's nutcracker			X
Douglas-fir mistletoe	X		
Douglas-fir	X		
Elk	X	X	X
Engelmann spruce		X	X
Fireweed		X	
Flammulated owl	X		
Glacier lily		X	X
Grizzly bear			X
Grouse whortleberry			X
Heartleaf arnica		X	
Lodgepole pine		X	
Mountain pine beetle		X	X
Northern flicker			X
Pileated woodpecker	X		
Pinegrass	X		
Ponderosa pine	X		
Quaking aspen		X	
Red squirrel			X
Red-backed vole			X
Saskatoon serviceberry	X		
Smooth woodrush			X
Snowbrush ceanothus		X	
Subalpine fir		X	X
Western larch	X	X	
Western redcedar	X		
White pine blister rust			X
Whitebark pine			X
Wild onion			X

***** PP=ponderosa pine/Douglas-fir ecosystem; LP=lodgepole pine/subalpine fir ecosystem; WB=whitebark pine/subalpine fir ecosystem.

22. Fire ecology puzzlers

Lesson overview: This activity uses a set of jigsaw puzzles (printed on laminated paper) to review species interactions and the role of fire in 3 forest ecosystems of the northern Rocky Mountains and the North Cascades. These are forests dominated by ponderosa pine/Douglas-fir, lodgepole pine/subalpine fir, and whitebark pine/subalpine fir. The activity can be done in 2 ways, if not more: as a classroom "grab-bag" competition among student teams, or as a quiet activity to be done singly or in small groups at stations.

Subjects: Science, Reading
Duration: 30 minutes
Group size: Whole class, working singly, in small groups, or as in large teams
Setting: Classroom

Lesson Goal: Students can distinguish characteristics of 3 forest ecosystems and integrate information on fire behavior, fire history, and species' adaptations to fire in each ecosystem.

Objective: Given a set of puzzle pieces with photographs and text as clues…

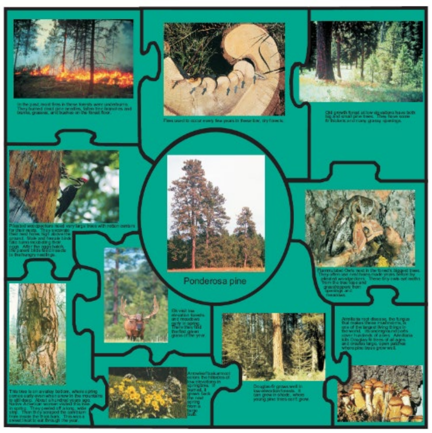
- Students can recognize some of the species and fire behavior patterns associated with 3 different forest ecosystems.
- Students can assemble jigsaw puzzles that represent the fire ecology of the 3 ecosystems.

Standards:		6th	7th	8th
Common Core ELA	Science/Technology	7,10		
NGSS	Structure, Function, and Information Processing	LS1.A. LS1.D		
	Matter and Energy Flow in Organisms and Ecosystems	LS1.C, LS2.A, LS2.B, LS2.C		
EEEGL	Strand 1	A,C,E,F,G		
	Strand 2.2	A,C,D		

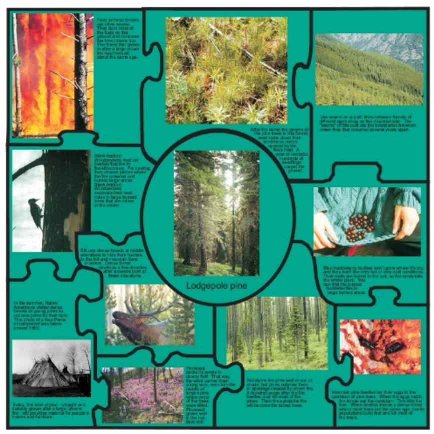
Teacher Background:

Discovering how the inhabitants of an ecosystem interact is a little like assembling a complicated jigsaw puzzle. In this activity, students use what they have learned about fire, organisms, and succession to assemble jigsaw puzzles that describe 3 forest communities in the northern Rocky Mountains and the North Cascades.

The activity is based on a set of 3 simple jigsaw puzzles (see the graphic below). Each puzzle represents 1 of the 3 forest ecosystems and is comprised of 11 pieces that are cut out from laminated printouts. A complete puzzle set thus contains 33 pieces. The 3 puzzles would be easy to assemble, except all three are cut from the same template, so pieces for the different ecosystems have the same shape. For example, each puzzle has a piece showing a bird that lives in that ecosystem and is adapted to the kind of fire that historically occurred there. To get each bird piece into the correct puzzle, students must either recognize the species and its habitat or figure that out from text "clues" written on the pieces.



Ponderosa pine/
Douglas-fir



Lodgepole pine/
subalpine fir

Whitebark pine/
subalpine fir

Your trunk may contain up to 4 puzzle sets. Each set of 33 pieces is stored in a separate envelope, and the pieces of that set are labeled on the back with a unique letter or number. If you want to mix up pieces from different sets, you can sort them out later by using the labels on the back of the pieces.

Materials and Preparation:

- Locate the "Puzzling It Out" kit in the trunk. The kit contains up to 4 puzzle sets (33 pieces in each set, with each set stored in a separate envelope). The kit also contains keys for correcting the puzzles. You can also use the 3 graphics above to check students' work, since you can see the photos even though the text is too small to read.
- Decide what approach to use for the activity:

- **To use the class “grab-bag” approach,** place the 33 pieces from one puzzle set on a table at the center of the room. Scramble the pieces, leaving them face-up. Arrange for an empty desktop or lab bench at each of 3 locations where student teams can assemble their puzzles. If you wish, have prizes on hand for the winning team(s). **To make this more challenging,** include pieces from more than one puzzle set!
- **To use the “station” approach**, place the 33 pieces from each puzzle set at a station where students can do the activity in groups of 1 to 3. Scramble the pieces, leaving them face-up. **If you want to make the activity more challenging**, scramble the pieces from 2 puzzle sets so students can’t use the process of elimination to assemble the puzzles correctly.

Procedure:

1. Explain: Discovering how the inhabitants of an ecosystem interact is a little like assembling a jigsaw puzzle. So today we’re going to draw on what we’ve learned about fire behavior, different organisms, fire history, and succession in order to assemble jigsaw puzzles that describe the 3 ecosystems we’ve been studying.
2. Explain:

To do the activity as a class grab-bag:	To do the activity quietly at stations:
Form the class into 3 teams, one for each ecosystem (ponderosa pine, lodgepole pine, whitebark pine). If the resulting group size will be too unwieldy, have each team select 4-5 students to represent them. Position each team at a different location around the edge of the center table that has the puzzle pieces. Make sure each team is next to a clean desk or bench where they can assemble their puzzle.	Explain: Each station has a set of 33 puzzle pieces (or possibly more, of you put in extra pieces). Assemble them into 3 puzzles, one representing each of the forest ecosystems that we’ve been studying. You’ll see that the pieces from different ecosystems are interchangeable in shape, so you have to know the ecology and/or read the clues to assemble them correctly.

Explain/suggest: At a signal from me, ONE member of each team will come forward and select ONE puzzle piece. Suggest that they start by finding the oval-shaped piece that shows their ecosystem's pine species. Each time I give a signal, a DIFFERENT student will come forward and select ONE MORE piece for the team's puzzle. Put it together with the other pieces, and have other team members read the text carefully to make sure it belongs in YOUR puzzle. If the team decides that a piece doesn't belong in their puzzle, you must wait for the next signal to exchange it for another piece.	Explain: When you've finished your puzzles, have another team check your work and check theirs. When you're satisfied that the puzzles are correct, have the teacher check.
Give the signals and try to control the traffic as the teams assemble their puzzles. The first team to complete their puzzle correctly wins.	After your work has been checked, scramble the puzzle pieces, leaving them face-up for the next students to use.

Assessment: When students have completed their puzzles, check them against the graphics above or the keys in the "Puzzling It Out" kit.

Evaluation: All 3 puzzles must be assembled correctly for full credit.

Unit VII.
People in Fire's Homeland

Carrying Fire the Pikunii Way: the Fire Carrier

Marvin Weatherwax
2/21/2009
Revised 2/27/2019

Lesson Overview: Students learn how the Pikunii (Blackfeet) people met the challenge of transporting fire from one camp to another as they traveled along historical migration routes. First, students build their own campfires to learn about the technological challenge of starting a fire and protecting "live" (smoldering) coals. Then they speculate on ways to carry fire, and they examine a model of a Pikunii fire carrier. Then they view a video in which a Blackfeet elder describes the construction and use of a traditional fire carrier. Finally, they review what they have learned using a cumulative-listening activity, in which they repeat what previous speakers have said and add their own statements.

Subjects: Science, Speaking and Listening, Health and Safety
Duration: Three half-hour sessions
Group size: Teams of 3-4
Setting: Outdoors and classroom
Vocabulary: *cumulative, elder, migratory people, oral teaching.* These terms are defined within the steps under **Procedures** (below).

This lesson is an excellent complement to activities on the Fire Triangle and the science of wildland fire.

Lesson Goal:
- Increase students' understanding of one native people's technology and ways of life
- Increase students' ability to listen respectfully and contribute to a discussion
- Increase students' understanding of combustion and their skill in handling fire safely

Objectives:
- Students can explain or demonstrate the technological difficulty of starting a fire and transporting live coals.
- Students can explain why it was important for the Pikunii people to have continuous fire during their migrations and how the people met this challenge.
- Students can listen attentively enough to one another so they can repeat what previous speakers have said and add to the discussion.

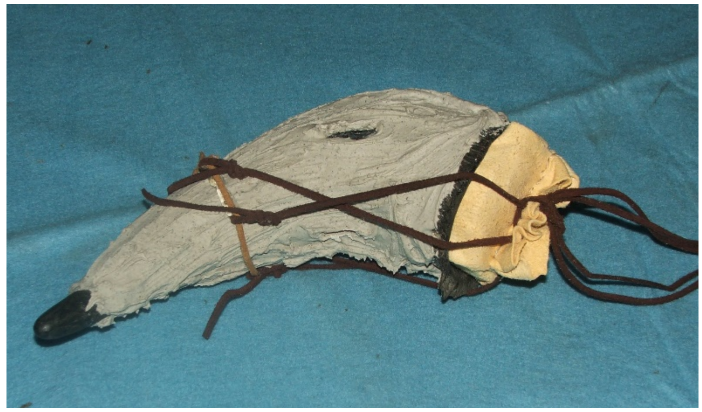
Standards	Elementary School	1st	2nd	3rd	4th	5th
CCSS	Speaking and Listening	1,3,4,6	1,3,4,6	1,3,4,6	1,3,4,6	1,3,4,6
	Language	1	1,3,4,5,6	1,3,4,5,6	1,3,4,5,6	1,3,4,5,6
NGSS	Engineering Design		ETS1.A,B,C		ETS1.A	ETS1.A,B,C
	Earth's Systems					ESS3.C
EEEGL	Strand 1	A,C,E				A,C,E
	Strand 2.2	C				C

Standards:	Middle School	6th	7th	8th
CCSS	Speaking and Listening	1,2,6	1,2,6	1,2,6
	Language Standards	1,4,5,6	1,4,5,6	1,4,5,6
NGSS	Waves and Electromagnetic Radiation	PS4.B		
	Energy	ETS1.A, ETS1.B		
	Earth's Systems	ESS3.A		
EEEGL	Strand 1	A,B,C,E,F,G		
	Strand 2.2	A		

Standards:	High School	9th	10th	11th	12th
CCSS	Speaking and Listening	1,4,6		1,4,6	
	Language Standards	1,3		1,3	
NGSS	Energy	ETS1.A			
EEEGL	Strand 1	A,C,D,E,F,G			
	Strand 2.1	B, C			

Teacher Background:

Many Native American peoples developed technology and traditions so they could carry fire from one place to another. The Pikunii people (one branch of the Blackfeet Nation) of the western Great Plains and Rocky Mountain Front used fire carriers made of buffalo horns[1] to carry burning coals from one camp to the next and to start a fire in the new camp. This was very helpful for the people as they arrived in the new camp, but the fire also served another important purpose: The fire provided spiritual and cultural continuity for the people because the same fire was used in one camp after another, even while the people traveled thousands of miles in their yearly migrations.



The Pikunii made fire carriers from a buffalo horn that was filled with pieces of wood and other fuel, arranged carefully so the fire would burn slowly but not go out. The horn had small slits in the sides to allow oxygen in so the coals would keep burning. The horn was covered on the outside with a combination of sand and dirt mixed with homemade glue, which provided insulation. Then the fire carrier was dried for several days. When it was ready for use, burning coals were placed on a flat rock inside and a few pieces of wood were placed on top of the coals. A rawhide-wrapped stone or piece of wood was placed in the open end and tied tightly in place with strips of leather.

This activity is part of *FireWorks for the Pikunii Nation*, an educational program that combines information on the way of life of the Pikunii people with information on the science and technology of wildland fire. The project was developed through a partnership between the Native Science Field Center at Blackfeet Community College, Browning, MT, and the Forest Service's Rocky Mountain Research Station Fire Sciences Laboratory, Missoula, MT. The project was supported by a Diversity Grant from the USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.
For more information on this project, contact the Missoula Fire Sciences Laboratory (https://www.firelab.org/) or the Native Science Field Center at Blackfeet Community College (https://bfcc.edu/native-science-field-center/).

Many thanks to: Audrey Peterson, Cass Cairns, Chuck Haney, David Hanna, Faith Ann Heinsch, Garon Smith, Greg Dillon, Helen Augare, Ian Grob, Ilana Abrahamson, Jim McCallum, Kinnerly Croisant, Kristine Lee, Mark Pieper, Marvin Weatherwax, Maure Sand, Melissa Little Plume-Weatherwax, Nancy McMurray, Nancy Trembath, Nathan P. Birkeland, Patti Bartlett, and Rick Thompson.

[1] **Appendix 3** lists scientific names for all plants and animals mentioned or shown in this activity.

This lesson has 4 parts--

- A hands-on activity and discussion in which students build small campfires and investigate various aspects of fire, such as how to start a fire, how to make it last a long time, and/or how to insulate coals so they will smolder without flaming.
- Examination of a physical model of a Pikunii fire carrier, which has been constructed to look like a real fire carrier but is NOT useable with actual coals. If you do not have access to a model of the fire carrier, you can use the photos available in https://www.frames.gov/documents/fireworks/curriculum/Pikunni/FireCarrierLesson/Printable_fire_carrier_diagram.pdf or follow the directions in **Appendix 2** to construct one.
- A 12-minute video interview with Pikunii elder Marvin Weatherwax (https://www.frames.gov/documents/fireworks/curriculum/Pikunni/FireCarrierLesson/CarryingFirePikunniWay_video.mp4) as he describes the importance, technology, and use of the fire carrier. The transcript for the video is available in **Appendix 1**. Scientific names for species mentioned in the video are listed in **Appendix 3.**
- An **Assessment** that emphasizes understanding of fire behavior and also concise speaking and attentive, respectful listening.

You can do this activity just with brainstorming and discussion, but it is much more engaging for students if they are first challenged to safely build a successful campfire. See Step 1 under Procedures.

This activity can be enriched by including activities in art (possibly constructing model fire carriers from materials such as clay or sugar cones) and music (learning about traditional Pikunii drumming and singing).

Materials and Preparation:

- Obtain a model fire carrier to show students (available from the Missoula Fire Sciences Laboratory, https://www.firelab.org/). If you cannot obtain a model fire carrier, download https://www.frames.gov/documents/fireworks/curriculum/Pikunni/FireCarrierLesson/Printable_fire_carrier_diagram.pdf – but don't show it until **Step 6** below.
- Make sure you have access (on the Internet or downloaded) to the 12-minute video "Carrying Fire the Pikunii Way" available at https://www.frames.gov/documents/fireworks/curriculum/Pikunni/FireCarrierLesson/CarryingFirePikunniWay_video.mp4.
- For the **Assessment** (**Part IV**), consider finding some quiet, wordless music or recordings of Indian drumming or singing to set the mood. Also, consider your class's ability to listen attentively throughout the activity. If that seems too difficult, break the activity up with short, wordless mimicking games (such as clapping a rhythm or doing body motions for students to mimic).

Procedures:

Part I. Build or imagine a campfire

> This activity was written to fit with activities in the FireWorks curriculum (https://www.frames.gov/fireworks/home). If you are not using that curriculum, decide what you'd like students to do to learn about fuel arrangement, ignition, and banking coals. If you would like students to learn how to bank a fire, this website may help: http://www.infobarrel.com/How_to_Bank_a_Fire.

1. Ask: Have you or your family ever built a campfire? What materials did you use? How did you light it? How long did it last? How did you put it out? Short brainstorming session. Maybe list materials and tools on the board.
2. Ask: Among all the materials and tools that we use to build a campfire, which ones were NOT available to Indian people hundreds of years ago? How did they manage without these conveniences? Open discussion, maybe with a list on the board.
3. Explain: In this lesson, we're going to learn about one group of Native Americans, the Pikunii ("Pih-KUN-ee") people, and how they used fire and moved it from one camp to the next. Who are the Pikunii people? "Pikunii" (spelled in several ways, including Pikuni, Pikunni, Pikani, and Piikáni) is the name for one of the four main branches of the Blackfeet Nation (http://blackfeetnation.com/). The Pikunii have lived for hundreds of years in the western half of Montana, especially in the prairies east of the Continental Divide. The center of their government and culture is now in Browning, Montana. Show it on a map. Even better, show it on Google Earth so you can zoom in and out, look at the kind of terrain in the area (mountains and prairies), and help students relate the location of Browning, Montana, to their own location.
4. If you want students to build a fire, this is the time for it. After the campfire activity, discuss how it went: What were their challenges and solutions? Open discussion.

Part II. Examine a model fire carrier

5. Explain: We've learned about some aspects of starting a fire and keeping it going. But those are not all of the challenges faced by the Pikunii people hundreds of years ago. Like many Native Americans, they were a migratory people – that is, they moved from one place to another throughout the seasons to obtain the foods, medicines, and other materials that they needed. They carried fire with them as they traveled. If you were asked to move a fire, how would you do it? What equipment would you need? Could you do it without modern technology, using only materials available in forests and prairies? Discussion.
6. Explain: Let's look at how the Pikunii carried fire. (Show the fire carrier and cross-section or display the printable version

(https://www.frames.gov/documents/fireworks/curriculum/Pikunni/FireCarrierLesson/Printable_fire_carrier_diagram.pdf) These are *models* of a fire carrier – not the real thing. We call them "models" because they help us understand how a real fire carrier works but they contain glue and plastic materials, so they cannot actually be used.

7. Explain: We will all handle the fire carrier and the cross-section, and we'll do so with respect because they represent something that is very important to the Pikunii people. When the materials come to you, **either make 1 observation about it or ask 1 question about it. You may take a moment of quiet before you speak.** The rest of us will listen quietly, and I will record your questions without trying to answer them.
8. Pass the fire carrier model(s) around the class. Record questions on the board.

Part III. Learn about carrying fire from a Pikunii elder (video)

9. Explain: We've made some observations and asked some questions. Now let's listen to Mr. Marvin Weatherwax, an elder of the Pikunii people, to get answers to our questions and learn more about the fire carrier. What does it mean to be an "elder"? An elder is not just someone who is older than other people, but someone who has a lot of knowledge and wisdom, so he or she is an authority for the people and an important teacher for children.
10. Explain: As we view this video and listen to Mr. Weatherwax, we're going to practice a skill that was extremely important to the Pikunii people in past centuries – LISTENING. This skill was ESSENTIAL TO THE PEOPLE'S SURVIVAL because they did not use writing to record their history and legends or to explain how to do things. There were no user manuals, no recipes in books, no online directions. Instead, they taught everything orally – that is, by speaking. If you were a Pikunii child, you needed to learn about your history and how to survive by listening very carefully and remembering EXACTLY what you heard. Then someday you could give that same information orally to the next generation, and they would listen very carefully to you.
11. FOR ELEMENTARY-AGE STUDENTS: Have students sit in a half-circle, perhaps with several rows. Remind them that, as Pikunii children, they would probably be sitting in a tipi or outdoors.
12. Explain: We'll watch the video once without speaking or making any noise. Then we'll see if we have found answers to our questions and if we have new questions.If we want, we can watch it again and stop it at any time to discuss it.
13. Show the 12-minute video "Carrying Fire the Pikunii Way" (https://www.frames.gov/documents/fireworks/curriculum/Pikunni/FireCarrierLesson/CarryingFirePikunniWay_video.mp4).

14. Ask if students can answer the questions on the board. Ask if they have new questions, and record them.
15. Optional: View the video again. The table below contains explanatory notes keyed to times in the video. Entries in bold print are points where you could stop the video and ask the students to discuss or answer a question. **Appendix 1** contains the full transcript for the video.
16. If students still have questions, discuss ways to learn the answers.

Information and cues for studying "Carrying Fire the Pikunii Way"	
Background:	
Speaker	Mr. Marvin Weatherwax is an elder of the Pikunii people and a teacher of Blackfeet Language and Culture at Blackfeet Community College, Browning, Montana (http://bfcc.edu/). The other voice heard on the video is the interviewer, Jane Kapler Smith, an employee of the U.S.D.A. Forest Service.
Location	The video was filmed in the Tipi Ceremonial Room at Blackfeet Community College. This room has been constructed to look and function like the inside of a tipi. It is built and ventilated so students and instructors can burn smudges and use ceremonial fires.
Art work	Several art pieces are visible in the video. They include: ~~A painting of running horses called "Winter Count," created by Blackfeet Studies students at Blackfeet Community College. ~~Designs shown in vertical strips on otherwise plain walls. These represent decorations that are painted on the liners of Pikunii tipis.
Sound	The audio track in the video contains occasional background noise from voices. This is because the video was taped while classes were in session at Blackfeet Community College, and students in the hallways were conversing as they moved from class to class. In addition, Mr. Weatherwax moved around the room while he described the annual migration of the Pikunii people, so some sections of the audio have varying volume and an "echoey" sound.
Cues for the video:	
0:45	**Interviewer asks, "How did they do that [carry fire], and why? You could stop here and have students answer the question.**
1:06	Take note of the surroundings. We are inside the Tipi Ceremonial Room, and the background is dominated by the "Winter Count" painting referred to above.
1:23	Shows plains prickly-pear, a type of cactus.
1:40	**Mr. Weatherwax says that, after fire, the land will "renew." You could stop the video and ask students what that might mean.**
1:43	Shows quaking aspen sprouting from a top-killed tree after fire.
1:49	Mr. Weatherwax refers to "pharmacies," meaning materials that can be used for health and healing. For more information about his and others'

	remarkable work in healing, see http://nativenews.jour.umt.edu/native2011.html.
1:54	The bright yellow flower is arrowleaf balsamroot.
1:54	Mr. Weatherwax refers to various plants as "weeds" – not meaning plants that are unwanted, but rather plants that grow aggressively after the trees have been removed.
1:56	Shows glacier lily
2:11	Shows willow leaves and western yarrow leaves and flowers
2:17	**Interviewer asks, "Why was it important to carry fire from one camp to the next?" You could stop the video and ask students to answer.**
3:32	**You could stop the video after the discussion of continuity and "It was a very spiritual meaning" and ask students what they have in their lives that ensures continuity – what knowledge or things get passed on from generation to generation?**
4:35	**When Mr. Weatherwax points to slits on the sides and bottom, you could stop the video and ask students what those might be for.**
5:11 & after	Mr. Weatherwax mentions using "hardwoods" because they burn a long time and "softwoods" because they are easy to ignite. The softwoods he is referring to include pine, Douglas-fir, and fir species. The hardwoods include aspen, cottonwood, chokecherry, sarvisberry (also called Saskatoon serviceberry), birch, willow, and buffaloberry. Buffaloberry was used because the wood smells bad when it burns—a warning to the runner that the fuels are nearly all burned.
6:49	**The interviewer asks, "How long do you think fire would last in a fire carrier?" You could stop the video and ask students what they think.**
7:06	**The interviewer asks, "Who carried fire for the people?" You could stop the video and ask students what would make a person good at carrying fire.**
8:36	This begins the section on the Cycle of the Buffalo, the Pikunii people's annual migration. Here is a guide to place names that you could locate on a map or using Google Earth: Augusta (Aw-GUS-tuh) Choteau (SHOW-toe) Calgary (CAL-guh-ree) Cypress Hills Great Falls Pincher Creek Shelby
9:08	Mr. Weatherwax refers to "Ulm Pis'kun," a cliff formation in west-central Montana that was used as a buffalo jump (a way to hunt and kill plains buffalo in large numbers). "Pis'kun," also spelled "Pishkun," is the Pikunii word for "buffalo jump." Ulm Pishkun lies within First People's

	Buffalo Jump State Park (http://stateparks.mt.gov/first-peoples-buffalo-jump/) in Montana.
9:24	Shows several buffalo. The one on its back is wallowing in dust to reduce parasites and soothe bites on the skin.
9:45	Shows sarvisberry leaves and berries (also called Saskatoon serviceberry)
10:07	Shows common chokecherries
10:12	Shows blue huckleberries
10:14	Shows limber pine cones. The seeds of these trees and of whitebark pines are very large and nutritious.
10:25	**The interviewer asks, "Do the Pikuni still carry fire?" Maybe stop the video and ask students if they think it is still important to carry fire.**
11:31	**The interviewer mentions "Sharing knowledge about the Pikuni way." Ask students how they have learned about their own way of life. Have they had a special family member or teacher who was especially helpful? How might they go about learning so they could become elders for their school, family, community, or country?**

Part IV. Assessment:

15. FOR ELEMENTARY STUDENTS: Have students sit in a circle on the floor, as if inside a tipi.

16. Start some quiet, wordless music (if you think that will help set a listening mood for the class).

17. Explain: We are going to use a cumulative-listening activity to review what we've learned. It is important for us to share knowledge, but it is **just as important to show that we can learn from one another by listening well,** just as we listened to Mr. Weatherwax in the video. "Cumulative" means that our knowledge will accumulate – it will get bigger and bigger – as we progress through the activity.

18. Explain: Each student will hold the fire carrier and say ONE SENTENCE about it, then pass it on to the next student. **When it is your turn, repeat what the last 2 students said and then add your one sentence. (To make this more challenging, increase the number of statements that should be repeated – or try to get them all!)** This means you must listen to everyone rather than be just thinking of what you are going to say when it is your turn. It is OK to take a moment of quiet to think before you speak. We will listen respectfully even during moments of silence. If you cannot remember what previous students said, ask them politely to repeat it. If you cannot think of anything to add, raise your hand and I will suggest an idea or ask a question to help.

19. Start the activity. If a student makes a serious error, correct it quietly and gently. If it is too difficult for them to listen quietly through the whole circle, break the activity up with short, wordless mimicking games (such as clapping a rhythm or doing body motions for students to mimic). Or have the class work in a small group (4-5

students) and remember everyone's statements. If you need to keep the discussion moving, try some of these prompts:

- Who are the Pikunii people? The Pikunii are a native American people, one branch of the Blackfeet Nation.
- Where did the Pikunii live in the times of the buffalo? The traditional territory of the Pikunii was thousands of square miles in central and western Montana, east of the Continental Divide.
- Where do the Pikunii live now? Pikunii people live all over the world, but their cultural center and the center of government for the Blackfeet Nation are on the Blackfeet Reservation in Montana, centered in the town of Browning.
- Why did the Pikunii travel so much? The most important resource for the Pikunii people was the buffalo. The people needed to travel so they could be near the herds of buffalo as they moved and grazed throughout the western Great Plains. The people also needed to travel so they could collect other foods and medicines, which could only be found in certain places at certain times of the year.
- Did the Pikunii ever burn the land? Why? They did burn the land to "clean up" their camps and to regenerate the plants that they needed for foods and medicines. (Additional information: Other traditional uses of fire included burning to improve forage, to defend a camp against enemies, and to keep enemies away.)
- What is a fire carrier? A fire carrier is something that holds smoldering coals so they can be moved safely from one place to another. Many native peoples in the Americas used fire carriers.
- Why were fire carriers important to the Pikunii people? Fire carriers were convenient because the people could move to a new camp and have a fire ready to use when they arrived. But fire carriers were even more important as a sign of continuity. The people had the same fire day after day, year after year, even though they moved from one place to another throughout the year.
- How does the fire carrier's design protect the runner from getting burned? The clay around the fire carrier provides insulation, and the fire inside burns very slowly so it doesn't produce as much heat as an open campfire.
- How are "hardwoods" and "softwoods" used differently in a fire carrier? Softwoods are used in the inner ring of fuels because they are easy to ignite. Hardwoods are used in the outer ring because they burn a long time.
- How is a fire carrier made? See the **video** and the directions in **Appendix 2** for details**.** Followup questions could address the materials used, the steps in construction, the fuels used, and their arrangement.

- Who carried fire for the Pikunii and how did they learn? Good runners were selected to carry fire because they needed to get to the next camp and prepare it before the rest of the people arrived. The runners learned from others who had carried fire before them.

- What would a runner do if the fuels in a fire carrier were almost all burned up? The runner would stop and transfer the coals to another fire carrier.

- ***If you are using the FireWorks curriculum***: How does the Fire Carrier include all parts of the Fire Triangle while making sure that the fire burns very slowly? The fire carrier contains lots of sticks and moss as FUEL. SMOLDERING COALS are its source of heat. OXYGEN comes in slowly through the slits in the sides and at the tip of the carrier.

- Can you think of additional ways to carry fire that would not use modern technology? Open-ended question. Might include ceramics, baskets, animal bones, thick and damp hides, turtle shells…

Evaluation:

Activity	Full credit	Partial credit	No credit
Building a campfire	Worked safely and carefully. Listened respectfully to other team members. Contributed suggestions. Helped team work together.	Worked safely and carefully. Listened respectfully to other team members. Contributed suggestions.	Ignored safety precautions, did not participate with others on team, or dominated project without input from other team members.
Examining fire carrier, listening to video	~~Handled fire carrier gently. ~~Offered 1 observation or question. ~~Listened respectfully to video.	Met 2 of the 3 criteria under **Full credit.**	Met 0-1 of the 3 criteria under **Full credit.**
Cumulative listening activity	~~Repeated previous 2 speakers' statements. ~~Contributed 1 sentence with accurate information.	Met 1 of the criteria under **Full credit.**	~~Did not repeat previous 2 speakers' statements accurately. ~~Did not contribute 1 sentence with accurate information.

Appendix 1.
Script for "Carrying Fire the Pikunii Way"

Interviewer: Carrying Fire the Pikunii Way

The Pikunii people, also called the Blackfeet,
have lived in the Northern Great Plains of the United States for hundreds and hundreds of years.

In the time before railroads,
before European-American settlement, and before Reservations,
they were a migratory people.
Every year, they moved from one place to another
so they could hunt the buffalo
and harvest other foods and medicines.

As the Pikunii traveled, they took fire with them.
How did they do that, and why?

Listen to the stories of Marvin Weatherwax,
an elder of the Pikunii people.
He will explain about the Pikunii way to carry fire
throughout the year, as the people followed the buffalo.

Weatherwax: Fire is very important to us in many areas.
One of the most important areas was conservation.
The Pikunii people were very, very conscious
of making sure that, when they left an area,
it was clean and it was going to come back
just the way they found it.
So when they left camp, they would burn the area,
so that the things they left there was all burned.
Everything was burned, all the grounds and all,
and what that did was it left it to renew.
It would grow back and renew.

Fire was very important in another aspect.
That was how they built their pharmacies.
After a fire, the first thing that comes up is the "weeds."
And many of them are the medicines
that we use for various ailments and the things that we need.
And we'll make a fire, deliberately burn an area

where we know that certain plants are.
It'll burn them down and then they'll grow back.

Interviewer: Why was it important to carry fire from one camp to the next?

Weatherwax: When we talk about the longevity
and the continuity of our people,
the fire played a very important part in that.
When we moved from one camp to the other,
it was very important that they took fire from the main fire.
They took some of that and brought it to the next camp
and started that fire with it.
In this sense, we had the same fire that went on and on and on.

In doing so, they had to have some way to transport it
because sometimes the camps were 20, 30, 40 miles apart.
And they had to have a way to transport that flame
from THAT fire to the new fire.
It would be very easy to go and start a new fire,
just to send someone to start a new fire, but the meaning,
the importance of taking the fire from one camp to the other,
the continuity, was very important.
It was a very spiritual meaning,

The vessel that they used was very important,
and that was the fire carrier.
This is a fire carrier here, that is a completed one
and this is the outer covering, which is mud or clay.
That goes on the outside,
then the covering, which is made out of wood or stone,
and that covers the top of it.

Sometimes they carried two or three of them,
depending on how far they were going to travel.
And they'd begin with one of them that had fire in it.
And then if they got to the point where this was getting hot down here on the end,
they would know it's coming to the end of this,
and then they would change, stop and take that,
and put that fire into another one,
and then they would start out again.

A slit on the sides and down on the bottom:
Not only ventilation, to get air - oxygen in there, to keep it going.
But the bottom one was

to let you know that it was time to change it.
The ingenuity that was used in building these
was absolutely phenomenal.
We'll go through one here that's built.

This is the horn, and down on the bottom of here,
we have moss, and it was usually kind of damp,
and that was pushed all the way down to the bottom.

And then they would put the wood on top of it,
going in a round circle.
But they would have softwoods in the middle.
There's a flat stone here,
where they would put the original piece of coal on there.
And they used the softwoods
because the softwoods are easier to ignite.

So from the coal, the softwood would ignite,
and then outside of that was the hardwood,
right on the outside.
And then after this burned, then the hardwood would burn.

And the thing that is good about the hardwoods
is that the hardwoods,
such as the cottonwood or the aspen,
it does not go out.
It'll burn until there is no more wood.
But the heat from the softwood
is what would get the hardwood going,
because that was a little harder to get started burning.
But once that got going, it went on and on.

The moss was not only on the bottom,
it was also around the outer edge,
and this was to keep it from flaming.
It would not flame, it would just stay a coal.

And then the top part was the cover,
which was very important, a very important part of it.
It was a stone, and most of the time it was wrapped
with something that would burn away,
like a piece of rawhide, sometimes,
but it would be wet, soaked in water,
so that when it was put down on there,

it made a seal, it covered it up, and it was tied down.

The bottom inside of that would normally burn from the heat.
This would be very very hot.

Interviewer: How long do you think fire would last in a fire carrier?

Weatherwax: Really, it depended on how big the fire carrier was,
because that would depend on
what the length of the hardwood would be,
that you put in there.

Interviewer: Who carried fire for the people?

Weatherwax: There were special people that were chosen,
and it was normally the long distant runners,
because they ran not only to find out where the buffalo were,
but they ran to get new camps, to where the camp was.
They didn't walk, they literally ran,
sometimes for 40, 50 miles, nonstop.

The people that put it together were
someone that had done it for a long time,
and he would teach someone else to do it.
And just my sense –
I would think that the runners that carried it
were the ones, that it was –
the knowledge of how to make it was passed on to them.

In my readings and talking with people,
most all the tribes had their own way of continuing.
Even the Indians in Alaska.
They used the whale bones and did something similar to this
and they transported their fires the same way,
and for the same reasons.
So the continuity of the fire was important
amongst all the native people.
All of us are so conscious about carrying things on
and making sure that things are continued.

Interviewer: The Pikunii traveled hundreds of miles each year, carrying fire. This was "the Cycle of the Buffalo."

Weatherwax: It was right around the Choteau area -

that's where our main camps always were.
In the spring of the year, this is where the buffalo were.

Up here and down toward, right above the Great Falls area,
there was usually a herd of female buffalo calving.

In this area down here by Great Falls,
there's a pishkun down there now.
They called it the Ulm Pishkun,
and it was used primarily for the elders.
What they would do is, some warriors would go down,
and they would take part of a herd - not a real large part –
and then they would run them off of that pishkun.
They did it in the spring of the year before the cows gave birth.

Previous to us being on the Reservation,
we traveled pretty much through the whole half of the state.

And they came around over by Shelby along the Marias River,
and they hunted the Sweet Grass Hills,
and they brought that back to Shelby,
and then they camped there for awhile.
And then they continued on over into Canada,
by the Cypress Hills.
Normally when they hit the Cypress Hills it was around July.

And then they came up from there toward Calgary.
They turned down along the mountains.
And then about this time of the year,
they were probably right in this area along the mountains,
right in the mountains by Pincher Creek,
right above Pincher Creek.
And then they would move down into the winter camp area.

Interviewer: Do the Pikunii still carry fire?

Weatherwax: What my grandfather told me about the fires:
He was told probably about the middle of the 1800s
was when they say the last fires went out.
It was probably just previous to the buffalo being gone.
And the reason for that was that
they moved their camps to follow the buffalo.
And then when the buffalo were gone,

then it was not necessary for them to move their camps anymore and follow the buffalo.
They could stay stationary,
and then they had to begin to depend on the wildlife that was there
or the cattle that the government was going to provide them…
the rations that the government was going to provide them.

That's when they all had to start living on reservations,
so that's when the fire ended.

Interviewer: Sharing knowledge about the Pikunii way

Weatherwax: One of my responsibilities in my life
is to pass on things that I have learned
from my grandparents and from the other elders.
Because I have finally become, I believe I've become an elder,
and I can pass this on.

Appendix 2.
Constructing a Replica or Model of a Pikunii Fire Carrier

These instructions explain how to make a useable fire carrier. If you would like to make a model of the fire carrier like the ones available at Blackfeet Community College or the Missoula Fire Sciences Laboratory, follow the instructions below, except for the following:

1. Use a complete buffalo horn, as below, and also a cross-section of a buffalo horn.
2. Cover the outside of the horn and cross-section with car-body putty or plastic clay instead of making coating from soil and glue.
3. As you assemble the fire carrier and the cross section, attach everything using a glue gun.

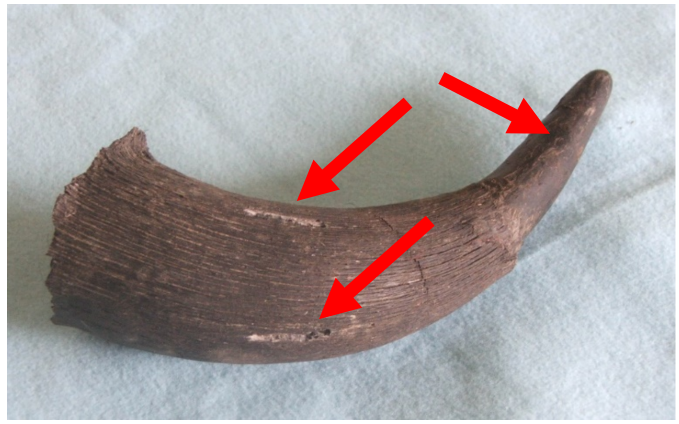
Do not try to use a model fire carrier (made with glue and other synthetic materials) to actually carry live coals.

Materials for making a fire carrier are found in our surroundings:

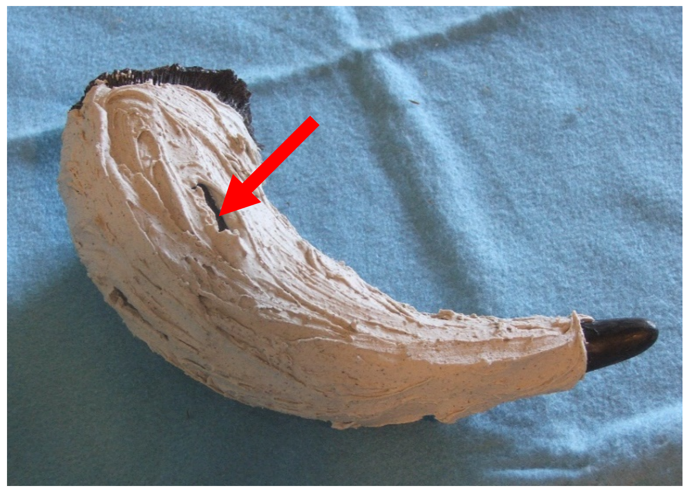
- Large buffalo horn
- Sand and dirt
- Glue (made from the insides of the hooves of a horse)
- FUELS:
  Wood—small branches of…
    - Softwoods:
        - Douglas-fir
        - Other fir species
        - Pine
    - Hardwoods:
        - Cottonwood
        - Aspen
        - Chokecherry
        - Sarvisberry (also called Saskatoon serviceberry)
        - Birch
        - Buffaloberry (used because they smell bad when they burn—a warning to the runner that the fuels are nearly all burned)
        - Willow (any species)

  Moss
  Sage leaves
  Stone (one small, flat stone that will fit inside horn and hold the burning coals)
  Rawhide piece about 10” square
- Block of wood large enough to cover opening of horn—or—piece of stone that is cone shaped. (Either can be shaped to cover the horn’s opening.)
- Strip of leather or rawhide ¼” wide and 30-36” long

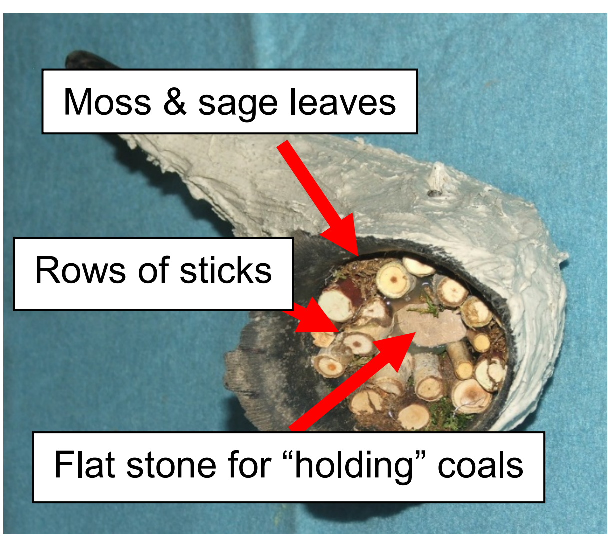
1. **Constructing the fire carrier:** Using a knife, drill, or other sharp object, cut 4 small openings in the buffalo horn about ¾ of the way up from the small end. Make the openings 1-2" long and 1/8" wide. Make additional openings at the narrow tip of the horn.



2. Mix sand, dirt, and glue. Knead into the consistency of dough.
3. Apply mixture to outside of horn in a layer about ½" thick. Make sure that you don't cover up the openings in the horn. Press down firmly to make sure that this insulating material has good contact with the horn and sticks well.



4. Let dry for about 3 days.
5. Fill the bottom of the horn with moss. Then line the inside of the horn with moss and sage leaves about ½" deep all the way to within ½" of the top, leaving enough room at the top for the cover to fit in tightly.
6. Place sticks in concentric circles inside the horn: The first row, just on the inside surface of the horn, should be hardwood. Put in more hardwood rows until about half of the horn's cross-section is filled.



7. Inside the hardwood sticks, add 1-2 rows of softwood sticks in rows until ¾ of the horn's cross-section is filled. Leave enough open area in the middle for the flat stone (see step 9).

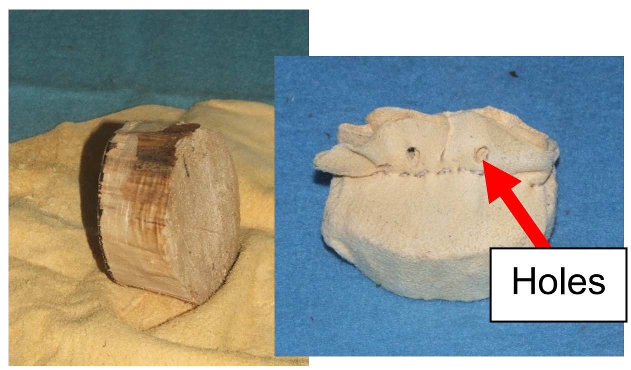
8. More about the sticks:

   - In the outside row, reaching all the way to the bottom of the horn, place one stick of buffaloberry. This will give off a very distinct, unpleasant odor to let you know when the fuels in the carrier are almost burned out.

   - Put at least one cottonwood stick in each row of sticks. Cottonwood continues to burn and does not go out until it is completely burned up. This will help ensure that the fire carrier will stay lit.

9. Place a flat, round stone in the center and push it down as far as it will go. This will wedge the sticks in place and hold the live coal.

10. **<u>Closing and sealing the fire carrier:</u>** Get a block of wood or stone and cut it to the size of the opening of the horn. Carve it into a tapered or cone shape that will fit inside the horn. Leave enough space for the rawhide covering.



11. Cut the rawhide so it will wrap around the wood/stone cover.

12. Soak the rawhide in water for at least 15 minutes before using. This will make it expand and seal the opening of the horn tight. Wipe excess moisture off the cover before use.

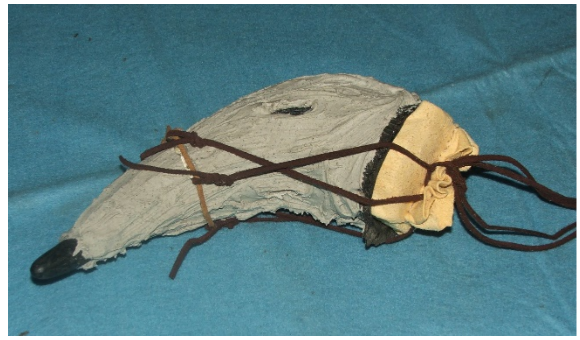
11. Cover the wood/stone with the damp rawhide and attach it to the cover with sinew. Make it tight. Make holes in the top of the rawhide cover about ¼" long to hold the strips of leather that secure the cover.

12. Cut leather into 5 strips, each about 14" long. These will be used to secure the cover.

13. Tie ends of four leather strips onto the fifth piece, which goes around the horn.

14. Tie the 5th piece of leather around the horn, about 1/3 of the way up from the bottom of the horn. Adjust the four loose strips so they are placed evenly around the horn.

15. Crisscross and lace the strips through the ¼” cuts made in the rawhide that covers the carrier cover.



16. When you have all pieces completed and they fit together perfectly, the fire carrier is ready to use. Open it and place burning coals on the flat stone in the middle. Put several pieces of hardwood on top of the burning coals to keep them in place. Put the cover on and tie the straps tight.

Appendix 3. Scientific names of plants and animals shown or mentioned in this lesson

Common name	Scientific name
buffalo	*Bos bison*
sarvisberry/Saskatoon serviceberry	*Amelanchier alnifolia*
arrowleaf balsamroot	*Balsamorhiza sagittata*
glacier lily	*Erythronium grandiflorum*
blue huckleberry	*Vaccinium membranaceum*
common chokecherry	*Prunus virginiana*
limber pine	*Pinus flexilis*
whitebark pine	*Pinus albicaulis*
willow	*Salix species*
western yarrow	*Achillea millefolium*
elk	*Cervus elaphus*
cottonwood	*Populus* species
quaking aspen	*Populus tremuloides*
pine	*Pinus* species
Fir, Douglas-fir	*Abies* species and Douglas-fir (*Pseudotsuga menziesii*)
birch	*Betula* species
buffaloberry	*Shepherdia canadensis*
prickly-pear	*Opuntia* species

24. Homes in the Forest: An Introduction to Firewise Practices

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 as they assess photos of wildland homes, make recommendations to the home owners, and justify their recommendations. Finally, they assess fire safety in a photo of a whole neighborhood.

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

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

Duration: one class period

Group Size: Whole class

Setting: Indoors

Vocabulary: *firewise*

Objectives: Students can…

- assess the fire hazards on and around homes in wildland settings.
- assess the fire hazards in neighborhoods that are embedded in wildland settings.
- recommend steps to improve home and neighborhood safety.
- give reasons for their recommendations based on their understanding of fire and fuels.

Standards:		6th	7th	8th
Common Core ELA	Writing	1,4	1,4	1,4
	Speaking and Listening	1,2,4	1,2,4	1,2,4
	Science and Technology	7	7	7
NGSS	Human Impacts	ESS3.B, ESS3.C		
	Engineering Designs	ETS1.A, ETS1.B		
EEEGL	Strand 1	A,C,E,F,G		

Teacher background: This activity challenges students to apply their knowledge about fire science to a real-world problem – the safety of homes and neighborhoods that or mixed in with wildlands. While the activity helps students integrate and apply their knowledge about fire, it is no substitute for a thorough assessment of home safety. The Firewise website https://www.nfpa.org/Public-Education/By-topic/Wildfire (produced by the National Fire Protection Association) provides excellent materials for that purpose. All photos in this activity were obtained from the Firewise homepage.

Here are the main Firewise questions that apply to the photos used in this activity. Discussion points are provided in **Step 6** of the **Procedures** below.

- Are there any ways that a surface fire could spread from the edge of the forest right up to the home?
- 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?
- Are there ladder fuels at the base of trees near the house, or are there trees arching over the house?
- Do you think the road is wide enough and good enough for a fire engine to get to the house – and then to turn around and leave?
- Are there ways to keep a fire from spreading from a single home throughout an entire neighborhood?

Materials and Preparation:

- Download and project ***M24_FirewiseHomes1.pptx***. This presentation contains photos of 4 homes for class discussion. If you want additional material for class discussion, download ***M24_FirewiseHomes2.pptx,*** which has another 8 photos. Slides and notes for the second presentation are in the **Appendix.**
- Make copies of **Handout M24-1: Making the rules and using them** for half of the class; make copies of **Handout M24-2: Making the rules and using them**, for the other half.

Procedure:

1. Write on the left side of the board: “Many wildland ecosystems need 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, stand up. Regardless of how many students stand up, have some discussion on this point. Ask for a few 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 are both true, but they also create a problem. What can we do with wildland fire? What should we do? What do you suggest? Discussion. Have students explain why they do or do not want fire, who might benefit and who might suffer from having more or less wildland fire, and what might be done to reduce risk. Ask them to explain their reasoning based on their understanding of fire and fuels. Try to get to the idea that people <u>can take action</u> to reduce the risk of injury and damage to their homes from wildland fire.

5. On the board, make a list with 2 columns: “Good job!” and “Needs work:” Explain: We’ll look at photos of a few homes in wildland settings. For each photo, we’ll list under “Good job!” some things that the home owner has done “right” to prevent the house from burning, and we’ll list under “Needs work” some things that the home owner should still work on.

6. Go through ***M24_FirewiseHomes1.pptx*.** With each slide, ask students to comment on features that show a “Good job!” and others that show “Needs work.” Also ask if they think a fire around this home is likely to spread throughout the neighborhood. Direct discussion with questions like these, and have the students explain their reasoning:

   - 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 they spread especially well in fine surface fuels. It is harder to burn wet fuels than dry fuels. It is harder to burn green fuels than dead (and 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, or are there trees arching over the house? Why does it matter? Heat rises… embers can fly and branches can fall from a burning tree crown.

   - Do you think the road is wide enough and good enough for a fire engine and a water tanker to get to the house – and then to turn around and leave? This question is not likely to emerge from their study of fire science, but encourage students to look for practical, logistical problems like this – and to propose solutions.

   - Can you think of ways to reduce the chances that a fire might spread from this single home throughout the entire neighborhood? All of the principles above apply to this question. Areas with sparse or discontinuous fuels, green fuels, and fuel breaks can all help. In addition, well-marked roads and safe road access for engines and water tankers (including sufficient width or pullouts that allow evacuees to leave as fire control vehicles come in) are extremely important in protecting neighborhoods.

Slide 1

Slide 2

Good job! Screened in porch is good, 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. Replace wooden latticework under porch with impermeable surface.
Neighborhood issues: It looks like trees are dense and continuous around this house. If the crowns are dry – perhaps in fall – fire could spread through the neighborhood.

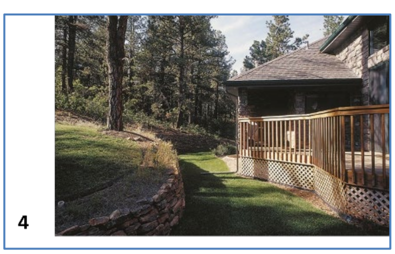
Slide 3

Good job! Roof looks clean, there's little vegetation next to house, there are no trees overhanging the house.
Needs work: Replace wood shake roof, rake needles from under trees.
Neighborhood issues: It looks like trees in the area may be well spaced; that would be good. If pine litter is continuous throughout the neighborhood, that should be removed, probably every spring.

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.
Neighborhood issues: There may be a road above the house; that would be a good fuel break, although trees could be thinned a bit to reduce crown continuity. Just hope no one lives on the steep hillside above this property – and burning debris doesn't roll downhill if a fire occurs up there.

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: Replace wooden latticework under deck with impermeable surface. Make sure there's no flammable stuff under there. Replace bark chips below deck with rocks.

Neighborhood issues: It looks like trees and surface fuels uphill from the property are continuous and fairly dense, so a fire on this property could easily spread through them. In addition, if a fire occurs uphill, burning materials could roll down to the base of this house.

7. If you want to evaluate more photos, go through ***M24_FirewiseHomes2*.pptx**. The slides and notes are included at the end of this activity.

Assessment:

1. Give each student a copy of either **Handout M24-1** or **Handout 24-2** (**Making the rules and using them**).
2. Have them complete their individual handouts.
3. Explain: Now you will become Fire Safety Officers. Pair up with someone who completed the other handout. Trade handouts and work together to improve them so both handouts provide the BEST POSSIBLE RECOMMENDATIONS to protect the home and the neighborhood from wildland fire.

Evaluation: Here are some points that the students could make on their handouts.

<table>
<tr><th>Evaluation:</th><th colspan="2">Complete</th><th>Incomplete</th></tr>
<tr><td>Question #1: The five rules could include any of these – and more!</td><td colspan="2">-Keep the roof and eaves free from burnable things, like pine needles, branches, birds' nests…
-Make sure the roofing material is not flammable.
-Make sure you have a strip of un-burnable stuff between the yard and the house.
-If shrubs are close to the house, make them short and far apart. Avoid highly flammable species, such as juniper and pfitzer bushes.
-If trees are near the house, get rid of low branches so they won't have ladder fuels.
-If trees arch over the house, trim branches that are close to the roof or likely to fall on it.
-Keep vegetation around the house green. Keep grass mowed short.
-Keep junk from accumulating under the deck, steps, etc. – or leaning against the foundation.
-Make sure the road is wide enough for a fire engine or tanker to get in while people are getting out. Make sure there's a place big enough for a vehicle to turn around.</td><td>Student listed <5 rules or listed incorrect/irrational rules.</td></tr>
<tr><td>Question #2a: Good Job!</td><td>**Handout M24-1**
-Roof looks clean and nonflammable.
-Woods near house are open; tree crowns are discontinuous.</td><td>**Handout M24-2**
-Cabin might have a metal roof.
-There seems to be little vegetation next to cabin.</td><td>Student did not write about "good job" items that were correct and relevant to their photograph.</td></tr>
<tr><td>Question #2b: Needs Work.</td><td>-Embers can get under the deck and stuck in that structure by the side steps.
-Mow grass near house.
-Water grass. Get it green if possible.
-Can't see any way for a fire engine to get in or out.</td><td>-Put barriers around foundation and bottom of porch so embers cannot get under there.
-Clean up litter and dead logs lying near cabin.
-Trees are close to cabin and lean over it. Remove some trees or at least make sure low branches are trimmed</td><td>Student did not write about "needs work" items that were correct and relevant to their photograph.</td></tr>
</table>

	-Worry about burning stuff rolling down the hill into all that dry grass.	and dead branches removed from roof regularly. -There's no sign of access for vehicles to get in or out.	
Question #2c: Why?	-Heat rises, so embers under wooden parts of the house can ignite it. -Fine fuels ignite easily. -Dry fuels ignite easily.	-If flaming branches land and smolder on roof, even if the roof is metal, they could eventually ignite the beams inside. - Heat rises. Embers under wooden parts of the cabin can ignite it. -Fine fuels near the cabin will ignite easily if they are dry.	Student did not write a logical response.
Question #3a: Improve neighborhood safety.	-Vegetation in both photos is continuous. In Handout 1, shrub vegetation is continuous; in Handout 2, tree crowns are continuous. Could fire suppression crews enter these areas safely? -Identify or establish some areas that have little or no fuel. These areas could be used to stage fire suppression equipment and also as safety zones for firefighters and residents. Make sure fire crews and residents know about these areas. -Consider placing cleared, open areas downhill from homes (especially important in Handout 1), since a fire moving uphill is very difficult to control. -Encourage residents to follow Firewise practices around their homes, in particular keeping fuels green throughout the summer.		
Question #3b: Problem for fire engine crew?	The photos don't provide detailed information on roads or access. Roads may not be wide enough or straight enough to maneuver an engine or water tanker safely. It may be hard to find a specific address. Is there any place where an engine or tanker could turn around? Are there blind corners where a vehicle going in might run into residents coming out?		

Handout M24-1. Making the rules and using them

Name: _______________

1. Use the “Good Job”/”Needs Work” list on the board to write 5 rules for improving a home’s chances of surviving a wildland fire. Write the rules so they sound like orders, such as “Do this,” “Do not do that.” This is called the “imperative voice.”
   a. ____
   b. ____
   c. ____
   d. ____
   e. ____

2. Use your 5 rules to evaluate the house in **Photo A**.
   a. Good Job:

   b. Needs work:

   c. Using your knowledge of fuels and fire, EXPLAIN WHY will this work will improve the home’s chances of surviving a wildland fire:

3. **Photo B** shows a neighborhood in a wildland setting.
   a. List one change that would reduce the chances that a wildland fire would spread through the whole neighborhood:

   b. List one problem that a fire engine crew might have in trying to protect this neighborhood:

Handout M24-2: Making the rules and using them

Name: _______________

1. Use the "Good Job"/"Needs Work" list on the board to write 5 rules for improving a home's chances of surviving a wildland fire. Write the rules so they sound like orders, such as "Do this," "Do not do that." This is called the "imperative voice."
   a. ____
   b. ____
   c. ____
   d. ____
   e. ____

2. Use your 5 rules to evaluate the cabin in **Photo A**.
   a. Good Job:

   b. Needs work:

   c. Using your knowledge of fuels and fire, EXPLAIN WHY will this work will improve the cabin's chances of surviving a wildland fire:

3. **Photo B** shows a neighborhood in a wildland setting.
   c. List one change that would reduce the chances that a wildland fire would spread through the whole neighborhood:

   d. List one problem that a fire engine crew might have in trying to protect this neighborhood:

Appendix. Slides and notes for *M24_FirewiseHomes2.pptx*

Slide 1

Slide 2

Good job! Asphalt shingles – that's good; they are fire resistant.
Needs work: Clean the roof, then the rain gutters! Prune the limbs of trees that hang over the roof.
Neighborhood issues: This photo doesn't give us a feel for fuels in the neighborhood.

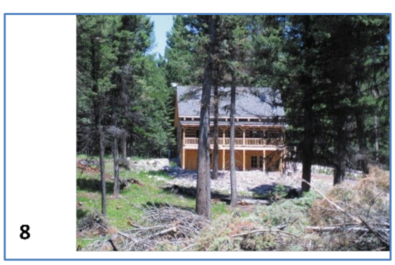
Slide 3

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. If that's a shingle roof, replace it with something fire resistant or nonflammable.
Neighborhood issues: Fuels look dense and continuous. Fuel breaks, thinning of trees, and reduction of shrub continuity would help.

Slide 4

Good job! Asphalt shingles – that's good because they are fire resistant.
Needs work: Clean the roof! Trees seem to be hanging over the house, and limbs surround the chimney. Clear the branches away.
Neighborhood issues: It looks like there are a lot of trees in the area… and many are deciduous. This means home owners should plan to clean their roofs and rake their yards at least once a year.

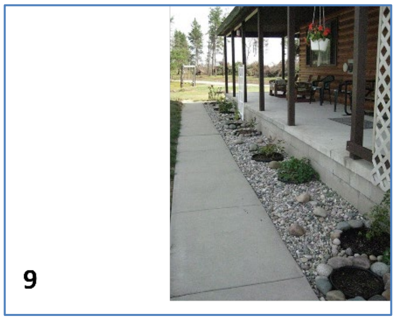
Slide 5



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 and roofing material is fire resistant.
Needs work: Get rid of logging slash. Prune lower branches from trees, especially in back of house. 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.

Neighborhood issues: It looks like trees are quite dense and crowns are continuous outside the cleared, gravel-covered area; some further thinning would be good. Wherever it occurs, slash MUST be removed!

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.
Neighborhood issues: Looks pretty good. You can even see good road access. Hope that is consistent throughout the neighborhood.

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? Replace them with something nonflammable, like rocks or gravel. Keep the landscaping shrubs watered and moist.
Neighborhood issues: Hard to tell from this photo.

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 other than maintenance.
Neighborhood issues: As the dead needles fall off the scorched trees and shrubs near the house, they should be removed; if they cover the rock landscaping, they transform it into a fuel bed!

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. Burning debris could roll

down the hill behind the house, so keep that area as clear of fuels as possible. If the driveway is back there, that would be good. If it's lawn, keep it green.

Neighborhood issues: Looks pretty good – including the side gravel road. Just hope no one lives on the steep hillside above the home. If a fire starts uphill, burning materials can roll down to the foundation of this house unless it has a barrier or fire-resistant landscaping.

25. Revisiting Wildland Fire

Use this activity only if you used Activity M01. Visiting Wildland Fire.

Subjects: Science, Writing, Speaking and Listening

Duration: one half-hour session

Group size: Whole class

Setting: Indoors

Vocabulary: *fire manager*

Lesson overview: Students return to the presentation that they viewed as they began studying wildland fire (***M01_VisitingWildlandFire.pptx*** in **Activity M01**). This time, they narrate the presentation themselves. Then they compare and contrast their current feelings about wildland fire with their earlier ones. Finally, they assess the content and difficulty of a fire manager's job.

Goals: Review students' knowledge about wildland fire behavior, effects, and management. Demonstrate to students how much they have learned. Demonstrate that learning can affect feelings, and feelings about a complex issue can change over time – or become stronger!

Objectives:

- Students can use what they have learned about wildland fire to narrate a presentation that surveys the content of this curriculum; in their narration, they can describe different kinds of fire behavior and relationships between fire, organisms, and ecosystems.
- Given a record of their feelings about wildland fire at the beginning of the curriculum, students can articulate and discuss their feelings and ways in which they may have changed.
- Students can describe some of the challenges facing wildland fire managers and assess the difficulty of the job and whether they would like to do it.

Standards:		6th	7th	8th
Common Core ELA	Writing	1,3,10	1,3,10	1,3,10
	Speaking and Listening	1,4,6	1,4,6	1,4,6
	Science and Technology	8	8	8

NGSS	Interdependent Relationships in Ecosystems	LS2.A,LS2.C,LS4.D
	Human Impacts	ESS3.B,C
	Weather and Climate	ESS2.C
	Matter and Energy in Organisms and Ecosystems	LS2.C,B
	Natural Selection and Adaptation	LS4.C
	History of Earth	ESS2.A
EEEGL	Strand 1	A,C,E,F,G

Teacher background: This activity provides a way to review concepts covered throughout the curriculum and an opportunity for students to articulate and validate their feelings about wildland fire and the challenges of managing fire.

Materials and preparation:

- Decide how many student teams you will use. Team size of 3-4 students is recommended. You need a computer or other digital display for each team, or you can make handouts of the presentation for each group.
- Make a copy of the presentation ***M25_RevsitingWildlandFire.pdf*. ….** Be sure to use the .pdf version because it does not have any notes in it. The notes would make the students' job way too passive and easy. Place this version of the presentation on each team's computer. ALTERNATIVE: Print a copy of the presentation for each team. If you want to print more than 1 photo per page, use the Powerpoint version; in the "Print" menu, under "Slides", select an option that does NOT include the notes.
- Find the flipchart with questions that students asked about fire in **Activity E01. Visiting Wildland Fire**. Post it in the classroom.
- Find the copies of **Handout M01-1** (containing sketches of fire behavior and a few other thoughts) that students completed in **Activity M01.**

Procedure:

1. Explain: To complete our study of wildland fire, we'll answer some of the questions that we raised when we began to study fire, and we'll revisit the feelings about wildland fire that we noted at that time. We'll view the presentation that we watched then, but this time we'll

explain the slides ourselves. We'll use what we have learned and as we studied fire to consider the challenges of a fire manager's job.

2. Refer to the flipchart that you made in **Activity M01** (listing students' questions about wildland fire). Explain: We probably know the answers to most of these questions now. Ask for answers to each question. If students can't answer, help them or suggest ways to find the answers. Discussion.

3. Group students into teams of 3-4, where each team has a computer with ***M01_VisitingWildlandFire.pdf*** or ***handouts*** of the presentation. Explain: In your team, you will view the same presentation that you saw when we first began studying wildland fire, but YOU must narrate it. Stop at each slide that shows fire behavior, and describe it using some of the terms we've learned, such as **fire severity** and **fire frequency**. Stop at each slide that shows a plant or animal, identify the organism, and describe how it is related to wildland fire. Use some of the terms we've learned, such as **cambium, rhizome, serotiny,** and **fire dependent.**

4. After the small group activity, go through the slideshow with the class as a whole. Ask a different student to explain each slide. Here are some notes that may help you check the students' narration and prompt them for additional information:

Slide 1


Photo by Garon Smith

Here is a look at some of the wildlands that you might see in the northern Rocky Mountains and the North Cascades. We don't see any flames in this picture, but fire has visited here in the past. We know that because, over the past hundreds of years, fire has visited nearly every landscape in this region. Unless an area was covered by snow, water, or rock, it probably has a history of fire.

Slide 2


Photo by Ilana Abrahamson

Here is a low-severity surface fire burning in a ponderosa pine/Douglas-fir forest. The only fuels burning are surface fuels: litter, fallen trees and branches, and low plants, including grass, wildflowers, shrubs, and tree seedlings. Duff could also be burning, especially where it is deep at the base of the big tree; we can't tell from this photo.

Slide 3


Photo by Ilana Abrahamson

This is what the land looks like after a low-severity fire. Most of the seedlings in this burned stand of ponderosa pines and firs are dead. Most of the litter has been removed. The fire is mostly out, but duff could be smoldering at the base of the big pine.

Slide 4


Photo by Emily Heyerdahl, USFS   Photo by Brady Smith, USFS

Many ponderosa pine trees survived low-severity surface fires every few years or decades until about 1900. Since 1900, there have been few surface fires. As a result, lots of undergrowth has developed. These ladder fuels can help surface fires get into the crowns of the big old trees.

Slide 5

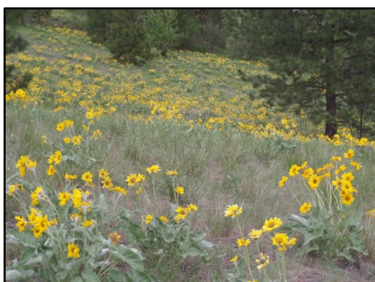


Photo by Ilana Abrahamson

This is arrowleaf balsamroot, a wildflower that occurs in low-elevation forests dominated by ponderosa pine. It has a thick underground stem called a caudex, which enables it to survive most fires and reproduce really well after fires.

Slide 6

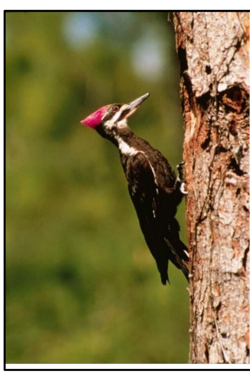


Photo by Superior National Forest

This is a pileated woodpecker, which feeds on insects (mostly ants) and loves to nest in big, old trees. Many big trees have persisted and avoided being killed by crown fire because frequent low-severity fires removed the young trees growing beneath them. This removed ladder fuels and competition for moisture from understory plants, so the big trees thrived and continued to grow, even if their tops broke off and their heartwood began to decay. Pileated woodpeckers prefer to nest in broken-topped trees with heart rot because the inner wood is soft and easy to excavate.

Slide 7


Photo by Dave Smith

This is a stand-replacing fire running through the crowns in a stand of lodgepole pines. Severe fires like this are typical in lodgepole pine forests of the northern Rocky Mountains and the North Cascades. The fires are able to spread easily through the tree crowns, especially when driven by wind, because the crowns grow close together and have interlocking branches. Stand-replacing fires are typical in lodgepole pine forests every hundred years or so. If fires don't kill the pines when they are mature, mountain pine beetles often do so.

Slide 8

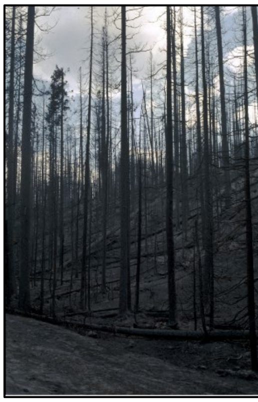


Photo by Hansueli Krapf

Stand-replacing fires, as their name suggests, kill most of the trees in a stand. Unburned patches may be left, although this photo doesn't show any. After fire, the ground is covered by ash. This means that there is no surface vegetation or litter left to protect the soil from the impact of raindrops and subsequent erosion. By the next spring, however, there will probably be a lot of herbs and shrubs sprouting from their "buried treasures" (bulbs, rhizomes, caudices, corms, etc.) that survived the fire.

Slide 9


Photo by AG Prof. Schmitz

Lots of insects come to a forest after fires to feed on the damaged or dead wood. This beetle is one of the first to arrive. It can detect heat from miles away; it comes to burned areas while the fires are still smoldering and lays its eggs under the bark. The environment inside the bark is protected from weather extremes and most predators, so it provides both protection for the eggs and food for the larvae when they emerge. Another beetle that we studied in class is the mountain pine beetle, which feeds on the cambium of mature, living pines and thus kills the trees.

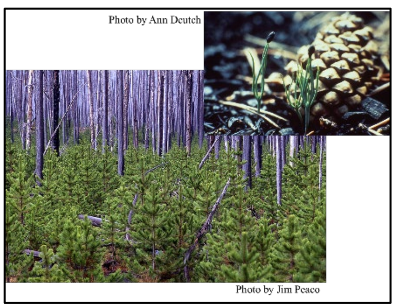
Slide 10

Here is a black-backed woodpecker. This bird arrives soon after severe fires to eat the insects under the bark of the dead trees - eggs, larvae, and adults of various species. It will nest in the area, probably in a broken-topped tree that has some heart rot. It will stay around for a few years but, as food supplies decline, it will move on to a newly burned area.

Slide 11

Here is a patch of fireweed. This plant has underground stems (rhizomes) that survive most fires. It sprouts in the year after fire and flowers abundantly because it has lots of sunlight, plenty of water (previously used by the trees), and plenty of nutrients in the ash layer. In the next few years, it will produce millions of seedlings and flowers.

Slide 12



Here are thousands of Rocky Mountain lodgepole pine seedlings that became established after a severe fire. They came from seeds in serotinous cones. Before the fire, the cones were sealed by a hard resin and stored throughout the tree crowns. The fire melted the resin, and the cones opened as they dried out. Their seeds fell out and found perfect conditions on the ground for germination and establishment: lots of sunlight, bare soil, and moisture (which had been taken up by the mature trees in the past).

Slide 13

Here is a mixed-severity fire; it is burning in surface fuels and occasionally torching individual trees or groups of trees. This is a high-elevation forest with whitebark pines and subalpine firs. Many of the whitebark pines are dead, however – killed by white pine blister rust and/or mountain pine beetles. Fires don’t occur often in these forests because they are relatively cool and summers are short. When fires do occur, they tend to be patchy because surface fuels are discontinuous. The forest doesn’t have continuous tree cover, like lodgepole pine forests do, so it rarely supports running crown fire.

Slide 14


Photo by Ilana Abrahamson

Here is a whitebark pine stand where most of the trees are dead. They may have been dead, killed by white pine blister rust and/or mountain pine beetle, even before a fire came through. Some plants are growing here, but there is also a lot of bare soil. It will be a long time before the site has surface fuels continuous enough to burn again. We can see a few whitebark seedlings in the photo, as well as some other trees. Many whitebark communities have lost so many trees to white pine blister rust and mountain pine beetle that there are no seeds available for generating a new whitebark pine forest.

Slide 15


Photo by Famartin

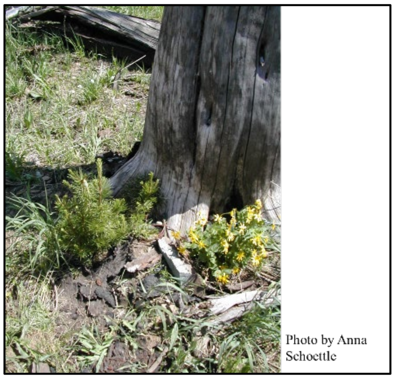
This big old whitebark pine has probably survived several fires – or perhaps it is growing in gravelly soils, where there are no surface fuels through which a fire could reach it. Notice the upward-reaching branches (different from the pointy shape of subalpine firs, its main competitor). The cones of whitebark pine also stick up or outward from the branches rather than hanging down. This makes it easy for Clark's nutcrackers to find the cones, pull them apart, and extract the seeds.

Slide 16


Photo by Michael Sulis

Here is a Clark's Nutcracker. This bird harvests the seeds of whitebark pines and caches many of them underground so it can eat them later. It likes to bury seeds in places where a lot of landmarks are visible; this apparently helps the bird relocate its caches. Burned areas provide ideal cache sites because downed logs, rocks, and patches of unburned trees provide good landmarks. The nutcracker doesn't retrieve every seed that it buries, so some germinate and grow even in the middle of large burns, which wind-dispersed seeds can't easily reach.

Slide 17



Whitebark pines often become established in clusters of 3 to 5 or more trees because several seeds from a single cache germinate at the same time. This cluster of whitebark pine seedlings probably grew from seeds in a nutcracker cache. The seedlings are getting a little protection from wind and sun from the dead tree towering above them. They may also be getting a little extra moisture from rainfall dripping down the trunk and snow that drifts around it in winter.

Slide 18

Wildland fires can burn for days or weeks after the flames have passed. They may burn in tree trunks, roots, duff, or the organic portion of the soil itself. The changes caused by the fires last a long time too - sometimes for hundreds of years. Fires can be very dangerous and destructive, but they can also create habitat that is essential for some plants and animals.

5. Return students' copies of **Handout M01-1**, the sketches of fire behavior that they made during **Activity M01.**

6. Explain/ask: Feelings are not "right" or "wrong," but they are important to us, and they influence our thoughts and actions. Read your answers to the final question on the handout, in which you described your feelings about wildland fire. Is anyone willing to describe their feelings about wildland fire and how they may have changed – or not – because of what we've learned? Discussion.

7. Explain/ask: We have a variety of strong feelings about fire in our class. Variety and strong feelings are typical in most communities near wildlands. A fire manager needs to take care of the ecosystems, provide for the safety of communities and firefighters, and answer to the people in the communities. What specific things do you think fire managers should do on the job? How hard would it be to get those things done? Brainstorming. Thoughts might include finding and putting out fires, providing fire in ecosystems where it is needed, helping people become "firewise," reducing fuels or fuel continuity in areas where it is needed….

Assessment:

1. Explain: Write a paragraph in which you describe your feelings about wildland fire and compare your feelings now with your initial feelings, recorded on **Handout M01-1**. Give at least three specific examples of how your feelings of wildland fire have changed or not after studying fire. Explain why.

2. Write a paragraph to answer these 3 questions: What are at least 3 things that you think a fire manager should do? What would be the biggest challenges in that job? Would you like to do it?

Evaluation:

	Full Credit	Partial Credit	No Credit
Small Group Discussion	-Student actively and frequently participated and listened during discussion. -Student gave others a chance to speak.	-Student gave a few contributions to the discussion. -Student listened to others.	-Student did not contribute. -Student was not listening or was distracting others.
Class Discussion	-Student contributed at least once during the large group discussion. -Student listened to others.	-Student did not contribute to large group discussion but was listening.	-Student did not contribute and was not listening or was distracting others.
Writing Assignment - feelings	-Student wrote a complete paragraph that clearly compared/ contrasted feelings. -Student provided 3 examples.	-Student wrote an incomplete paragraph that compared/ contrasted feelings. -Student provided 2 examples.	-Student wrote a poorly structured paragraph. -Student provided 0-1 example.
Writing Assignment – fire manager's job	-Student wrote a complete paragraph that answered the questions. -Student listed 3 or more requirements of the job. -Student stated whether or not he/she would like the job.	-Student wrote an incomplete paragraph or did not answer the questions. -Students listed just 2 requirements of the job. -Student stated whether or not he/she would like the job.	-Student wrote a poorly structured paragraph or did not answer the question. -Student provided 0-1 requirements of the job. -Student did not state whether or not he/she would like the job.