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FireWorks Curriculum Featuring Ponderosa, Lodgepole, and Whitebark Pines

March 2019

by Jane Kapler Smith, Ilana Abrahamson, Caitlyn Berkowitz, and Nancy E. McMurray

**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 (dominated mostly by ponderosa

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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/](https://www.feis-crs.org/feis/)).

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.

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

- EEEGL: Excellence in Environmental Education: Guidelines for Learning ([http://resources.spaces3.com/89c197bf-e630-42b0-ad9a-9f0bc55c72d.pdf](http://resources.spaces3.com/89c197bf-e630-42b0-ad9a-9f0bc55c72d.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).

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

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.

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<thead>
<tr>
<th>Unit &amp; Theme</th>
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<th>MIDDLE</th>
<th>HIGH</th>
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<td>M01. Visiting Wildland Fire in the Northern Rocky Mountains and North Cascades</td>
<td>H01. Introduction to Wildland Fire in the Northern Rocky Mountains and North Cascades</td>
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<tr>
<td></td>
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<td>H06. Pyrolysis</td>
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<td>H07. Fire Spread Processes: Putting it all together: Heat transfer, fuel properties, and pyrolysis</td>
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<td>M08. Fire Behavior, Fire Weather, and Climate</td>
<td>H09. Ladder Fuels and Fire Spread</td>
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<td></td>
<td>See H05.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H10. Fire Behavior, Fire Weather, and Climate</td>
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<tr>
<td></td>
<td>M10. Fire, Soil, and Water Interactions</td>
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<td>H12. Fire, Soil, and Water Interactions</td>
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<th>H14. Researching a Plant, Animal, or Fungus</th>
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<td>M13. Tree Identification: Figure out the “Mystery Trees”</td>
<td>H13. Tree Identification: Create a Dichotomous Key</td>
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<td>E11. Recipe for a Lodgepole Pine Forest: Serotinous Cones</td>
<td>E11. Is appropriate for middle school</td>
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<td>M14. Who Lives Here and Why? Modeling Forest Communities</td>
<td>H15. Forest Communities and Climate Change</td>
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<td>M15. Bark and Soil: Nature’s Insulators</td>
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<td></td>
<td>M22. Fire Ecology Puzzler</td>
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<td>M23. Carrying Fire the Pikuni Way</td>
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<tr>
<td>E17. Revisiting Wildland Fire</td>
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Unit I.
Introduction to Wildland Fire
Lesson Overview: Students view a narrated photo presentation that shows wildland fires and some of the plants and animals they are going to learn about in this curriculum. The photos and narrative are in a PowerPoint presentation, also shown at the end of this lesson. During the presentation, students record their observations about fire behavior. Afterwards, they discuss their observations and feelings about the presentation. The presentation’s narrative is brief because this activity is meant to orient the students and let them express their feelings about fire – not to teach science content.

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

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

<table>
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<th>4th</th>
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<td>2, 7, 10</td>
<td>2, 7, 9, 10</td>
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<td>Ecosystems: Interactions, Energy, and Dynamics</td>
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<td>LS2.A</td>
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<td>Earth’s Place in the Universe</td>
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<td>ESS1.C</td>
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<tr>
<td>Engineering Design</td>
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<td>ETS1.B</td>
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<tr>
<td>Earth’s Systems</td>
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<td>ESS2.D</td>
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</table>
Teacher Background: If you walk through a recently burned area, you might encounter some places where all the vegetation looks dead and other places that have a lot of green vegetation left. You might see deep holes in the ground where roots have burned away, and you might see patches of leaf litter that is just lightly scorched. Fire behavior and fire effects vary with topography, weather, and vegetation. As a result, some patterns are typical of certain kinds of landscapes and vegetation. For example, steep hillsides are more likely to support fast-moving fires than flatlands or moist ravines, and forests with trees close together are more likely to support crown fires (spreading through the tree canopy) than forests where the trees are far apart. As an introduction to the study of wildland fire, this photo presentation highlights variation in fire behavior and its relationship to specific plants and animals.

This version of FireWorks 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 (pp. ii-iii) for an overview of these ecological communities.

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

Materials and preparation:

- Load photo presentation E01_VisitingWildlandFire.pptx
- Copy Handout E01-1 for each student
- Make a sketch of Handout E01-1 on the board—all three sections—or project it
- Set up flipchart or other media for recording questions and feelings. You’ll want to look at this list at the end of the unit on fire: Lesson E16, “Revisiting Wildland Fire”
- Have students get out crayons or markers, clean paper, and pen or pencil.

Procedure:

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

2. Give out copies of Handout E01-1. Explain that you’ll let students know when you’d like them to draw.
3. Show the presentation. You can use the narrative in the presentation notes below or give your own narrative, but keep it brief. Welcome students to discuss and ask questions about what they see. Record the questions on a flipchart or other medium, but don’t necessarily try to answer them during the presentation. Instead, explain that the class will seek the answers during this unit on wildland fire.

**Slide 1**

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**

Here is a fire burning in a forest of the northern Rockies/North Cascades. **Explain:** We’re going to make some observations so we can learn how wildland fires vary. We’ll do the first one together. Look carefully at the flames in this photo and describe them: How long are the flames? What parts of the plants are they burning? What “layer” of vegetation is burning – just material on the ground? … only needles in the tree tops? Ask the students to make their own sketches of the fire behavior in Part A on their handouts. They should draw flames only in the parts of the vegetation that they see on fire in the photo.

**Slide 3**

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

**Slide 4**

Here are some plants and animals that live in the forest after fire: A ponderosa pine tree that has survived many fires.
Slide 5

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

Slide 6

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

Slide 7

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. Sketch the fire behavior on your handout (part B).

Slide 8

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

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

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

Lodgepole pines that grew from seed after fire.

Here is a third 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. Sketch the fire behavior on your handout (part C).
This is what the land looks like after that kind of fire.

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

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

A clump of whitebark pine seedlings that sprouted from seeds that nutcrackers buried
Fires in our forests can burn for a long time after the flames have passed. They may burn in tree trunks, in roots, or in the soil itself. The changes they cause last a long time, sometimes for hundreds of years. We’ll learn more about all kinds of wildland fire in the activities to come.

4. Prepare for writing assignment: Ask the students to look at the first two kinds of fire behavior (A and B). Write “Same” and “Different” next to them, and ask students to describe to the class some ways in which the two kinds of fire are similar and different. Note some of their comparison/contrast phrases on the board.

5. Ask the students how they feel about the fires that they saw in the presentation. Record their “feeling words” on a flipchart or other medium so you can discuss them again at the end of the curriculum. Explain that people’s feelings often differ without being “right” or “wrong,” so all of the feelings from class members are valid and deserve respect.

6. Keep the flipcharts that list students’ questions and feelings. You will use them for Activity 16, “Revisiting Wildland Fire.”

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

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

**Evaluation:**

<table>
<thead>
<tr>
<th></th>
<th>Present</th>
<th>Not-Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fire Similarity Sentence(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Fire Contrasting Sentence(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Fire Feelings</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Color each sketch to show a typical fire.

   A. Ponderosa pine:

   B. Lodgepole pine:

   C. Whitebark pine:

2. Write:
   Write a sentence about how fires B and C are the same.

   Write a sentence about how fires B and C are different.

   Write at least two words that describe your feelings about the pictures.
Unit II.
Physical Science of Wildland Fire
Lesson Overview: In this activity, students describe and organize what they already know about fire so it fits into the conceptual model of the Fire Triangle. They examine the geometric stability of a triangle and how that property applies to fire.

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

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

<table>
<thead>
<tr>
<th>Standards:</th>
<th>1st</th>
<th>2nd</th>
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</table>

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

For more background on the chemistry of combustion, see the Teacher Background section of Middle School Activity 3 (M03) or High School Activity 3 (H03).


Materials and preparation:

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

Procedure:

1. Explain: Students will share what they already know about fire and then organize this knowledge to better understand what makes fires burn and what makes them go out.

2. Ask students what is needed to make a fire. List their responses on the board (they may include matches, paper, cardboard etc. as well as wildland fuels). Try to write them in three loose clusters (fuel, heat, and oxygen), which you’ll label later.

3. Ask students to come up with a word that describes each category. Guide them to the concepts of fuel, heat, and oxygen, and then label the categories. These are the 3 parts of the Fire Triangle. You may need to explain what oxygen is: an invisible gas, one of several “ingredients” in the air we breathe. It comprises about 21% of air, and we use only about 20% of that in a single breath. If we used all of it, cardiopulmonary respiration (CPR) would not work!

4. Display the Fire Triangle poster (FireTrianglePoster.pptx) and/or label the sides of your drawing. Explain: you can use a triangle to illustrate what makes fires burn and what makes
them go out. Triangles are used in constructing buildings and bridges because they are much stronger shapes than squares or other many-sided shapes. (OPTIONAL MATHEMATICAL EXERCISE: Ask students to use their gumdrops and toothpicks to make a triangle, a square, and a pentagon. See which one is most stable and which is easiest to deform.)

5. Ask each student group to:
   a) Build a triangle from gumdrops and toothpicks, make a small label for each leg of the triangle (fuel, heat, oxygen), and attach the label with tape.
   b) Show each other what happens when one leg of a triangle is removed. (The triangle collapses.)
   c) Put the triangle back together and use it to explain to each other what happens to a fire when one component of the Fire Triangle is removed. (The fire goes out, or fire cannot start in the first place.)

6. Ask students to explain how you can put a fire out using the components of the Fire Triangle. Examples:
   - When you throw water (or dirt, or use a household fire extinguisher) on a fire, you cut off oxygen and remove heat.
   - Fire retardant dropped from airplanes removes heat and cuts off oxygen from wildland fires.
   - When all the wax is gone from a candle, or all the fuel is burned in a campfire, or the gas tank in the car is empty, the fires go out.

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

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

<table>
<thead>
<tr>
<th>“Stop, Drop, and Roll” response</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
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<tbody>
<tr>
<td>- Identified oxygen and heat as the parts of the Fire Triangle removed.</td>
<td>- Identified oxygen or heat as a part of the Fire Triangle removed.</td>
<td>- Did not identify oxygen or heat as part of the Fire Triangle removed, but showed some understanding of the concept of Fire Triangle.</td>
<td>- Did not identify oxygen or heat as part of the Fire Triangle removed.</td>
<td>- Did not show understanding of the concept of Fire Triangle.</td>
</tr>
</tbody>
</table>

### Extension:

**Extension:** In 2012, the Alan Alda Center for Communicating Science ([https://www.aldacenter.org/](https://www.aldacenter.org/)) sponsored a competition to find an explanation of flames that would be understandable to an 11-year-old. The winning entry was a 7-minute video produced by Austrian scientist Ben Ames. As of August 2016, it is available at [http://vimeo.com/40271657](http://vimeo.com/40271657). This video cartoon describes the basic chemistry of combustion and the related processes of pyrolysis, oxidation, chemiluminescence, and incandescence. It even contains a theme song that helps viewers learn and pronounce these technical terms.
Lesson Overview: This activity contains three demonstrations in which students observe real fires to see how the conceptual model of the Fire Triangle applies to real combustion.

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

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

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Teacher Background – initial background is in the previous activity (E02). Further background: The three demonstrations in this activity show how the Fire Triangle model applies to actual combustion. In Demonstration 1, students observe the shape of a fire’s heat plume. In Demonstration 2, they see what happens when heat and fuels come together in different spatial arrangements. In the third, they observe what happens when a fire is deprived of oxygen (O₂). All three demonstrations use fire – burning individual matches or votive candles. Take all safety precautions outlined in the FireWorks Safety poster.
Demonstration 3 shows that oxygen is required for fire. We describe 2 ways to do this; both of them use carbon dioxide. Option A, which is written into the lesson below, uses carbon dioxide gas produced by mixing baking soda and vinegar; if you use this option, you can explore the chemical reactions between baking soda and vinegar. Option B, which is described after the "Evaluation" section at the end of the lesson, uses carbon dioxide gas produced from dry ice; if you use this option, you can explore the difference between phase change and chemical change.

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

\[
\begin{align*}
\text{vinegar} & + \quad \text{baking soda} \\
(\text{acetic acid}) &+ \quad \text{(sodium bicarbonate)} \\
\text{CH}_3\text{COOH} &+ \quad \text{NaHCO}_3 \\
\rightarrow & \quad \text{carbonic acid} \quad \text{sodium acetate} \\
& \quad \text{H}_2\text{CO}_3 \quad \text{NaCH}_3\text{COO} \\
\end{align*}
\]

[1]

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

\[
\text{H}_2\text{CO}_3 \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}
\]

[2]

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:

<table>
<thead>
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<th>Element</th>
<th>Atomic weight</th>
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<tbody>
<tr>
<td>Carbon (C)</td>
<td>12 g</td>
</tr>
<tr>
<td>Oxygen (O)</td>
<td>16 g</td>
</tr>
</tbody>
</table>

A mole of CO₂ weighs 12 g + 2 * 16 g = 44 g
A mole of O₂ weighs 2 * 16 g = 32 g

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

Additional background for Option B. When you use dry ice for this demonstration, you convert dry ice (frozen carbon dioxide) from the solid phase, at a temperature of -78.5 °C (-109.3 °F) or lower, into its gaseous phase. Note that carbon dioxide does not form a liquid at Earth’s atmospheric pressure, so it goes directly from the solid to the gas phase – hence the term “dry” ice. We say that the dry ice “sublimes,” and the process is called “sublimation.”
Materials and preparation:
We recommend doing this activity as three demonstrations for the whole class. First, choose your location. Demonstrations 1 and 2 can produce flames 10-15 cm long. Can you do this safely in your classroom and without setting off a smoke alarm? Can you take your students to a lab where it will be safer? It would be very difficult to do these demonstrations outdoors, because even the slightest wind will blow out single matches and candles.

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

- Display the FireWorks Safety poster (FireWorks_Safety_poster.pptx). Follow safety guidelines about clothing and hair when you prepare for this activity. Have a package of hair bands in your pocket so you can give them out if needed.

- Get a box of wooden kitchen matches. The box need not be full.

- Display the Fire Triangle poster (Fire Triangle poster.pptx from Activity E02) or simply draw it on the board.

- Set up your work station with this equipment:
  - Box of wooden matches
  - Fire extinguisher, fully charged
  - Spray bottle, filled with water
  - 1 ruler
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 2 votive candles
  - 2 beakers or other containers
  - 1 pair safety goggles
  - 1 oven mitt
  - 1 support stand
  - 1 metal rod with alligator clips at the ends
  - About ½ cup of baking soda
  - About ½ cup of white vinegar
  - a long fireplace match
  - 1 clamp

- Have a METAL trash can WITHOUT A PLASTIC LINER available.
Set up your demonstration table for **Demonstration 1** (see photo at right): Place the support stand in the center of the metal tray. Attach the clamp to the stand. Attach the metal rod with alligator clips so it forms a “+” with the stand. Place a wooden match in one alligator clip, with its tip pointing down.

![Demonstration setup](image)

Draw the illustration at left on the board or print/display it from the file *GraphForDescribingHeatPlume.pdf*.

**Procedure, Demonstration 1, “Where does the heat Go?”**

1. Explain: According to the Fire Triangle, a fire cannot burn if it does not have all three of these things: heat, fuel, and oxygen. Now we will watch fire burning individual matches to see if the model seems to be valid – if it “works” to explain what we observe. In this activity, the teacher will perform the demonstrations with student assistance.

2. Do a **Safety Briefing** using the FireWorks Safety poster (*FireWorks_Safety_poster.pptx*).

3. Organize your team:
   - An **Observer** who is dressed safely
   - A **Measurer**, also dressed safely
   - A data **Recorder**

4. Explain:
   - **Observer**: Your job is to find out how tall and wide the heat plume is from a burning match. You’ll start by holding one hand about 40 centimeters to one side of the match. When the match is completely on fire, you’ll bring your hand in closer until you can sense a change in temperature. The goal is to sense even a LITTLE warmth – NOT to see...
how close you can get without getting burned! We’ll use as many matches as needed to get observations from two sides of the flame, above it, and below it. When you make the “below” observation, don’t put your hand directly under the burning match, in case the tip breaks off and falls. Instead, hold your hand just a little to one side.

- **Measurer:** After each match is out, you’ll measure the distance from its tip to the observer’s hand (in centimeters).
- **Recorder:** You’ll mark an axis of the graph to show each measurement.

5. Light the first match. As soon as it is completely on fire, obtain a “side” measurement. After it goes out, USE THE OVEN MITT to remove it from the clip, put a fresh one in, and get a measurement from the other “side” ... then a “below” measurement... then an “above” measurement. Use as many matches as you need. Dispose of burned matches in the ashtray or on the metal tray.

6. Connect the marks on the four axes, making a roughly oval shape.

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

**Procedure, Demonstration 2, “Why Does the Match Go Out?”**

8. Organize your team:

- One student (the **Timer**) should measure the duration of burning (in seconds).
- One student (the **Measurer,** who is dressed safely) should measure the length of flames.
- One student (the **Recorder**) should record data.

9. Copy this table onto the board:

<table>
<thead>
<tr>
<th>Match is pointing...</th>
<th>Down</th>
<th>Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>How long did the flame get (centimeters)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How long did the match burn (seconds)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Why did the fire go out?</td>
<td></td>
<td></td>
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</tbody>
</table>
10. Place a downward-pointing match in one clip and an upward-pointing match in the other. Light a separate match and use it to ignite the downward-pointing one. Measure flame lengths and burning times and record measurements on the board. Repeat, if necessary. If you use additional matches, use the oven mitt to handle the alligator clips.

11. Ask: Why did the fire go out? Ask students to use the Fire Triangle to explain. The downward-pointing match probably burned almost completely. (Combustion is complete if you can pulverize any remaining pieces into powdery ash.) The fire went out mainly because it ran out of fuel. If a tiny stub of unburned wood remained in the alligator clip, it didn’t burn because the clip absorbed much of the heat and limited the oxygen getting to the fuel.

12. Light a match and use it to ignite the upward-pointing match. Take measurements and record them on the board. Repeat, if necessary. Ask: Why did the fire go out? Use the Fire Triangle to explain. The match went out before it burned completely, so it was NOT limited by fuel. It was not limited by oxygen either – since everyone in the classroom was still breathing comfortably. However, most of the heat was moving up, away from the fuel. If any heat was going down, it was not sufficient to keep the wood burning.

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

**Procedure, Demonstration 3, “Why Does the Candle Go Out?” Option A – using vinegar and baking soda**

13. Do safety reminders.

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

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

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

17. Spoon 1-2 tablespoons of baking soda around the base of the candle in the beaker, about enough to coat the bottom. Don’t get baking soda on the
candle itself. Alternatively, you can add the baking soda to an empty beaker and then place the candle on top of it.

18. Relight the fireplace match from the burning candle on the metal tray. Then use it to light the candle in the beaker to demonstrate that the baking soda did not alter its ability to burn. Then blow it out.

19. Pour about ¼ c (60 mL) of vinegar into the baking soda around the candle. Do this slowly so the mixture doesn’t foam so enthusiastically that it wets the candle wick.

20. Relight the fireplace match from the candle on the metal tray. Then use it to relight the candle in the beaker. (You probably can’t.)

21. You may repeat the experiment and use different techniques to light the candle in the beaker.

22. Ask: Why was it so hard to light the candle after the vinegar was combined with baking soda? When baking soda and vinegar are combined, they form CO₂, an invisible gas that is heavier than oxygen. The resulting CO₂ gas crowded the O₂ out of the beaker. Thus there was not enough O₂ available for burning.

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

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

Procedure, Demonstration 3, “Why Does the Candle Go Out?” Option B – using dry ice

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

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

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

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

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

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

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

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

8. Ask: Why was it so hard to light the candle with dry ice present? **Dry ice was turning from a solid to a gas as it warmed up – a process called sublimation. We say the dry ice is “subliming.” The resulting CO2 gas was crowding the O2 out of the beaker for two reasons: because CO2 is heavier than O2 – based on its molecular weight – and because the CO2 gas subliming from dry ice is very cold, which means the gas is more dense than it would be at room temperature. Thus there was no O2 available for burning.**

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

**Assessment #3, Option B:** In writing, have students use the Fire Triangle to explain why it was hard to light the candle after dry ice was placed inside the beaker.
### Evaluation:

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<th></th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
</table>
| Assessment #1-2           | -Heat moved up, so it was not reaching the fuel.  
- Fuel and oxygen were still present. | -Heat moved up, so it did not reach the fuel.  
- Heat was removed. | Unclear if student understood. | |
| Assessment #3 Option A    | -When baking soda and vinegar combined, they produced carbon dioxide, which is heavier than oxygen. The carbon dioxide sank to the bottom and crowded the oxygen out of the beaker. 
- No oxygen was available for burning. | -Carbon dioxide sank to bottom and crowded oxygen to top. 
- No oxygen was available for burning. | -No oxygen was available for burning. | -Student did not indicate that they understood the experiment. |
| Assessment #3 Option B    | -Dry ice (frozen carbon dioxide) is changing from the solid phase to the gas phase. The carbon dioxide is heavier than oxygen and also very cold (that is, dense), so it stays at the bottom of the beaker and displaces the oxygen upward and out. 
- Thus no oxygen is available for burning. | -Dry ice changed to gaseous carbon dioxide and crowded oxygen to the top. 
- No oxygen was available for burning. | -No oxygen was available for burning. | -Student did not indicate that they understood the experiment. |
Unit III.
The Wildland Fire Environment
Lesson Overview: Students use a physical model to learn how slope and the density of trees (or other kinds of standing fuels) affect fire spread.

Lesson Goal: Increase students’ understanding of how wildland fires spread in forests and other kinds of standing fuels.

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

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

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

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

Fires are strongly influenced by wind, a topic that students can investigate in Activity E06.

There are many kinds of fire behavior in wildland environments. This activity is most often used to illustrate the behavior of crown fires; individual matchsticks in the model represent individual trees. (The analogy is far from perfect, a topic explored in the Middle School Activity M05.) Other kinds of fire behavior include surface fire (in which the fire spreads mainly through fuels on the surface of the ground, such as grasses, forbs, leaf litter, and shrubs) and ground fire (in which the fire spreads mainly through partly-decomposed material in the top layer of soil). These kinds of fire behavior are studied more thoroughly in the Middle School curriculum.

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

• Demonstration 2A illustrates basic principles as they apply to all kinds of plant communities subject to fire (any kind of forest, woodland, or shrubland, the world over).
• Demonstration 2B illustrates the principles as they apply to specific kinds of forest in the northern Rocky Mountains and the North Cascades. In this version of FireWorks, Demonstration 2B covers dense lodgepole pine forests, open ponderosa pine forests, and high-elevation whitebark pine forests.
Table 2. Three demonstrations that use matchstick forest models

<table>
<thead>
<tr>
<th>Experimental question</th>
<th>Potential hypotheses &amp; explanations</th>
<th>Experimental setup</th>
</tr>
</thead>
</table>
| **Demo. 1:** How does slope affect fire spread? | Fires moving uphill tend to spread faster and burn more completely than fires moving downhill.  
**Explanation:** As heat moves uphill, it dries and warms the fuels above. In addition, flames are closer to uphill fuels than to fuels on level ground or downhill from the fire. | Use 49 matches/board.  
Lay 1 board flat.  
Set up 2 tilted boards using two long bolts (1 bolt in each board).  
Ignite by lighting a full row of matches along the edge of each board:  
• On flat board, ignite one side.  
• On one tilted board, ignite the top row.  
• On other tilted board, ignite the bottom row. |
| **Demo. 2A:** How does density of a forest stand (or other standing fuels) affect fire spread? | Fires generally spread faster and combustion is more complete in dense stands than in open stands.  
**Explanation:** Heat and flames are more likely to reach fuels that are close together, drying them out and igniting them. | Use long bolts (to create steep slopes) for all models. Use the following matchstick densities/board (see the figure below).  
• 49 matches  
• 25 matches (50%), distributed evenly  
• 12 matches (25%), distributed evenly  
• 12 matches (25%) in clusters  
Ignite all boards from the bottom row. |
| **Demo. 2B:** How does tree density affect fire spread in forests with different ecology and fire history? | 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 them out and igniting them. Frequent fires tend to reduce stand density by killing small trees and those of fire-sensitive species. Frequent fires also reduce fuels, both horizontally and vertically, so fires are not likely to be severe enough to kill most of the trees. | Use long bolts (to create steep slopes) for all models. A single board represents about 1/40 hectare, an area about 16 meters on a side. Use the following matchstick densities/board:  
• 49 matches to represent dense lodgepole pine stands that originated 50-100 years ago, after a severe fire  
• 5 matches, spaced far apart, to represent open-grown ponderosa pine stands that have experienced frequent low-severity fires  
• 13 matches, distributed in clusters, to represent high-elevation whitebark pine stands  
Ignite all boards from the bottom row. |
Materials and preparation:
Do the two experiments as demonstrations. Students can help you set up the boards with the right number of matches. Ignite the matchstick forests one at a time from the bottom row of matches, so all students can observe all fires.

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

- Download E04_downhill-uphill diagram.pptx to use in the assessment.
- Get plenty of wooden kitchen matches (not provided in the trunk). You will need at least 300.
- If you burn outside and there is a breeze, you may need to ignite with a lighter. It may be helpful to have 4-5 pieces of poster-board that students can hold at a safe distance to protect the flames from wind.
- Have a fully-charged fire extinguisher handy.
- Set up your work station with this equipment (available in the trunk):
  - Two spray bottles. Fill them with water.
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
    - 4 masonite ("matchstick forest") boards from the matchstick forest kit. Instructions for making matchstick forest kits are available: [https://www.frames.gov/documents/fireworks/trunks/NRockies-NCascades/Trunk_Availability/TrunkItems_NRockyMtnsNCascades.pdf](https://www.frames.gov/documents/fireworks/trunks/NRockies-NCascades/Trunk_Availability/TrunkItems_NRockyMtnsNCascades.pdf)
    - Nuts and bolts from the matchstick forest kit (3-4 bolts that are 4" long and 1-2 that are 2" long)
    - 1 pair of safety goggles
- FireWorks safety poster from Activity M02 (FireWorks_Safety_poster.pptx)

- Have a METAL trash can WITHOUT A PLASTIC LINER nearby.
- Stop watch or clock with a second hand.

Procedure:
1. Do a safety checkup with students using the FireWorks safety poster (FireWorks_Safety_poster.pptx from Activity M02).

2. Explain a crown fire: A fire that moves from tree top to tree top.

3. Show students your box of 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? The board can represent the ground surface. Individual matches can represent a tree or other standing fuel, with the match tips representing tree crowns.
4. Ask: What aspects of fire behavior can we investigate with this model? Brainstorm. Here are a few good ones: 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. Students may suggest others that can’t be investigated with this model, and that’s OK too. It may be subject for later discussion.

5. Discuss experimental design with the class, including the principle of changing only one variable at a time to figure out cause-and-effect. You’ll change only slope in Demonstration 1 and only matchstick density in Demonstration 2.

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

6. Explain: A prediction or guess that you can test is called a hypothesis. Ask students to offer hypotheses – that is, to predict what will happen – when each board is burned. They may have several hypotheses. Write them all on the board.

7. Assign a student to record the start time and end time of each burn. Make sure a clock showing seconds is available or have the timer use a stopwatch. (If you have a stopwatch, you don’t need the “Start time” and “End time” columns in the table below.)

8. Copy this table on the board:

<table>
<thead>
<tr>
<th>Slope</th>
<th>Start time</th>
<th>End time</th>
<th>Duration (seconds)</th>
<th>Matches burned (tree crowns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flat</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2. Steep – burning downhill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Steep – burning uphill</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

9. Refer to Table 2 for further instructions.

10. Dispose of burned matches in the ashtray or on the metal tray.

11. After all of three matchstick forests have burned, calculate the fire duration for each. Discuss the results. Were their hypotheses correct? Ask students to describe how the fire moved through the “tree crowns” or match heads.

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

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

13. Change the first column of the table on the board to reflect the three matchstick densities you will use (Table 2, Demo 2A or 2B).

14. Ignite the matchstick forests one at a time, always by igniting the bottom row of matches.
15. After all boards have burned, calculate the fire duration for each. Discuss how the fire moved through the “tree crowns” (match heads).

16. Discuss the results. Were their hypotheses correct?

17. **Clean up**: Use a metal trash can without a plastic liner. If in doubt whether fire is out, dump materials in a bucket of water before putting them in the trash.

**Assessment**: Project *E04_downhill-uphill diagram.pptx* or sketch something like it on the board. Have students explain in writing or by drawing what direction the fire would be most likely to spread and what part of the forest would be most likely to have crown fire. Have them use complete sentences to explain why.

<table>
<thead>
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| **Full Credit**: Student indicated that the fire is more likely to spread uphill and crown on the hillside above the flames than on flat land or below the flames. Student indicated in complete sentence(s) that trees on the slope are dried and heated by the heat rising from the fire, and/or fuels are closer to the flames, and/or trees are most dense on the steep section above the flame. If the student suggested that cross-slope or down-slope winds could overwhelm the effects of slope or that embers rolling downhill could start a fast-moving fire below, those answers are also very good.

| **Partial Credit**: Student indicated that fire is likely to crown uphill from the flames.

| **Less than Partial Credit**: Student indicated that the fire is likely to spread faster on a flat area or downhill, and/or student did not indicate understanding of how slope affects fire spread and potential for crowning. |
Downhill-Uphill Diagram:
Circled area is most likely to support crown fire
Lesson Overview: In this activity, students explore how different properties of fuels affect fire behavior – especially how hard it is to ignite fuels and how long they are likely to burn. Students consider various combinations of fuels (“fuel recipes”), predict how they will burn, then test their hypotheses.

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

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

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<td>ETS1.B</td>
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</table>
Teacher Background: Anyone who has built a campfire knows that you have to choose your fuels wisely and arrange them carefully. Four fuel properties influence fire behavior: amount, size, moisture content, and spatial arrangement. These properties determine how flames heat the fuels and how much oxygen is in contact with them, and thus how quickly they will ignite and how long they will burn:

- All other conditions being equal, larger amounts of fuel will produce the most heat. Whether they burn quickly or slowly, however, depends on their moisture, size and arrangement.
- Small particles tend to ignite more easily than large particles because they have more surface area (per volume) exposed to heat and oxygen. (Interesting exceptions to this guideline are explored in the High School curriculum, Activity H07.) Large fuels, once ignited, usually burn longer than small ones.
- It is more difficult to ignite moist fuels than dry ones; they also burn more slowly, make more smoke, and tend to burn less completely.
- Spatial arrangement of fuels is complex: If they are packed so tightly that oxygen isn’t available, they won’t ignite; if they are so far apart that heat from one particle can’t reach the next, they won’t ignite.

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

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

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

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

Spread them out in a dry place so they are uniformly dry by the time you use them.

- The day before you do the activity, remind students to dress appropriately for burning. Post and refer to the FireWorks Safety poster (*FireWorks_Safety_poster.pptx* in Activity E03).

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

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

<table>
<thead>
<tr>
<th>Recipe</th>
<th>Ingredients</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small twigs</td>
</tr>
<tr>
<td></td>
<td>Big sticks</td>
</tr>
<tr>
<td>2</td>
<td>Big sticks</td>
</tr>
<tr>
<td></td>
<td>Green conifer needles</td>
</tr>
<tr>
<td>3</td>
<td>Dead, dry conifer needles</td>
</tr>
<tr>
<td></td>
<td>Big sticks</td>
</tr>
<tr>
<td>4</td>
<td>Dead, dry conifer needles</td>
</tr>
<tr>
<td></td>
<td>Small twigs</td>
</tr>
</tbody>
</table>

- Set up your teacher area with:
  - The Fuel Recipe box. Be sure to select the recipes labeled “E” for Elementary students.
  - 4 grocery bags or boxes containing fuels (dead, dry conifer needles; small twigs (<0.5 cm); big sticks (2-3 cm); green needles). Label the bags. You can use the tie-on labels in the trunk. If there’s a label for “duff,” ignore it.
  - Fire extinguisher
  - 2 spray bottles, filled with water
  - Other water (bucket, charged hose, etc.) to ensure you can easily put a fire out

- Set up student work stations. Four work stations work well (1 station/recipe), but you can have more stations and repeat recipes. Each station needs:
  - One 9” diameter aluminum pie tin with tilted edges
  - 1 metal tray (i.e., cookie sheet) can be used beneath the pie tin, if desired
  - 1 match box with **7 matches** (not in trunk)
  - 1 ashtray
  - 1 pair of safety goggles
• 1 oven mitt

- Have a METAL TRASH CAN WITHOUT A PLASTIC LINER on hand.
- Decide whether you will project E05_PhotosShowingFuelProperties.pptx for the assessment or provide a copy for each student. Make copies if necessary.

Procedures:

1. Explain: Students will work in teams to build small “campfires,” but they don’t get to choose their own fuels. They will use specific combinations of fuels. The experimental questions are:
   - What kinds of fuels are easiest to start on fire (“ignite”)?
   - What kinds of fuels burn longest?

2. Using the recipes listed on the board, ask students to “vote” on:
   - which will be easiest to start on fire
   - which will be hardest to start on fire

3. Then have them vote on:
   - which will burn out in the shortest time
   - which will burn longest

   Record their votes on the board. Explain: These are their hypotheses.

4. Do a safety checkup with students using the FireWorks Safety poster (FireWorks_Safety_poster.pptx from Activity E03). Remind students of the item on the poster that says they should never lean over a burning fire.

5. Group students into teams (4 teams works well).

6. Explain the procedure. The whole team is responsible for safety. If any student is hurt, the team must alert the teacher and use water to put out their campfire immediately. Each team will:
   a. Draw a recipe from the Recipe Box.
   b. Collect the two ingredients on their recipe from the labeled ingredient bags. Fuels are “measured” by the “handful,” which is subjective, but the point is to use about the same amount of each fuel in a campfire.
   c. Discuss and work together to arrange the fuels. The goal is to make the fuels ignite as easily as possible and burn as completely as possible. The fuels must fit inside the pie tin; they may not spill over the sides. **The 7 matches may be used within the fuels or to ignite the fuels.** Obviously, at least 1 match will be needed for ignition.
   d. Have a teacher or other adult verify that they have met the requirements. Answer any questions. Explain that, after ignition, the team may not rearrange the fuels, but they may blow on the fire.
7. Have yourself or another adult light the match(es) for each team. If you have 1 adult per team, all teams can ignite at the same time. If not, ignite the fires one at a time so you can supervise. After ignition, monitor progress and watch for safe practices. Dispose of burned matches in the ashtray or on the metal tray.

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

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

- **Amount of fuel.** The more fuel, the longer your fire can burn and the more heat it can produce... if you can get the fuels to ignite.

- **Fuel particle size.** Fine fuels – that is, small pieces – are usually easiest to ignite (if they are dry, of course), because even a small heat plume can surround them and heat them up fast. But because they are small, they burn up quickly. Large fuels tend to burn slowly because it takes time for the outside surface to burn away, exposing new layers to oxygen and heat.

- **Fuel moisture.** Moisture makes fuels hard to ignite and also makes them burn slowly. This is because the moisture must be removed before a particle can be heated to ignition temperature.

- **Spatial arrangement**
  
  - The fluffiness of fuels determines how easily heat and oxygen can reach the fuels. An important skill in building a campfire is to get the spatial arrangement of fuels “just right” so lots of heat and oxygen are available to the unburned fuels. Fuels have to be sort of near each other for fire to spread from one piece to another. For example, if you crumple up 20 pieces of newspaper and scatter them across a large room, a fire cannot spread from one piece to another. But the pieces can also be too tightly packed for heat and oxygen to disperse among them. For example, a tightly piled stack of newspapers will be hard to start on fire. (Once started, however, that pile of newspapers could smolder for a long time.)

  - Vertical arrangement: A clever campfire builder takes advantage of heat’s tendency to rise by putting easily-ignitable fuels beneath those that are hard to ignite. That is, we place small (“fine”) fuels, which we call kindling, near the bottom of the fuel bed and then place layers of large (“coarse”) fuels directly above. This principle also applies in forests: If the gaps between surface fuels and tree crowns are large, a fire cannot get from the surface fuels into the tree crowns. If the gaps are small – if the surface litter and grass are connected with shrubs and saplings, and these are
connected with the lowest branches of the trees – then fire can climb up these ladder fuels and reach the crowns.

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

**Assessment:** Project *E05_PhotosShowingFuelProperties.pptx* or provide a copy to each student. Write the 4 fuel properties on the board: **amount, size, moisture, arrangement.**

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

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

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

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

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

Objectives:

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

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

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<tr>
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Subjects: Science, Writing, Speaking and Listening, Health and Safety
Duration: One half-hour session
Group size: Whole class
Setting: Indoors or outdoors
Vocabulary: backing fire, downwind, head fire, spot fire
Students learned in Activity E03 that most of the heat from a fire tends to go upward. They called this the “heat plume.” Hot gases rise because they are less dense than the surrounding air, and air at the ground is usually denser than that above it due to gravity. A gust of wind is like a bubble of dense air. It bends the heat plume so it is no longer vertical but instead leans over - toward whatever fuels lie downwind. Wind also bends flames so they are more likely to touch the downwind fuels. For these reasons, fires tend to spread more rapidly with the wind than against it or in still air.

When the wind is blowing uphill, it adds to the effect of slope and accelerates fire spread. When the wind is blowing crosswise or downhill, its effects are harder to predict. A fire burning uphill or with the wind is called a “head fire”; a fire burning against these influences is a “backing fire.” Of course, even if slope and wind favor a fast-spreading head fire, the fuels may be too far apart to sustain combustion, as the students observed with the matchstick forests in Activity E04, when they observed boards with 49 matches vs. boards with only 5 to 12 matches on them.

Materials and preparation:
None

Procedure:

1. Show students that each of them can “model” the heat plume. If you pretend that your head is a match tip – or the crown of a tree or the top of another standing fuel, then you can show the shape of a heat plume by clasping your hands together high above your head. Your shoulders, arms, and hands represent the outside of the heat plume. A little heat is going down and to the sides, while a lot of it is going up. Ask the students to imitate you – so each of them becomes a model of a heat plume.

2. Explain: When they stand with their hands at their sides, each of them will be a model of a living tree (or other standing fuel), and their heads will represent the tree crowns. When they stand with their hands arched above their heads, each of them will be a model of a tree with its crown on fire!

3. Have students line up side by side in a straight line with their arms at their sides – modeling living trees - about half an arm’s length apart. Have 1-2 “trees” at the far end of the line stand 2-3 arms’ lengths away from their nearest neighbor and also separate from each other. Select 2-3 students from the near end of the line to help you in the next step.

4. Explain: The students in the line are modeling a forest stand. Most of the trees are close together, although the ones at the far end are a bit further apart. The trees are not on fire, so the students should keep their hands at their sides.
5. Have the class make the sounds for a crash of lightning and a loud rumble of thunder. Tell the “tree” at the near end of the line that he or she has been struck by lightning and fire has run up through ladder fuels into the tree crown. Ask: How does that look? The student should now clasp hands above his/her head, modeling the heat plume of a tree with its crown on fire. Point out that the heat plume goes straight up. It does not reach the next student in line, so that student’s hands remain by his/her side, and the fire is not spreading.

6. Now have your helper students act out a gust of wind running up to the “burning tree” at the near end of the line. Include sound effects!

7. Have the “burning tree” show that the wind bends its heat plume over so it reaches the next “tree” – which is ignited. Keep the “wind” students going strong, so the next and the next trees are ignited too. Ask: What do we call this kind of fire, which is running from treetop to treetop? It is a crown fire (a term that they learned in Activity E04). Explain: A fire spreading with the wind or up a hill is also called a head fire, while a fire spreading into the wind or downhill called a backing fire.

8. Continue the wind and fire spread until the “fire” ignites the second-last tree. Ask: Can that tree bend its heat plume enough to ignite the last one? If so, the entire forest has burned in a crown fire; if not, this part of the forest is too open for crown fire to spread, and the crown fire must stop.

9. Ask: Are there other ways for the fire to spread to that unburned tree? The fire could spread along the surface rather than through the crowns. It could also “spot” ahead of the main fire front if the wind carries embers from the burning tree crowns forward, downwind of the fire. It is very common for strong winds to produce spot fires a kilometer or more ahead of the fire front.

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

11. Ask: Do you think the effects of wind on fire are similar to the effects of slope, which we looked at with the matchstick forests in Activity E04? Wind and slope both put the flames closer to fuels on one side (the uphill side or the downwind side), so the fuels dry out and heat up faster and ignite more easily than fuels on the other side. If there is no fuel on the uphill/downwind side, of course, the fire cannot spread in that direction.

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

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

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

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

<table>
<thead>
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<tr>
<td></td>
<td>Uses 2 components of Fire Triangle</td>
<td>Uses 1 component of Fire Triangle</td>
<td>Uses 0 components of Fire Triangle</td>
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<td></td>
<td>correctly.</td>
<td>correctly.</td>
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Unit IV.
Fire Effects on the Environment
Lesson Overview: In this activity, students learn that smoke from wildland fires can either disperse readily or stick around, reducing visibility on the earth’s surface and making it difficult to breathe. Then they apply health guidelines regarding smoke to a very important question: Can Physical Education (PE) Class proceed with the scheduled 1-km run, or do we need to change plans?

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

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

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

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

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

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

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

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

Materials and preparation:

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

Procedures:

1. Ask students: What is smoke? Smoke consists of water, gases, and tiny particles of unburned and partially burned fuels. These are called “particulates” or “particulate matter”. The particulates are light enough to circulate in the atmosphere instead of settling immediately to earth, as larger particles do.
2. Go through E07_smoke_slides.pptx:

Slide 1
We’ve measured the shape of the heat plume from small fires, and we’ve watched the smoke from our classroom experimental fires. Here are photos of smoke from wildland fires. Where does the smoke usually go? Smoke usually goes up for awhile, and then it goes in the same direction as the wind. It also stays around the base of the fire where it is being produced.

Slide 2
Smoke doesn’t just disappear into the air. Satellite photos show that it can travel a long way. Discussion: Use the 25-km scale on the left photo to figure out how wide the smoke plume is (50-75 km) and how far it has traveled (at least 300 km). Think of some towns or other landmarks that are that far away.

Slide 3
Smoke sometimes settles down near the ground and stays there for days or even weeks. This might be smoke from a fire nearby, or it could be smoke from fires hundreds of miles away.

Slide 4
Here are two contrasting views, looking eastward from St. Mary Lookout, Bitterroot National Forest, MT. Top: Summer 2013. Smoke disperses upward from a fire in the valley, then drifts northward. Bottom: Smoke has settled into the valley overnight. Now it keeps sunlight from reaching the valley floor, so the air above the smoke layer is warmer than in the valley. The smoke is trapped in the cold, heavy, dense valley air.
In the next few pictures, you can see what smoke does to visibility.

OPTIONAL INFO: What is that number at the bottom of the slide? It is a way of measuring the concentration of particulates in the air. It is read “micrograms per cubic meter of particles less than 10 micrometers in diameter.” It is the weight of smoke particulates of a certain size (and smaller) in a specific volume of air. PM10 is the weight of particulates 10 micrometers across and smaller. PM2.5 is the weight of particulates 2.5 micrometers across and smaller.

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

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

This slide summarizes slides 5-9. It shows the changes in visibility with 5 vs. 90 mg/m³ of PM10.

3. Ask: How does smoke affect us? Smoke reduces visibility, as the photos showed. Smoke also makes it harder to breathe as the particles get stuck inside our lungs. The particles interfere with our ability to absorb oxygen and release carbon dioxide.

4. Explain: Scientists have provided guidelines for outdoor recreation to help us protect our lungs from smoke. Give each student a copy of Handout E07-1. What Will We Do with PE Class?

5. Go back to Slides 7-9. For each photo, use the handout to decide together what to do with PE class: Are these conditions OK for a soccer match? for a 1-km run? for a basketball game? How about volleyball — indoors or outdoors? If a student has asthma, should he/she have additional restrictions?

Assessment: Instruct the students:

1. Pair off. One of you be the school nurse, the other be the Physical Education (PE) teacher. There have been some large fires in your area recently. You look out the window, and you see that the air is smoky. You can just barely see the top of a hill 4 miles away. You had planned to have your PE class do a timed 1-km run today, but now you are not sure you should do that. Talk the situation over, use the handout, and decide what to do about PE class. Make sure your plan will take care of the 3 students who have asthma.

2. Together, report to the class. Answer these questions:
   - What kinds of activities does the handout recommend for the amount of smoke in the air today?
   - What will you do in PE class today and why? If you are not going to do the scheduled 1-km run, what activities will you do instead?
   - Do you have special instructions for the students who have asthma?
**Evaluation:**

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

*Appropriate alternative activities:*

- If outdoors, the activities should be low-exertion and possibly short in duration. This might be an opportunity to practice kicks and footwork in soccer, pitching/batting in softball, etc. It is difficult to assess what the handout means by “prolonged periods of time,” but a 40- to 60-minute PE class is probably acceptable. However, asthmatic students cannot participate outdoors.

- If indoors, can be high-exertion and use the whole class period, and asthmatic students can participate. However, it might be good to err on the side of caution, since indoor air can become quite polluted when outdoor smoke concentrations are high.

- A classroom lesson or activity, perhaps something related to health or diet, might be a good alternative – especially if the gym is not available.
**Handout E07-1: What Will We Do with PE Class?**

### Decision making recommendations during wildfire season for Outdoor Sporting Events

Based on visibility and air quality

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

*Visibility: How far can you see? To figure this out:
1. Face away from the sun.
2. Look for landmarks at a known distance from you.
3. If you can’t see a landmark, then you know that visibility is less than that distance.

Source: [http://www.missoulacounty.us/home/showdocument?id=5543](http://www.missoulacounty.us/home/showdocument?id=5543)
8-1. What’s a Community? All the Living Things in the Ecosystem

Lesson Overview: In this activity, students learn about the nature of biological communities. This concept is important to the science of wildland fire because fire behavior, fire history, fire effects, and even fire management depend a lot on what plant communities are burned.

Lesson Goal: Students can describe what they know about human communities and use this knowledge to understand the nature of a biological community.

Objectives:

- Students can discuss the nature of a community.
- Students can distinguish between a biological community and an ecosystem.
- Given a feltboard model of a specific forest community, students can name all members of that community. They can also sketch and name some members of other forest communities.
- Students can sketch or list two nonliving parts of an ecosystem (i.e., not members of a biological community because they are nonliving).

Standards:

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<th>Group size: Whole class</th>
<th>Setting: Indoors</th>
<th>Vocabulary: community, ecosystem</th>
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### Standards:

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September 27, 2019 E08-1
**Teacher Background:** A biological community consists of all the organisms in a particular area that are connected by food webs and other relationships. That is, a biological community consists of the living things within an ecosystem (that is, “living” as in comprised of cells). Like people living together in a human community (a school, a family, a village or town), the organisms in a biological community depend on one another and also compete with one another. A community differs from an ecosystem in that an ecosystem contains non-living things as well as living things. In other words, an ecosystem is a biological community plus its non-living environment.

After a brief discussion, students create displays in the classroom that depict three different biological communities from the northern Rocky Mountains and North Cascades (forests dominated by ponderosa pine, lodgepole pine, and whitebark pine). They sketch and learn the names of many organisms in these communities.

**Materials and Preparation:**

1. Locate in the trunk:
   - Three feltboard backgrounds, labeled on the back with the dominant tree species in that forest community (ponderosa pine, lodgepole pine, and whitebark pine).
   - Three looseleaf notebooks containing materials for the feltboards: *Creepy Crawly Fires* (about ponderosa pine communities), *Roaring Tree-Top Fires* (about lodgepole pine communities), and *Rollercoaster Fires* (about whitebark pine communities).

2. Hang the feltboard backgrounds up in your classroom, preferably with the one for ponderosa pine on the left, lodgepole pine in the middle, and whitebark pine on the right. (This arrangement follows an elevation gradient, from low-elevation forests on the left to high-elevation on the right.) It would be great if you could keep the feltboards on display throughout the time you are studying Units V and VI.

3. In a pocket inside the cover of each loose-leaf notebook, find the laminated label for each forest community. Put it up next to the correct background.

4. Plan student work teams and assignments. You will need 3 teams (2 or more students each) to assemble the feltboards.

**Procedures:**

1. Explain/ask: A biological community is all of the living things in a place. Our classroom contains a biological community. Can you name the living things in the classroom? Obviously, people are the main living things. But there are no doubt many other kinds of organisms – plants, animals, fungi, germs, molds … all living things comprise the biological community.

2. Explain/ask: An ecosystem is all the living things plus their environment. Name some of the nonliving things in the classroom. Be sure to have them include air! Ask: So which contains
more “stuff” — a community or an ecosystem? An ecosystem contains more “stuff” because it has both living and non-living things in it.

3. Explain: We’re going to learn about three specific forest communities: those with a lot of ponderosa pine, those with a lot of lodgepole pine, and those with a lot of whitebark pine. We’ll use these feltboards to learn about some of the living things in each community.

4. Give each feltboard team a looseleaf notebook about a forest community (*Roaring Tree-Top Fires, Creepy Crawly Fires, or Rollercoaster Fires*) and show them which feltboard background to work on. Ask them to assemble their feltboard so it looks like the photo that’s shown at the front of the looseleaf notebook.

**Assessment:** When all feltboards are prepared, ask students to get out a blank piece of paper and drawing supplies. Have students fold the paper into 3 sections and write the name of one of the forest communities at the top of each section.

1. Have each feltboard team:
   - Tell the class the name of their forest community.
   - Point to and name each species in their community.
   
   Require that all team members speak during the presentation.

2. After each feltboard presentation, have the students sketch and label 3 members of that biological community under the correct heading on their folded paper. They may ask the presenting team for the names of community members.

3. Review the definition of an ecosystem — the living things AND THE NONLIVING THINGS that occur together and interact in a given place. Then have the students turn their paper over and, on the back, list or sketch 2 nonliving parts of ecosystems.
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<tr>
<td>Feltboard assembly and Presentation</td>
<td>Student actively participated in assembling the felt board. Student allowed other group members to participate in assembly process. Student spoke during the presentation.</td>
<td>Student did not help the group assemble the feltboard or took over and did not let other group members participate. Student did not speak during the presentation.</td>
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<tr>
<td>Community member sketches</td>
<td>Student sketched 3 members of each forest community.</td>
<td>Student sketched fewer than 3 members of each forest community or sketched nonliving things rather than organisms.</td>
</tr>
<tr>
<td>Ecosystem member sketches</td>
<td>Student listed or sketched 2 nonliving parts of an ecosystem. Examples: water, air, sunlight. “Soil” is also acceptable, even though it consists of both living components (insects, worms, bacteria…) and nonliving ones (sand, silt, clay…).</td>
<td>Student listed or sketched fewer than 2 nonliving parts or sketched living things rather than nonliving things.</td>
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</table>
Overview: This activity introduces a suite of organisms that live in 3 forest communities of the northern Rocky Mountains and North Cascades (forests 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 2- to 3-minute presentation on it to the class – complete with a mask, costume, or puppet (or other medium, such as painting, poster, computer presentation, or written description). BUT SEE THE FOOTNOTE BELOW (*) FOR A FUN, SHORT WAY TO DO THE PRESENTATIONS.

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

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

It is good to schedule the presentations for all conifer trees as soon as possible, because the next 3 activities are about trees. Schedule lodgepole pine right before you do Activity E11. Recipe for a Lodgepole Pine Forest: Serotinous Cones. Schedule the herbs and shrubs (and possibly the two deciduous trees – quaking aspen and black cottonwood) right before you do Activity E12. Buried Treasure: Underground Parts that Help Plants Survive Fire.

Objectives:

- Students can create an art work (mask, costume, puppet, or other medium) depicting their “adopted” organisms.
- Students can give a 2- to 3-minute presentation to the class that describes the biology of their adopted organisms and the organism’s relationships to fire. BUT SEE THE FOOTNOTE BELOW (*) FOR A FUN, SHORT WAY TO DO THE PRESENTATIONS.
- Students can recognize several characteristics of organisms: their kingdom, family or life-form, way(s) of obtaining energy, and typical responses to fire.

*Students can perform charades for a very abbreviated version of this activity. Each student is assigned 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 what community the species lives in and one thing about its relationship with fire.
Teacher background: Different kinds of plants and animals have different needs. Some plants grow well only in sunny openings, for example, while some others grow well in shade, and others require special soil conditions or large amounts of water. Different species that live in the northern Rocky Mountains and North Cascades have different ways to live, grow, reproduce, survive fires, and thrive after fires. The traits that help them persist in habitats that burn are sometimes specific to a certain kind of fire, so changes in the kinds of fire or the frequency of fire may make life difficult for the organism.

In this activity, students teach each other about some of the species that live in the 3 communities covered in this FireWorks curriculum: forests dominated by ponderosa pine, lodgepole pine, and whitebark pine. (If you want to focus on only 1 of the 3 communities, use the last column in Table E08-2-1 “preferred forest type” to decide which organisms to assign.) Each student “adopts” a plant, animal, or fungus. Students learn about their adopted organisms by studying the short technical essays in the FireWorks Encyclopedia (Elem_FireWorksEncyclopedia_NRM-NC.pdf). Then each student prepares an art work (mask, puppet, costume, or other medium) that describes his or her organism and presents the organisms to the class.

Detailed information on most of the species in the FireWorks Encyclopedia is available in the literature syntheses of the Fire Effects Information System (https://www.feis-crs.org/feis/).
**Materials and Preparation:**

- Find in the trunk or make available to students (in print or electronically): *FireWorks Encyclopedia (Elem_FireWorksEncyclopedia_NRM-NC.pdf).*
- Print 1 copy of Table E08-2-1: Species in the *FireWorks Encyclopedia*, Key to “Walk Your Talk.” Use this list to record the species adopted by each student. The list contains more than 30 species; if you do not need all of them, start with **those shown in bold print (and shaded in blue)**, since these are the species shown on the 3 feltboards used in Activities E08-1 (“What’s a Community?”) and E14 (“Story Time”).
- Art supplies for masks, puppets, costumes, etc.

**Procedure:**

1. **Explain:** We’re going to learn about some of the organisms that live in 3 forest communities of the northern Rockies and North Cascades – forests dominated by ponderosa pine, lodgepole pine, and whitebark pine. We learned many of their names in **Activity M08-1**, when we learned about biological communities. We’ll only learn about a few of the species though. There’s a lot of biodiversity in our wildlands. 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:** Each of you will “adopt” an organism that lives in one (or more) of the 3 forest communities. Then you will:
   - Learn about the organism from the essay in the *FireWorks Encyclopedia*.
   - Prepare an art work (mask, costume, puppet, or other medium) to use in a short presentation to teach the class about the organism.
   - Give a 2- to 3-minute presentation on your adopted organism. Include a short description of the organism, its needs and habitat, the kind(s) of fire that occur there (surface fire, crown fire, or a mixture of these), and how it deals with fire.

   **TEACHER – PLEASE SEE THE FOOTNOTE ON THE FIRST PAGE OF THIS LESSON FOR A SHORTER WAY TO DO THIS.**

3. Make species assignments and hand out (or provide computer access to) essays from the *FireWorks Encyclopedia (Elem_FireWorksEncyclopedia_NRM-NC.pdf).*

*Students can perform charades for a very abbreviated version of this activity. Each student is assigned 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 what community the species lives in and one thing about its relationship with fire.*
Assessment:

1. Have students give their 2- to 3-minute presentations.

2. Review: After the presentations, have all students get into or display their art work and form a circle around the classroom. Better yet, do this activity outdoors! Then go through this “Walk Your Talk” activity. It might be fun to spread out the different parts of the activity over several days. Solutions for the prompts in the activity are listed in Table H08-2-1 below.

   1) Explain: Living things are grouped according to their kingdoms. We have been studying organisms in 3 kingdoms – plants, animals, and fungi.
   
   2) Designate a space in the classroom for each kingdom. Then instruct: Everyone, walk to your kingdom!
   
   3) Have students form a circle from wherever they are standing. Then... Walk your talk - what kind of organism are you?
      
      a. All mammals, take 2 steps forward¹. One at a time, announce your species name, have the class repeat it, and then step back.
      
      b. Birds, take 2 steps forward. One at a time, announce your name, etc.
      
      c. Insects, take 2 steps forward. One at a time, announce your name, etc.
      
      d. Fungi, take 2 steps forward. One at a time, announce your name, etc.
      
      e. Trees, take 2 steps forward. One at a time, announce your name, etc.
      
      f. Shrubs, take 2 steps forward. One at a time, announce your name, etc.
      
      g. Explain: Grasses, sedges, and wildflowers are all called herbs (pronounced “ERBS”). Herbs, take 2 steps forward. One at a time, announce your name, etc.
      
   4) Walk Your talk – how do you earn your living?
      
      a. If you get energy directly from sunlight, you are an autotroph. Autotrophs, take 2 steps forward. One at a time, have the organism to your RIGHT say your name and have the class repeat it. Then step back.
      
      b. If you get your energy from other organisms (plants animals, or fungi – living or dead), you are a heterotroph. Heterotrophs, take 2 steps forward. One at a time, have the organism to your RIGHT say your name, etc.
      
   5) Walk Your talk – how do you deal with fire? Be flexible with this one, since many organisms have effective ways to respond to almost any kind of fire.

¹ You can vary the “stepping forward” part by adding a different motion each time, such as turning around, raising their arms, walking backwards, jumping, etc.
a. If you don’t like fire, take 2 steps forward. One at a time, have the organism to your LEFT say your name and have the class repeat it. Then step back.

b. If you like most fires, regardless of whether they burn just the surface fuels or burn through the tree crowns, take 2 steps forward. One at a time, have the organism to your LEFT say your name, etc.

c. If you like surface fires a lot better than crown fires, take 2 steps forward. One at a time, have the organism to your LEFT say your name etc.

d. If you like crown fires a lot better than surface fires, take 2 steps forward. One at a time, have the organism to your LEFT say your name etc.

e. If your forest has EVER experienced a wildland fire, take 2 steps forward. This should include everyone! Now go around the circle and have the whole class say the name of each organism.

<table>
<thead>
<tr>
<th>Evaluation:</th>
<th>Excellent</th>
<th>Fair</th>
<th>Needs Improvement</th>
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</thead>
<tbody>
<tr>
<td>Presentation</td>
<td>-Presentation was 2-3 minutes in length.</td>
<td>-Presentation was over or under 2-3 minutes.</td>
<td>-Presentation was greatly over or under 2-3 minutes.</td>
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<tr>
<td></td>
<td>-Student prepared a visual component using considerable effort and creativity.</td>
<td>-Student prepared visual component.</td>
<td>-Student did not prepare visual component, or put minimal effort into preparing it.</td>
</tr>
<tr>
<td></td>
<td>-Student provided a basic and accurate description of organism, its needs, and how it deals with fire.</td>
<td>-Student’s basic description of organism, its needs, and its relationship to fire were incomplete or contained minor inaccuracies.</td>
<td>-Basic information was missing or largely inaccurate.</td>
</tr>
<tr>
<td>“Walk Your Talk” activity</td>
<td>Student gave all correct information.</td>
<td>Student gave mostly correct information.</td>
<td>Student gave mostly incorrect information or did not participate.</td>
</tr>
</tbody>
</table>
### Table E08-2-1: Species in the FireWorks Encyclopedia, Key to “Walk Your Talk”

<table>
<thead>
<tr>
<th>Species</th>
<th>Student name</th>
<th>Responses for “Walk Your Talk”</th>
<th>Preferred forest type*</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Kingdom</td>
<td>Other group</td>
</tr>
<tr>
<td>American black bear</td>
<td>Animal</td>
<td>Mammal</td>
<td>Other organisms</td>
</tr>
<tr>
<td>American marten</td>
<td>Animal</td>
<td>Mammal</td>
<td>Other organisms</td>
</tr>
<tr>
<td>American three-toed woodpecker</td>
<td>Animal</td>
<td>Bird</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Armillaria root fungus</td>
<td>Fungus</td>
<td>Fungus</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Arrowleaf balsamroot</td>
<td>Plant</td>
<td>Herb</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Beargrass</td>
<td>Plant</td>
<td>Herb</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Black cottonwood</td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Black-backed woodpecker</td>
<td>Animal</td>
<td>Bird</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Blue huckleberry</td>
<td>Plant</td>
<td>Shrub</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Black fire beetle</td>
<td>Animal</td>
<td>Insect</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Clark’s nutcracker</td>
<td>Animal</td>
<td>Bird</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Douglas-fir mistletoe</td>
<td>Plant</td>
<td>Shrub</td>
<td>BOTH sunlight and the sap of host trees</td>
</tr>
<tr>
<td>Douglas-fir</td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Species</td>
<td>Category</td>
<td>Type</td>
<td>Sunlight</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>Elk</td>
<td>Animal</td>
<td>Mammal</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Engelmann spruce</td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Fireweed</td>
<td>Plant</td>
<td>Herb</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Flammulated owl</td>
<td>Animal</td>
<td>Bird</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Glacier lily</td>
<td>Plant</td>
<td>Herb</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Grizzly bear</td>
<td>Animal</td>
<td>Mammal</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Grouse whortleberry</td>
<td>Plant</td>
<td>Shrub</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Heartleaf arnica</td>
<td>Plant</td>
<td>Herb</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Lodgepole pine</td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td>Mountain pine beetle</td>
<td>Animal</td>
<td>Insect</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Northern flicker</td>
<td>Animal</td>
<td>Bird</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Pileated woodpecker</td>
<td>Animal</td>
<td>Bird</td>
<td>Other organisms</td>
</tr>
<tr>
<td>Pinegrass</td>
<td>Plant</td>
<td>Herb</td>
<td>Sunlight</td>
</tr>
<tr>
<td><strong>Ponderosa pine</strong></td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>Quaking aspen</strong></td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td><strong>Red squirrel</strong></td>
<td>Animal</td>
<td>Mammal</td>
<td>Other organisms</td>
</tr>
<tr>
<td><strong>Red-backed vole</strong></td>
<td>Animal</td>
<td>Mammal</td>
<td>Other organisms</td>
</tr>
<tr>
<td><strong>Saskatoon serviceberry</strong></td>
<td>Plant</td>
<td>Shrub</td>
<td>Sunlight</td>
</tr>
<tr>
<td><strong>Smooth woodrush</strong></td>
<td>Plant</td>
<td>Herb</td>
<td>Sunlight</td>
</tr>
<tr>
<td><strong>Snowbrush ceanothus</strong></td>
<td>Plant</td>
<td>Shrub</td>
<td>Sunlight</td>
</tr>
<tr>
<td><strong>Subalpine fir</strong></td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td><strong>Western larch</strong></td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td><strong>Western redcedar</strong></td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td><strong>White pine blister rust</strong></td>
<td>Fungus</td>
<td>Fungus</td>
<td>Other organisms</td>
</tr>
<tr>
<td><strong>Whitebark pine</strong></td>
<td>Plant</td>
<td>Tree</td>
<td>Sunlight</td>
</tr>
<tr>
<td><strong>Wild onion</strong></td>
<td>Plant</td>
<td>Herb</td>
<td>Sunlight</td>
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</tbody>
</table>

* PP=ponderosa pine/Douglas-fir forest community; LP=lodgepole pine/subalpine fir community; WB=whitebark pine/subalpine fir community.*
Lesson Overview: In this activity, students learn to name parts of a tree, describe their functions, and explain how some trees can survive fire or reproduce well after fire.

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

Objectives:
- Students role-play various parts of a tree as they form a living model of a tree.
- Students can identify numerous parts of a tree.
- Students can describe how some morphological traits help trees survive fire or reproduce well after fire.

### Standards

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<th>Subjects</th>
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| NGSS | 
| Heredity: Inheritance and Variation of Traits | LS3.B |
| Biological Evolution: Unity and Diversity | LS4.D |
| Engineering Design | ETS1.B |

### Vocabulary:
- bark
- branch
- cambium
- cone
- flower
- ground fire
- inner wood ("heartwood")
- leaf
- phloem
- photosynthesis
- root
- seed
- surface fire
- xylem ("sapwood")

Teacher Background: In Unit V, students learn how trees can survive wildland fire and grow back or reproduce after fire. To do this, they need to know a few terms. In this activity, they work together and take on roles - complete with actions and sounds - to create a model of a
functioning tree. They also describe how some tree parts help it survive fire or reproduce after fire.

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

- Thick bark can protect a tree’s sensitive phloem and cambium from the heat of surface fires. However, it provides no protection from crown fires.
- If a tree tends to shed its low branches as it grows taller, surface fires are less likely to climb into the tree crowns than if the tree’s branches are continuous from ground to crown. This “self-pruning” tendency thus helps protect it from crown fire.
- If young trees of a species 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 into mineral soil are protected from the heat of surface and ground fires. If the roots are shallow or mainly in the duff (organic) layer, they are vulnerable to heat from any fire. Deep roots, however, do not prevent damage to the cambium from surface fires or damage to the leaves and seeds from crown fires.
- If a tree can protect its seeds from fire, new trees can become established afterwards. Tightly sealed cones or capsules protect the seeds of some trees from crown fire. Burial underground protects seeds from all kinds of fire – unless they are in duff or organic soil, which may burn.
- If a tree can sprout from the roots, the base of the trunk, or other underground parts after its top is killed, it can survive both surface fire and crown fire. Its ability to survive ground fire depends on how well its underground parts are protected.

Materials and preparation:

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

Procedure:

1. Explain: We’ll work together to assemble a living model of a tree. This will help us learn how trees work and how they might survive fire.

2. Ask two tall students to stand back-to-back, with their arms stretched high and reaching slightly outward. Their bodies are the inner wood (“heartwood”) of the tree trunk, which provides support for the tree but does not take an active part in the tree’s life functions.
Their arms are the tree's **branches**, and their fingers are its **leaves**, which gather energy from sunlight and turn it into nutrients that all living cells in the tree can use (photosynthesis). Their branches also hold their **flowers** or **cones** and **seeds**, so give each student a package of nuts or seeds to hold. Ask them to pantomime photosynthesis by wiggling their fingers. Have them create and practice a sound that represents their functions. **With this role and those that follow, after the students have prepared, let them stay in place but pay attention as you “construct” the rest of the model tree.**

3. **Ask:** How can leaves and branches be protected from fire? **Leaves and branches are safe from fire only if they are high up on the tree, and if the tree is in an open stand so it is unlikely to catch fire from neighboring tree crowns. Low branches and leaves are vulnerable to surface fires, and they serve as ladder fuels that make the tree more likely to support a crown fire.**

4. **Ask:** How can seeds be protected from fire? (1) **Store them high in the tree to keep them safe from surface and ground fires. (2) Bury them underground to keep them safe from surface and crown fires – although this may not protect them from ground fires if the heat penetrates the soil. (3) Keep them sealed tight inside their cones in the tree crown until the fire has passed, then release them onto the burned soil.**

5. **Ask 4-6 students to stand in a circle around the inner wood, with their right shoulders to the inside and their left shoulders to the outside. They are the **xylem** cells (also called “sapwood”). Xylem cells pump water and dissolved minerals from the roots up to the leaves and flowers or cones. Have the students create a motion and a sound to represent this process.**

6. **Ask 4-6 more students to stand shoulder-to-shoulder in a circle around the xylem, facing out. These are **cambium** cells. They can form new xylem cells (at their backs – to the interior of the tree) and also new phloem cells (at their fronts). Have the students create a motion and a sound.**

7. **Ask 4-6 more students to stand outside the cambium holding hands. They are the **phloem** cells. They carry nutrients throughout the tree—from leaves to roots, from roots to leaves and flowers/cones, or wherever they are needed. Have the students create a motion and a sound.**

8. **Review these layers of cells: **xylem, cambium, phloem.** The tree needs all 3 of these layers to live. Which is most important? **Cambium is most important, because it produces new xylem and phloem. If xylem and phloem cells are killed, they can be replaced. But if the cambium layer is killed, the tree cannot produce new xylem and phloem cells. Ask: What does the tree need to protect its cambium from the heat of fires? Bark! The thicker the better!**

9. **Ask 5 more students to stand shoulder-to-shoulder outside the phloem, facing out and looking very strong. They represent the tree's **bark**, which contains mostly dead cells and air, and protects the inner layers from injury. Have the students create a motion and a sound.**
10. Ask the remaining students to lie on the floor—feet at the base of the tree, heads and arms spread out along the ground. They are the roots, with their tips and tiny hairs (called “root hairs”) growing out, searching for water. Have the students create a fitting motion and sound.

11. Place some seed packages on the ground.

12. Ask: How can roots and buried seeds be protected from fire? Soil protects them. The deeper they are, the better. Roots are only vulnerable to fire if the soil gets very hot or if they are living in soil that contains a lot of dead plant material, which can burn in a ground fire.

13. Review the action and sound for each group of students. Then ask them to all do their work at once. They will see that a living tree is a very busy, hard-working kind of organism!

14. When you’ve had enough bedlam, review: Have the students disassemble the tree but stay in groups of similar tree parts. Ask each group to describe how they can be protected from fire. Supplement their ideas with these:

- Inner wood: Grow thick xylem and bark.
- Branches, leaves, flowers/cones, and seeds in the crown: Grow tall really fast to get the leaves and seeds away from surface fires. Shed low branches so surface fires can’t climb into the tree’s crown. Pack seeds into thick, tightly sealed cones or capsules so they won’t be killed by crown fire.
- Xylem: Fill up with lots of water so you can’t be easily overheated. Make sure you have thick bark.
- Cambium and phloem: Get very thick bark for insulation from surface fire.
- Bark: Grow thick.
- Roots and fallen seeds: Grow roots deep so you can survive even if the litter and duff on the surface are burned. Be able to sprout new growth if the tree parts above ground are killed. Store seeds deep in soil, too.

**Assessment:** Give each student a copy of Handout E09-1: Tree Parts. Go through the directions at the top of the handout, then have them complete it:

1. Use the word bank to label the parts of the tree. Note that the word bank contains “catkin,” which is a special kind of flower produced by many trees and shrubs.

2. At the bottom, list two things that help a tree survive fire or grow well after fire.
**Evaluation:** Refer to *Answer Key for Handout E09-1: Tree Parts* below.

<table>
<thead>
<tr>
<th></th>
<th>Full Credit</th>
<th>Partial Credit</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labeling component</td>
<td>9-11 correct labels</td>
<td>6-8 correct labels</td>
<td>&lt;6 correct labels</td>
</tr>
<tr>
<td>Writing component</td>
<td>Correctly listed two things that help a tree survive fire or grow well after fire.</td>
<td>Correctly listed one thing that helps a tree survive fire or grow well after fire.</td>
<td>Did not list anything that helps a tree survive fire or grow well after fire.</td>
</tr>
</tbody>
</table>
Handout E09-1: Tree Parts

Fill in all of the red boxes.

Word bank:
bark
branch
cambium
catkin – a special kind of flower cone
inner wood (“heartwood”)
leaves
phloem
roots
seeds
xylem (“sapwood”)

What’s in these 3 colored rings?
Inner rings (yellow):
Middle ring (purple):
Outer ring (green):

List 2 things that help a tree survive fire or grow well after fire:
List 2 things that help a tree survive fire or grow well after fire: Has thick bark, sheds low branches, grows fast, has deep roots, buries seeds in soil, stores seeds in sealed cones, is able to sprout after top is killed...
10. Tree Identification: Using a Key to Identify “Mystery Trees”

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

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

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

Subjects: Science, Mathematics (logic), Writing, Speaking and Listening
Duration: One half-hour session
Group size: Whole class, possibly working in teams of 2-3
Setting: Classroom or outdoors
Vocabulary: bundle, dichotomous key

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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 learn how to use a dichotomous key to identify 10 of the important trees in the northern Rocky Mountains and North Cascades.

FOR STUDENTS WITH GOOD READING SKILLS – UPPER ELEMENTARY GRADES: Have the class as a whole to identify 1 species from the photos and botanical specimens provided in the trunk.
Then have students visit 9 stations, each with specimens from 1 species, and use the key to identify them. The “Materials and Preparation” and “Procedures” sections below are written for this approach.

FOR STUDENTS WITH LIMITED READING SKILLS – EARLY ELEMENTARY GRADES: Do the activity together as a class, but use 10 student teams, one “in charge” of each set of botanical specimens:

- Project **Handout E10-page 1: Identify 10 summer trees!**
- Provide to each student team: a set of specimens from the trunk (tree bark/trunk, cone or flower, foliage, photo collection). This is also available online: **E10_TreePhotos.pdf**.
- Read the questions on the projected key together as a class.
- After reading each question, have the student teams examine the specimens. Have members of the teams raise their hands if they can answer “yes” to the question based on “their” tree specimens. Thus move through the key together to determine the correct species.

The code letters for the trees in this version of FireWorks are:

- 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

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

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

**Materials and preparation:**

- Print 1 copy/student of **Handout E10** (two pages)
- Keep the specimens/photos for species D (western redcedar) at your desk.
Assemble 9 stations in the classroom, each containing the following for a species other than D:

- Tree bark/trunk specimen (in trunk)
- Cone or flower specimen (in trunk)
- Foliage specimen (in trunk)
- Photo collection of the tree species (in trunk and also available: Tree_ID_photos.pdf)

Project Handout E10-page 1: Identify 10 summer trees!

The Mystery Trees box in the trunk contains labels with the species names on them (Tree_spp_labels.pdf). Do not hand these out with the specimens. You will use them later.

Procedure:

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

2. Explain: Today we'll add to what you already know by learning how to use a dichotomous key to identify tree species. By the end of class, you'll be able to identify 10 species that live in Northern Rocky Mountains or northern Cascade Mountains forests. This key is not just useful for identifying dead tree parts in the classroom, like we're doing here. Once you know how to use the key, you can take it outdoors and identify trees in the forest. We'll identify one species together, and then you will do 9 others at stations.

3. Give each student a copy of Handout E10.

4. Project the first page of the handout. Starting at the top left side of the key, work with the students to identify “D,” western redcedar. As you do this together, students will see how to identify a tree based on characteristics of the leaves, bark, cones, flowers, etc. Make these points:

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

- Once you think you’ve made an identification, you must check your specimen against the species description on the back of the handout. Why? This key has only 10 species, but there are many more in the field. You’ll need the extra clues to make sure you’ve got the species right.

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

Have students circulate from one station to another (order doesn’t matter), identify the tree species at each station, and enter the correct code letter in the handout. You may want to use a timer to make sure students move from one station to another and everyone gets a chance to examine every set of specimens.

OTHER IDEAS FOR ASSESSMENT OR FOLLOWUP: Quiz students by holding up a set of specimens (photos, bark, cones, leaves) and having them identify it using their completed keys.

Quiz students by describing or sketching a trait and having them ask questions until they identify the species.

Evaluation:

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<td>species</td>
<td>fewer than 5 species</td>
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Handout E10-page 1. Identify 10 summer trees!

**Name ____________________**

Does it have needle-shaped leaves*?

- **yes**
  - Are the leaves a lot shorter than your thumb?
    - **yes**
      - Do the cones hang down from the branches?
        - **yes**
          - Do its needles grow in bundles on little woody bumps?
            - **yes**
              - Western larch?
        - **no**
          - Do the cones have a lot of 3-pointed, papery things coming out from under the scales?
            - **yes**
              - Douglas-fir?
          - **no**
            - Engelmann spruce?
    - **no**
      - Subalpine fir?
      - **yes**
      - Lodgepole pine?
      - **no**
      - Ponderosa pine?
        - **yes**
          - Whitebark pine?
        - **no**
          - Quaking aspen?
            - **yes**
              - Western redcedar?
            - **no**
              - Black cottonwood?

- **no**
  - Are the leaves tiny, looking like overlapping scales?
    - **yes**
      - Western redcedar?
      - **yes**
      - Subalpine fir?
      - **no**
      - Quaking aspen?
        - **yes**
          - Lodgepole pine?
        - **no**
          - Ponderosa pine?
            - **yes**
              - Whitebark pine?
            - **no**
              - Black cottonwood?

- **no**
  - Is the bark smooth?
    - **yes**
      - Western redcedar?
    - **no**
      - Black cottonwood?

This key works best for mature trees. Use it to make a good guess at what kind of tree it is. Then read the notes on the back to check your guess. It could be a different species!

*Needles are a special kind of leaf.
Handout E10-page 2. Check your tree identification:

1. **Black cottonwoods** have long, wide leaves that may be very shiny and have pointed tips. The buds at the ends of their twigs are pointy. In spring, they are very sticky. Old cottonwoods have gray, deeply furrowed bark. Cottonwood seeds are packaged with lots of cottony fluff, which helps them float a long way on wind and water.

2. **Douglas-firs** have short, flat needles and brown, furrowed bark. The buds at the ends of their twigs are pointy. Their cones feel kind of papery (like spruce cones) but with this difference: Little, 3-pointed “wings” stick out from under the cone scales. It looks like tiny mice are trying to burrow in, but they can’t hide completely!

3. **Engelmann spruces** have short needles with very sharp tips, which gives them the name “sticky spruce.” Their cones feel kind of papery. Their bark is grayish, with roundish scales that sometimes flake off.

4. **Lodgepole pines** have fairly long needles that usually grow from the twig in bundles of 2. Their cones are pointy and very prickly. Sometimes their cones are closed tight so the seeds can’t get out; sometimes they are open. Lodgepole pine bark is dark and scaly.

5. **Ponderosa pines** have long needles that usually grow from the twig in bundles of 3. Their cones are big and have prickers on the scales. Their bark is yellowish or brown, sometimes even orange. It falls off in pieces that look like they belong in a jigsaw puzzle. Ponderosa pine bark has a vanilla-like smell, especially in the springtime.

6. **Quaking aspens** have roundish leaves with a pointed tip. Their leaves move almost constantly on the tree because they are very sensitive to wind. Their bark is mostly grayish-white and smooth, although old trees can have furrowed bark near the ground. Their seeds are packaged with cottony fluff that helps them float long distances on wind and water.

7. **Subalpine firs** have short, flat needles and gray bark. Their bark often looks like it has spots or blisters in it. Their cones grow at the very tops of the trees, pointing upward toward the sky. The cones don’t fall off. Instead, they fall apart on the tree, and the pieces fall to the ground.

8. **Western larches** have short, soft needles, which grow in tufts of 10 or more out of little woody bumps on the twigs. Their leaves turn gold in the autumn and then fall off. Therefore, they are conifers (cone bearers) but not evergreens like pines, firs, and spruces. Western larch cones are small and lightweight. The tree’s bark is brown to reddish-brown.

9. **Western redcedars** have leaves that look like tiny, overlapping scales. Because many leaves grow together, the trees may look a little like they have small ferns for leaves. Their cones are small—about as big across as your thumbnail. Western redcedar bark is grayish, with furrows and loose strands. It looks like someone tried to peel or shred the bark.

10. **Whitebark pines** have fairly long needles that grow from the twig in clusters of 5. Their cones are purplish-brown but turn brown as they age. The cones don’t usually fall off the tree. Most of them ripen in the treetops and then get pulled apart by Clark’s nutcrackers, who want their large seeds. The pieces of cone that the nutcrackers remove fall to the ground under the tree. Whitebark pine’s bark is whitish on young trees and gray to black on older trees.
Identify 10 summer trees!

**Handout E10. Answer Key**

1. **Does it have needle-shaped leaves?**
   - yes, go to question 2
   - no, go to question 3

2. **Are the leaves a lot shorter than your thumb?**
   - yes, go to question 4
   - no, go to question 5

3. **Western redcedar?**
   - yes, go to question 6
   - no, go to question 7

4. **Quaking aspen?**
   - yes, go to question 8
   - no, go to question 9

5. **Is the bark smooth?**
   - yes, go to question 10
   - no, go to question 11

6. **Black cottonwood?**
   - yes, go to question 12
   - no, go to question 13

7. **Are the needles in clusters of 2?**
   - yes, go to question 14
   - no, go to question 15

8. **Lodgepole pine?**
   - yes, go to question 16
   - no, go to question 17

9. **Ponderosa pine?**
   - yes, go to question 18
   - no, go to question 19

10. **Whitebark pine?**
    - yes, go to question 20
    - no, go to question 21

**Western larch?**
- yes
- no

**Douglas-fir?**
- yes
- no

**Subalpine fir?**
- yes
- no

**Engelmann spruce?**
- yes
- no

This key works best for mature trees. Use it to make a good guess at what kind of tree it is. Then read the notes on the back to check your guess. It could be a different species!

*Needles are a special kind of leaf.
11. Recipe for a Lodgepole Pine Forest: Serotinous Cones

Lesson Overview: In this activity students extract seeds from serotinous cones of Rocky Mountain lodgepole pine (also called “closed cones”), count the seeds, report their results, and analyze their pooled data. Then they calculate the number of seeds from serotinous cones that might germinate in a small forest after a crown fire has swept through.

Lesson Goal: Students will understand that many lodgepole pine trees have serotinous cones, which means that wildland fire helps them reproduce: Heat from a fire opens their cones, and their seeds drop onto a perfect seedbed. Students will understand that lodgepole pine seeds and subsequent seedlings may be amazingly abundant after a severe fire.

Objectives:
- Students can explain how seeds can get out of a serotinous lodgepole pine cone.
- Students can identify filled versus empty seeds.
- Students can count the number of filled seeds in a cone and record their data on a chart.
- Students can combine the class’s data with other information to estimate the abundance of lodgepole pine regeneration after fire.

About Student Presentations: If you assigned lodgepole pine to a student in Activity E08-2. Who Lives Here? Adopting a Plant, Animal, or Fungus, this would be a great time for that presentation. If you did not do that activity or did not assign lodgepole pine, we recommend that you either
- have students read the essay on lodgepole pine in the FireWorks Encyclopedia (Elem_FireWorksEncyclopedia_NRM-NC.pdf in Activity E08-2) or
- teach some of the information provided in the Teacher Background below.

*The only trunk items needed for this activity are closed serotinous lodgepole pine cones, pie tins, and the histogram poster (also available in E11_SeedHistogram.pdf).
Teacher Background: Forests of Rocky Mountain lodgepole pine\(^1\) cover very large areas in the West. Most of these forests were established after fire sometime during the past 150 to 300 years. Many of the fires were severe, torching and crowning - at least in patches. These forests will probably burn again in the next century or two, just as they have for thousands of years.

A few years after fire, burned areas in lodgepole pine forests can be home to millions of lodgepole pine seedlings. Why? Some lodgepole pine trees store their seeds in resin-sealed cones that stay on the tree for decades. These serotinous cones – also called “closed cones” - open when heat melts the resin. This frees the seeds, and they fall to the ground in perfect conditions for establishing a new forest: lots of sunlight, bare soil, little shade from overstory trees, and lots of nutrition in the soil for at least a few years.

In this activity, students extract the seeds from serotinous lodgepole pine cones, count them, pool their data, and determine the median and other descriptive statistics. Then they use multiplication and division to estimate the number of seedlings that might germinate in a small forest of burned lodgepole pine trees after a crown fire has occurred.

You can complete this activity in 1 day or 2. See the Procedure section below.

Materials and Preparation:
For Day 1:
- 1 lodgepole pine cone/student (in trunk)

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\(^{1}\) Rocky Mountain lodgepole pine is just one variety of the species. The biology and reproductive patterns of the other two varieties, Sierra lodgepole pine and shore pine, are very different from those of the Rocky Mountain variety.
• 1 Dixie cup/student or similar non-meltable container. You will heat the cones in aluminum pie tins with hot water to melt the resin, then place the cones in the cups, which will prevent the seeds from falling out as the cones open.
• Set up 3-4 stations, each with an aluminum pie tin, 8- or 9-inch diameter.
• Boiling or nearly boiling water

For Day 2:
• 1 sticky note/student (7.5 cm wide)
• 1 paper plate/student
• Display the poster E11_SeedHistogram.pdf (in trunk and also available for download). Note that its columns are 7.5 cm wide, the same width as the sticky notes.
• Look at Step 14 below to decide how deeply you want to get into the statistics. To finish the activity, you only need to discuss the median.
• Download E11_LotsaTrees.pptx to display at the start of the Assessment.

Procedure: This activity has two parts (Day 1 and Day 2). On Day 1, students see what happens when hot water is poured on serotinous lodgepole pine cones. This is a quiet, observational activity, and it doesn’t take very long. On Day 2, students examine the cones that have been opened by heat and count the seeds that come out, then pool their data and analyze it extensively with descriptive statistics and calculations. Day 2 is a busier, longer activity.

If you prefer to do this activity in one day, skip the Day 1 procedure and heat the closed cones ahead of time (see the NOTE that follows step 8), saving some closed cones for students to compare with the opened ones. Begin the Day 2 procedure with Step 9.

Day 1 Procedure... melting the resin and opening the cones:
1. Distribute the closed lodgepole pine cones and cups, 1/student. Ask: These cones have lots of seeds inside. How can they get out? Students will observe that the cones are closed up tight, and it seems there is no way to get the seeds out. They may try pounding or poking or picking at the cone scales... don’t let them hurt themselves!

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

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

4. Explain: The cones are from a lodgepole pine tree. They are sealed tight by resin, which is like hardened glue. Not all lodgepole pines produce this special kind of cone, but many do. This sealed-up-cone property is called serotiny. Let’s use heat to try to melt the resin and
help the seeds get out. We’ll use boiling water. The cones will cool off and dry out, and then we’ll examine them to see if they’ve opened up.

5. Explain: Students at each pie-tin station, place your cone in the pie tin. I will pour boiling-hot water over the cones. Don’t reach into the water until it cools off. Just observe. **You must be very quiet to listen, smell, and watch** for signs of the resin melting.

6. Pour boiling or very hot water into the pie tins.

7. After a minute, ask for observations. Students may see little bubbles coming from between the cone scales as the resin is melted and the air inside expands and escapes; they may hear the bubbles hiss as they come out of the cones; and they may smell the resin as it melts.

8. After the water has cooled, tell students to label their cups with their names, take their cones out of the water, and placed them in the cups. Then collect the cups for drying.

**NOTE:** It may take several days for the cones to open if you air-dry them. You can dry them quickly by heating them as follows; then the seeds will begin falling out in a few hours or the next day. Leave the cones in their cups to do this so the seeds from various cups won’t get mixed up.

- Microwave: 1 minute on high. If the cones do not open well with this much heat, try another minute. Let them cool before handling them.

- Oven: Place the cones (in cups) on foil on a cookie sheet and heat them in a conventional oven at 300º F for at least 30 minutes. The foil will catch any wax that melts off the cups.

**Day 2 Procedure... after the cones are dry and at least partly open:**

9. Give students their cone-filled cups, with cones that are now dry and at least partly open.

10. Give each student a paper plate for collecting the seeds when they are extracted from the cones.

11. Explain:

- From the open cone in the cup, extract as many seeds as you can. You can shake, bang (carefully), and pull – but don’t hurt yourselves! Some seeds may have already fallen out into the cup. Some cones may not have any seeds. That is not a problem. In fact, it is very important information to record.

- Look for **filled seeds**. Explain: Each seed has two parts – a papery “wing” and the actual seed. If the seed has an embryo in it (that is, a baby tree), it will be a dark oval, 1-2 mm across; this is called a filled seed. Ignore any seeds that are smaller; they do not contain an embryo.

- Count the filled seeds and write that number with big print on your sticky note.
• Place your sticky note in the correct column of the frequency diagram (i.e., E11_SeedHistogram.pdf poster), building up from the bottom. This way we can see how many cones have various numbers of seeds.

12. Ask: What does the frequency diagram show? Cones vary a lot in the number of seeds they contain, from zero to (perhaps) a large number. Some columns of the graph seem more common than others.

13. Together with the class (or individually for advanced students), figure out any or all of the following descriptive statistics. **The MEDIAN is the only statistic that you MUST have to complete the Assessment.**

   Explain: We use statistics to describe the patterns we see in data like the those we just collected – the numbers of seeds in lodgepole pine cones.

   • What is the minimum number of filled seeds per cone? Smallest number – probably zero.

   • What is the maximum number of filled seeds per cone? Greatest number counted – in the right-most column of the histogram.

   • What is the range of our data? Our data range from the minimum to the maximum.

   • What is the mode? In other words, what is the most “popular” number? This is the number with the tallest column, the most sticky notes. It could be zero.

   • What is the median? Have two students help, one at the left side of the frequency diagram and one on the right. With a pencil, have them circle the number on each sticky note – one at a time – until they meet in the middle. That is the midpoint of the data set, the median.

   • What is the average or mean? With students’ help, add the values on all the sticky notes and divide by the number of notes.
Assessment:

1. Project *E11_LotsaTrees.pptx*. Explain: Lodgepole pine forests in the northern Rocky Mountains and North Cascades sometimes have LOTS of tree seedlings, especially after a fire. Just how many is “lots”? For example, how many seedlings might we find in an area as big as a football field? Write some guesses on the board.

2. Explain: We can use our data to estimate how many seedlings might come up in a forest as big as a football field the year after a fire.

3. Give each student a copy of Handout E11-1. *From cone to forest*. Read through the introduction with them as needed. Have them all answer Question 1 together – that is the median number of filled seeds/cone (from the data gathered by the class). Have students complete the rest of the handout.

4. After the students finish, compare their answers with the guesses they made in Step 1. Discussion.

Evaluation: Refer to Answer Guidelines for Handout E11-1. *From cone to forest* below.

Note that the correct answer for each question after #1 depends on the previous answer. If one answer is incorrect, you’ll need to calculate all subsequent answers based on that incorrect one in order to figure out if the later calculations were done correctly.

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Handout E11-1. From cone to forest

Use the class’s data to estimate how many baby lodgepole pine trees you might find in a forest the summer after a crown fire$^2$:

Suppose we have a small lodgepole pine forest near our school. It is about as big as a football field. It contains 500 trees, and most of the trees produce serotinous cones.

1. Suppose the **median number of filled seeds per cone** in our forest is the same as what we observed in class: ______ seeds/cone.

2. Suppose each of the trees in our forest produces about 800 cones in a typical year. **How many filled seeds is it likely to produce in 1 year?**

3. Suppose most of the cones and their seeds stay healthy for at least 20 years.$^3$ This means that they contain embryos that can grow into healthy trees. The stored seeds are called a seed bank. **How many seeds are in an average tree’s seed bank?**

4. Recall that our small forest has 500 lodgepole pines in it. **How many seeds are in the seed bank for the whole forest?**

5. Suppose a crown fire burns through our little forest, releasing about half of the seeds in its seed bank. **How many seeds fall to the ground?**

6. Suppose about 1/3 of the seeds that fall to the ground produce baby lodgepole pines the next spring. **How many baby trees will be in our football-field-sized forest?**

$^2$ The numbers in this handout (cones/tree, trees/unit area, etc.) are not just made up; they came from a literature review of fire effects on Rocky Mountain lodgepole pine (www.fs.fed.us/database/feis/plants/tree/pinconl/all.html).

$^3$ Once a serotinous cone produces seeds, it will not produce any more seeds in future years, but the tree can produce more cones in future years.
Answer Guidelines for Handout E11-1. From cone to forest

Use the class’s data to estimate how many baby lodgepole pine trees you might find in a forest the summer after a crown fire:

Suppose we have a small lodgepole pine forest near our school. It is about as big as a football field. It contains 500 trees, and most of the trees produce serotinous cones.

1. Suppose the median number of filled seeds per cone in our forest is the same as what we observed in class: ______ seeds/cone.

2. Suppose each of the trees in our forest produces about 800 cones in a typical year. How many filled seeds is it likely to produce in 1 year? Multiply the median from the class’s data * 800. Example: If the median was 6 filled seeds/cone: 6 filled seeds/cone * 800 cones/tree = 4,800 seeds/tree in 1 year

3. Suppose most of the cones and their seeds stay healthy for at least 20 years. This means that they contain embryos that can grow into healthy trees. The stored seeds are called a seed bank. How many seeds are in an average tree’s seed bank? Multiply the answer from (2) * 20. Example: 4,800 seeds/tree/year * 20 years = at least 96,000 seeds in that tree’s seed bank

4. Recall that our small forest has 500 lodgepole pines in it. How many seeds are in the seed bank for the whole forest? Multiply the answer for (3) * 500. Example: 96,000 seeds/tree * 500 trees = 48,000,000 seeds in the forest’s seed bank

5. Suppose a crown fire burns through our little forest, releasing about half of the seeds in its seed bank. How many seeds fall to the ground? Divide the answer for (4) by 2. Example: 48,000,000 seeds in the forest’s seed bank/2 = 24,000,000 seeds on the ground

6. Suppose about 1/3 of the seeds that fall to the ground produce baby lodgepole pines the next spring. How many baby trees will be in our football-field-sized forest? Divide the answer for (5) by 3. Example: 24,000,000 seeds on the ground/3 = 8,000,000 baby trees!
Lesson Overview: Students look at specimens of 9 plant species – grasses, wildflowers, and shrubs – and examine their underground parts. They learn how these parts enable the plants to survive and/or reproduce after fire.

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

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

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

ABOUT STUDENT PRESENTATIONS: If you did Activity E08-2. 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 and black cottonwood. That way they can connect the concept of “buried treasures” to the underground parts of particular species that they’ve been studying.
Teacher Background: Most children are familiar with the above-ground appearance of plants. But they are not usually familiar with the plants’ underground parts, and yet these buried treasures are the features that enable some native trees and most grasses, shrubs, and wildflowers to survive wildland fire and/or reproduce successfully after fire.

There are many kinds of buried treasures; this activity covers only a few, but these should be enough to demonstrate to children the variety in plants that are native to the northern Rockies and North Cascades and are well adapted to fire. This activity does not require that students learn the technical names for plants’ buried treasures; however, you can add that requirement to the lesson if you wish. The correct terms are used in the species descriptions provided in the FireWorks Encyclopedia (Elem_FireWorksEncyclopedia_NRM-NC.pdf in Activity E8-2.)

Most of plants’ buried treasures enable plants to sprout new growth after their above-ground parts are removed. Buried roots, stems (“caudices”), bulbs, corms, and rhizomes account for the ability of perennial plants to sprout after fire, cold winters, grazing, and other forces that top-kill them – that is, that kill off their aboveground parts.

Seeds are also buried treasures, if they are stored deep enough in the soil to be protected from the heat of fires. To survive fire, of course, the seeds must be buried in soil that will not burn; seeds buried in duff or peat are very vulnerable to fire. Some plants produce seeds that cannot germinate until they are heated. These species become very sparse a few years after a fire and then show up by the thousands after the next fire. This response to fire is typical of Plant #8 in the trunk’s specimen collection, snowbrush ceanothus.
Buried treasures are one kind of trait that enables plants to thrive in an environment with fire. Other such traits include thick bark (found in mature ponderosa pines, western larches, and Douglas-firs), which students observed if they learned to identify trees in Activity E10 and serotinous cones (produced by many lodgepole pines), which they examined in Activity E11.

Materials and preparation:

- Find the 9 plant specimens in the trunk (probably stored in a “Buried Treasures” Box). The list below shows the plants’ code numbers, names, and the kind of buried treasures they possess.

<table>
<thead>
<tr>
<th>Code</th>
<th>Plant Name</th>
<th>Type of Buried Treasure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>arrowleaf balsamroot</td>
<td>caudex, i.e., underground stem</td>
</tr>
<tr>
<td>2</td>
<td>beargrass</td>
<td>rhizome, another kind of buried stem</td>
</tr>
<tr>
<td>3</td>
<td>fireweed</td>
<td>rhizome</td>
</tr>
<tr>
<td>4</td>
<td>glacier lily</td>
<td>corm, yet another kind of buried stem</td>
</tr>
<tr>
<td>5</td>
<td>pinegrass</td>
<td>rhizome</td>
</tr>
<tr>
<td>6</td>
<td>serviceberry</td>
<td>rhizome</td>
</tr>
<tr>
<td>7</td>
<td>smooth woodrush</td>
<td>rhizome</td>
</tr>
<tr>
<td>8</td>
<td>snowbrush Ceanothus</td>
<td>buried, long-lived seed; its hard seed coat is broken by heat</td>
</tr>
<tr>
<td>9</td>
<td>wild onion</td>
<td>bulb, consisting of modified leaves</td>
</tr>
</tbody>
</table>

Real specimens from the field would, in most cases, be better for this activity than the specimens in the trunk. If possible, bring in fresh samples of some of these species or take a field trip where you can see several of these species in the field.

If you do this, however, be sure to explain the principles ethical collecting to the students and model it in the field: Collect only with permission from the land owner; collect only from a location that has abundant specimens of that species (20 or more is a rule of thumb); replace the disturbed soil carefully; and collect only as much as you need.

- Make 1 copy/student of Handout E12-1: Buried Treasures.
- Preview the 1:21-minute video that shows the seeds of stork’s bill (*Erodium cicutarium*) “drilling” themselves into the ground: [https://www.youtube.com/watch?v=TOJG5mF6OLs](https://www.youtube.com/watch?v=TOJG5mF6OLs).

---

1 The video does not specify the time that actually elapsed during the filming.
Optional: Teach about the nature of seeds.

What does a seed need to make a new plant? A seed contains an embryo (baby plant), plus the nutrition needed to grow up to the top of the soil and start photosynthesizing, plus some kind of protection from rotting or being eaten before the plant can start to grow.

In most seeds, the embryos are very tiny, so they can't be identified without a microscope. But peanut embryos are big enough to see with the naked eye. If no one in your class is allergic to peanuts, get a bag of roasted peanuts and give one to each student. Have the students remove the shell and papery seed coat and break the peanut in half. Then they can see the tiny embryo with two cotyledons and a small root wad, surrounded by nutritious, fatty tissue that can support the baby plant until its leaves emerge into sunlight and can begin photosynthesizing. And then they can eat the peanut!

Procedure:

1. Ask: When you see green grass outdoors in the spring, where does it come from? Does it grow anew from seed every year? Most of the plants that come up in our yards and gardens in the spring are perennials, which sprout from parts that survived the winter underground. Examples: grass, tulips, dandelions, daffodils, iris, roses...

2. Explain: Special underground parts help many kinds of plants survive cold winters, grazing by animals, and even fire! In this activity, we'll learn about the buried treasures that enable plants to survive fire or reproduce successfully afterward.

   Seeds, of course, are one important way for plants to reproduce after fire – if they do not burn up and if they are buried deep enough to be protected from the fire's heat.

3. Ask: How can seeds get into the ground if we don't plant them? What are some ways that seeds can get buried in nature? Sometimes seeds are buried as litter accumulates on top of them. Sometimes birds and small mammals bury the seeds or pile them up in caches. Animals eat fruits and berries – which contain seeds in a nutritious covering. While animals digest the juicy parts, the seeds are harder to digest and pass right on through – to be deposited on the soil in feces, a perfect package of fertilizer. Some seeds have little appendages that help them “drill” themselves into the soil! Here is a link to a short video that shows this process in the seeds of stork's bill (Erodium cicutarium), a wildflower that is native to the United States and is widespread throughout the world:

https://www.youtube.com/watch?v=TOJG5mF6OLs

4. Show the class Plant #8, snowbrush Ceanothus. Explain: This plant produces seeds that can be buried underground for many years without rotting. The seeds don’t just survive fires; they need the heat from fire to grow a new plant. The seeds accumulate in the soil for years, “waiting” for a fire to occur. The plant’s seeds are buried in the soil’s seed bank, just

2 The video does not specify the time that actually elapsed during the filming.
as the seeds of some lodgepole pines (in their serotinous cones) are stored in a seed bank on the tree itself (see Activity E11. Recipe for a Lodgepole Pine Forest: Serotinous Cones).

5. Explain: Plants have many other kinds of buried treasures that enable them to sprout new tops if their above-ground parts are removed. They can sprout after deer eat off their tops, after winter freezes them, and after fire kills all of their above-ground parts. Even though these plants may look dead after a fire, many of them are still alive underground. We don’t say they are “killed”; we say they are “top-killed”. Let’s look at some of these.

6. Give each student a copy of Handout E12-1: Buried Treasures. Place Plant Specimens 1-7 and 9 on tables throughout the room. Instruct the students to circulate around the room and draw each plant’s buried treasure in the box below the photo.

7. When everyone has finished, ask students to compare the kinds of plants: Which look familiar and which look weird? Which ones have similar buried treasures? The bulb of wild onion resembles the corm of glacier lily, even though the corm is actually a modified stem while the bulb is a cluster of modified leaves. Arrowleaf balsamroot’s caudex is also a modified stem, perhaps the weirdest-looking specimen in the collection. The rhizomes of fireweed, pinegrass, and smooth woodrush all look kind of similar. Beargrass also has rhizomes, but they are thick and rope-like. Serviceberry has rhizomes, but they are woody and look like branches.

8. Discuss which species might be best protected from fire and which might be more vulnerable. Try to draw out the idea that deeper burial enhances protection. Size might help as well – but a thick rhizome lying on the soil surface would be very vulnerable.

### Assessment:
Explain: You will design a brand-new kind of plant that can survive fire because it has two or more buried treasures.

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

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

The second part of a scientific name distinguishes the individual species from similar ones. Sometimes the species name refers to a special feature of the plant. For example, the species name for quaking aspen is *Populus tremuloides*, because its leaves “tremble” all the time. Sometimes the species name refers to the person who first described it (to Europeans). For example, the species name for Douglas-fir is *Pseudotsuga Douglasii*, in honor of David Douglas, a Scottish botanist who lived and explored in the 1800s.
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<th>Partly successful</th>
<th>Unsuccessful</th>
</tr>
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<td>New Plant</td>
<td>-Student created a plant that has 2 buried treasures. (These can be similar to those in the specimens, or totally new and imaginative.) -Student gave logical explanation of how each of the buried treasures enables the plant to survive and/or reproduce after fire.</td>
<td>-Student created a plant that has 1 buried treasure. -Student gave logical explanation of how the buried treasure enables the plant to survive and/or reproduce after fire.</td>
<td>-Student created a plant without buried treasures OR -Student did not give logical explanation of how the buried treasure(s) enable the plant to survive and/or reproduce after fire.</td>
</tr>
</tbody>
</table>
Handout E12-1. Buried Treasures

Plant 1. Arrowleaf balsamroot (by Dave Powell, USDA Forest Service, Bugwood.org).

Plant 2. Beargrass (by Chris Schnepf, University of Idaho, Bugwood.org).

Plant 3. Fireweed (by Harlan B. Herbert, Bugwood.org).

Plant 4. Glacier lily (by Vernon Smith, calphotos.berkeley.edu).
Plant 5. Pinegrass
(by Dave Powell, USDA Forest Service, Bugwood.org).

Plant 6. Serviceberry

Plant 7. Smooth woodrush
(by Keir Morse, calphotos.berkeley.edu).

Plant 9. Wild onion
Unit VI.
Fire History and Succession
Lesson Overview: In this activity, students examine a fire-scarred tree cross section (sometimes called a “tree cookie”) and a display that shows tree growth rings. Then they record their own personal histories using growth rings as a metaphor.

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

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

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<th>3rd</th>
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<td>A,B,C,E,F,G</td>
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<td>Earth’s Place in the Universe</td>
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<td>ESS3.B</td>
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Teacher Background: In temperate ecosystems, tree growth rates vary throughout the year: In winter, trees are dormant and don’t produce any new xylem cells. In spring and early summer, when trees have plenty of moisture, they usually grow rapidly and produce very large xylem cells with thin walls. These large cells form a light-colored band in the wood, which is called earlywood. Trees usually grow more slowly in late summer and fall, when they have less moisture, so they produce much smaller xylem cells. These cells form a dark-colored band called latewood. With a microscope, you can see the relative sizes of the earlywood and
latewood cells. Without a microscope, you can still see the bands of wood. The combination of a light-colored band and a dark-colored band is a growth ring, and it represents one year’s growth – usually. We will make that assumption in this activity.

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

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

Materials and preparation:

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

- Download and project GrowthRingsForm.pptx.

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

1. Explain: In this activity, we’re going to learn how trees grow and compare that to the ways in which we humans grow.

2. Ask: How is your body different now from when you were a baby? When the students describe obvious changes (taller, heavier, more hair, teeth...), try to get them to describe how those things happened. For example, how did your legs get longer? My bones grew longer & I put more muscle on them.... How did your head get bigger? My skull grew and I kept filling it with new brain cells.

3. Ask: Trees get taller and heavier too as they grow up. They also get wider and grow more branches. Do they do it just like we humans do, by growing longer bones and adding muscle cells, brain cells, etc? No, trees grow mainly by producing new rings of wood every year and adding length to their top, branches and roots. Refer to GrowthRingsForm.pptx and any real tree cookies that you can pass around. Explain: Scientists Chris Baisan and Rex Adams obtained the “tree cookie” that’s shown in this photo from a Douglas-fir tree in New Mexico. They used it to learn about how old the tree was and how it grew. How do you think they did that? They counted its growth rings to estimate the tree’s age.

4. Can you see growth rings in the tree cookie? Explain, referring to the microscope photograph shown in the GrowthRingsForm.pptx display. In spring and early summer, when trees have plenty of moisture, they usually grow rapidly and produce very large xylem cells. These large cells form a light-colored band in the wood, which is called earlywood. In late summer and fall, trees usually grow more slowly because they have less moisture, so they produce much smaller xylem cells. These small cells form a dark-colored band called latewood. The combination of a light band and a dark band is a growth ring, and it represents one year’s growth.

5. Ask: In the cookie shown in GrowthRingsForm.pptx, what is the brown ring on the outside? The brown ring is bark, which protects the tree but doesn’t get counted as a growth ring because it stays outside the tree’s growing wood as it produces new rings from year to year. Bark is a little bit like our skin, which stays on our outside as bones and organs on the inside get bigger. Like our skin, a tree’s bark fits perfectly around its insides.

6. Review with students: We can count growth rings to estimate the age of a tree and learn other things about its history, like when the tree had an especially good or difficult year. Ask: How do you think the ring from a very dry, stressful year might look? Probably narrow. What would the ring from a perfect year look like – plenty of water, plenty of sunshine, plenty of space and nutrients? Probably wide.

7. OPTIONAL: Explain that COUNTING growth rings can only give us an estimate of a tree’s age, because sometimes trees grow in unusual ways. Once in a while, they grow two
rings in one year, or a partial ring, or no ring at all! For now, we will assume that every ring represents one year of growth.

8. We’re going to use some imagination now. We’ll pretend that we have growth rings, just as trees do, and we’ll use these growth rings to show our autobiography. Explain: You must know the year of your birth to do the activity. (Help them figure that out if they don’t know.)

9. Give each student a sheet of drawing paper. Have them write their names and “My Tree Autobiography” at the top. Have them fold their paper in half the “short way,” then unfold it. Explain: The left side is for drawing their growth rings, and the right side is for writing an autobiography. (See the example below. Note that it was prepared with PowerPoint though. Don’t expect your students to all draw tidy circles!)

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

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

**TEACHERS,** it might be fun to post the students’ autobiographies, but be cautious about this. Some may not want to share their histories, or they may record sensitive, personal events that should not be shared.
<table>
<thead>
<tr>
<th>Evaluation:</th>
<th>Full credit</th>
<th>Partial credit</th>
<th>No credit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drawing</strong></td>
<td>Student drew a reasonable likeness of a tree cookie, with 1 growth ring for every year of his/her life.</td>
<td>Student drew a reasonable likeness of a tree cookie, with several growth rings.</td>
<td>Student’s diagram did not resemble a tree cookie.</td>
</tr>
<tr>
<td><strong>Writing</strong></td>
<td>Student listed all the years of his/her life and used a complete sentence to identify something special about at least 5 years.</td>
<td>Student listed most of the years of his/her life and identified something special about 3-5 years.</td>
<td>Student listed only a few years of his/her life and identified something special about fewer than 3 years.</td>
</tr>
</tbody>
</table>
Example Tree Autobiography

2007 – I was born.
2008 – In this year, I had my first birthday.
2009 – My sister was born.
2010 – We went to the ocean. I found seashells.
2011 –
2012 – My dog Sadie was born.
2013 – I started Kindergarten.
2014 – My cousin stayed at our house.
2015 –
2016 – This year I am in 3rd grade.

Fold paper in middle.
Lesson Overview: Students will learn that trees can sometimes survive fire. They will create a human model that demonstrates how trees survive fire and how fire scars form. Then they will describe the fire history of cross sections (“tree cookies”) from fire-scarred trees.

Lesson Goal: Increase students’ understanding that some trees survive many fires and that there can be a lot of variety in the fire scar record among trees within a forest.

Objectives:
- Students can identify a fire scar on a tree cookie.
- Students can recognize variety in trees’ fire histories give some reasons for variation.

<table>
<thead>
<tr>
<th>Standards:</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
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<tr>
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<td>2, 7, 9, 10</td>
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<td>Speaking/Listening</td>
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<td>1, 2, 4, 6</td>
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<td>Earth’s Systems</td>
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<td>ESS2.D</td>
<td>ESS1.C</td>
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Subjects: Science, Mathematics, Reading, Writing
Duration: Two half-hour sessions
Group size: Whole class
Setting: Classroom
Vocabulary: catface, fire scar
Teacher Background: Fire has been a part of the history of most forests in North America for thousands of years. Tree growth rings and fire scars (scars made by fires on tree trunks) tell about a forest’s fire history. In this activity, students participate in a short drama that helps them visualize how fire can scar a tree without killing it. Then they make observations, record data, and use this information to imagine and tell the history of a single tree that has survived several fires during its lifetime.

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

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

Materials and preparation:

- Find a small whisk broom and a piece of black plastic or cloth about 25 cm wide and 0.5-1.0 m long.
- View the video at www.youtube.com/watch?v=MyFBYQh_S_M to see how the human model of fire scar formation works. The model is also described in Step 3 below.
- Download and project E13_2_FireScars.pptx. You will show the presentation in 3 separate parts:
  - Use Slide 1 to introduce the concept of a fire scar (Step 2 below).
  - Use Slides 2-8 to show how fire-scarred tree cookies are sampled in the field (Step 4).
  - You may want to use Slide 9 to introduce the Assessment. It is the same graphic that is given in Handout E13-2-01.
- Display the long poster that shows a fire-scarred tree trunk (LifesizeFireScar.pptx). Hang it so its bottom reaches the floor.
- Display the fire-scarred tree cookie(s) from the FireWorks trunk. Every FireWorks trunk contains different specimen(s). Materials in your trunk should contain keys to the cookies’ fire history.
- Get out the tree cookie photo posters and the Cookie Book from the trunk for use in the Assessment. These are also available in the folder FireHistoryMaterials:
  CookiePostersNRM-Cascades.pptx and CookieBookNRM-Cascades.pptx.
Procedure:

1. Examine the long poster of the fire-scarred tree trunk (in the trunk or projected from *LifesizeFireScar.pptx*) with the class. Ask: Have you ever seen a *catface*¹ like this on a tree trunk? What caused it? Anything that scrapes away the tree’s bark and kills part of its cambium can create a scar like this, called a “catface”. The catface on this tree was created by many fires. Fire-scarred catfaces usually start from the ground and are roughly triangular.

2. Explain: The photo is only about half the height of the actual catface. Let’s measure ourselves against the size of the catface. Measure the heights of a few tall students in the classroom, and place sticky notes on the poster to show their height relative to the height of the catface.

3. Show the **first** slide in *E13_2_FireScars.pptx*. Explain: These are photos of catfaces. Look at the close-up, which shows just half of a catface. Why do you think it shows vertical “folds” in the black scar? Each fold shows where the tree grew new wood from the living cambium at the edge of the fire-damaged wood. Each fold is a *fire scar*. How many fires have scarred this tree? (If you show the slide in “Normal” view, you can select the close-up photo and zoom in so students can count the scars.) The photo shows scars from at least 14 fires.

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

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¹ The term “catface” probably originated when turpentine collectors made successive gashes, year after year, on the trunks of pine trees in the forests of the southeastern United States. The vertical stacks of diagonal cuts looked a little like a cat’s whiskers, hence the term.
a) One student stands up and holds his/her arms out in a circle, forming a ring that represents the tree’s cambium – the layer under the bark that is essential for continued growth.

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

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

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

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

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

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

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

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

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

5. With the class, examine the fire-scarred tree cross section(s) from the trunk.

6. Explain: Let’s see how scientists get samples like these. Go through Slides 2-8 of *E13-2_FireScars.pptx*:

These 3 wood specimens (sometimes called “tree cookies”) and all of the specimens used in the Assessment were collected for the following study and are photographed and used with the authors’ permission: 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 Forestry. 44(6): 593-603.
Assessment:

1. Ask: Do you think every surface fire in a forest scars every tree, or is there some variety? Why? Open discussion. Many things influence the amount of variation, including how
uniform the fuels are, how uniformly moist they are, whether they are all in shade or sun, how uniform the trees are in bark thickness and history of previous scarring.

2. Explain: We will work in groups to look at 11 fire-scarred cookies, all taken from one location in central Oregon. The first one is on Handout E13-2-01. Give each student a copy of the handout. Either complete Questions 1-4 together as a class (using Slide 9 from E13_2_FireScars.pptx) or have the students complete them independently.

3. Get out the cookie photo posters (Cookie Posters NRM-Cascades.pptx). Show students the photo poster for Tree 01, which is the one featured on their handout. Hand out the other 10 photo posters from the trunk, one to each pair or group of students. Explain that the data table on the photo posters gives information on that tree’s fire history. You may want to go through the rows in the data table with the class – tree identification number, species, inner ring (oldest wood), outer ring (youngest wood), the years of all fire scars, and the years between fire scars.

4. Explain: Use the photo and data on the poster to answer questions 5 and 6 on your handout. Then we’ll discuss how much variety this forest had in its fire history and how well (or poorly) the trees grew after the fires. DO NOT WRITE ON THE PHOTO POSTERS.

5. After students have completed Questions 5 and 6, lead a discussion using at least the first 2 of the following questions:

   - How much do trees vary in the number of fires that have scarred them? Start with “Who has a cookie with just 1 fire scar?” Tree 21 has just 1 scar from fire, although it has some other form of damage around the year 1970. “Who has 2… 3… more?” “Who has the most?” Tree 08, with 7 fire scars. (You can have students stand in the order of number of scars, least to most, showing their posters.)

   - What was the shortest time between fires? 26 years on Trees 03, 07, and 08. What was the longest time? 160 years on Tree 20 (You can have students move around to show these items in order, if you wish.)

   - Who has a cookie that showed very healthy growth after a fire? There are many. One of the best is Tree 07 after the 1580 fire. Show the class. Why might this happen? Maybe fire killed neighboring trees, so this one could get more water or sunlight. Maybe ash in the soil provided extra nutrition for the tree.

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Who has a cookie that showed very poor growth after a fire? Several cookies show very narrow growth rings for 4-5 years after fire. Then most seem to increase growth for at least a while. Show the class. Why might this happen? Maybe the roots or crown were damaged by the fire. Maybe too much of the cambium was damaged, so the tree couldn’t get much water from the ground to the crown – or couldn’t get nutrients from the needles to the rest of the tree.

How old is the oldest growth ring in these cookies? Tree 30’s inner ring is the oldest, dated 1514.

Which cookie has the most growth rings? Tree 03, which has 347 growth rings.

6. Explain: Now we’ll return to the question we started with: **Do you think every surface fire in a forest scars every tree, or is there some variety? Why?** EITHER COMPLETE THIS DISCUSSION TOGETHER OR HAVE STUDENTS WRITE A 1-PARAGRAPH ANSWER ON THE BACK OF THEIR HANDOUTS.

**Evaluation:**

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<th>Fair</th>
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<td>Questions 1-4</td>
<td>See the <a href="#">Answer Key for Handout E13-2-01. Tree Stories</a></td>
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<td>Questions 5-6</td>
<td>See the FireWorks cookie book (<a href="#">CookieBook_NRM-Cas.pptx</a>)</td>
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<td>Volunteered at least 1 correct answer.</td>
<td>Volunteered at least 1 answer, even if not correct.</td>
<td>Did not participate.</td>
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<td>Essay (if used)</td>
<td>~~Wrote complete paragraph. Stated that most forest stands with fire scars show variety because not every surface fire scars every tree. ~~For further explanation, see the discussion notes under Step 1 of the <a href="#">Assessment</a>.</td>
<td>~~Did not write complete paragraph. ~~Stated that most forest stands with fire scars have variety, but gave little explanation.</td>
<td>~~Did not write complete paragraph. ~~Stated that all surface fires scar every tree and/or ~~Gave no reasons for answer.</td>
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**Notes:**

- **Excellent:** Scored 100%
- **Fair:** Scored 0-99%
- **Poor:** Scored 0-99%

---
Here is a cookie from a fallen log or stump that was found in central Oregon. The tree was a lodgepole pine. It has one fire scar.

1. Draw an arrow marking each end of the fire scar. Label your arrows.
2. Draw an arrow to show first growth ring in the tree. This is called the *pith*. Label the arrow.

3. About how old was **Tree 01** when it was scarred by fire? About _________ years old
4. Count as many rings on **Tree 01** as you can between the fire scar and the bark. The rings right under the bark are too tiny to count, so your count will be a *minimum*. Then complete this sentence: *At least _________ years went by after the fire.*

**ANSWER THESE QUESTIONS ONLY AFTER YOU ARE ASSIGNED A TREE PHOTO POSTER:**

5. How many scars on your tree cookie were made by fire? ____________
6. How many growth rings are on your tree cookie? ________________
Answer Key for Handout E13-2-01. Tree Stories

Here is a cookie from a fallen log or stump that was found in central Oregon. The tree was a lodgepole pine. It has one fire scar.

1. Draw an arrow marking each end of the fire scar. Label your arrows.

2. Draw an arrow to show first growth ring in the tree. This is called the pith. Label the arrow.

3. About how old was Tree 01 when it was scarred by fire? About 33 years old

4. Count as many rings on Tree 01 as you can between the fire scar and the bark. The rings right under the bark are too tiny to count, so your count will be a minimum. Then complete this sentence: At least [any number >25 is acceptable here] years went by after the fire.

ANSWER THESE QUESTIONS ONLY AFTER YOU ARE ASSIGNED A TREE PHOTO POSTER:

5. How many scars on your tree cookie were made by fire?

6. How many growth rings are on your tree cookie?

[Consult the FireWorks cookie book (CookieBook_NRM-Cas.pptx) for answers.]
Overview: Students use feltboard materials to tell the story of fire and succession in 3 ecosystems of the northern Rocky Mountains and the North Cascades – forests dominated historically by ponderosa pine, lodgepole pine, and whitebark pine.

NOTE: There is 1 feltboard background and narrative kit (loose-leaf notebook with script and felt pieces) for each of the 3 ecosystems. You probably will need 1 class period to go through each story.

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

Objectives:

- Students can listen to and learn about how fires affect the plants and animals that live in forests of the northern Rocky Mountains and the North Cascades.
- Students can listen to and learn about how these forests change over time, especially time since fire.
- Students can help use materials to illustrate a story and provide appropriate sound effects on cue.
- Students can write about or illustrate different types of fire and the responses of various organisms to fire.

Subjects: Science, Reading, Speaking and Listening

Duration: Three 30-minute class sessions (1 for each of 3 feltboards)

Vocabulary: riparian, succession

ABOUT STUDENT PRESENTATIONS: If you did Activity E08-2. Who Lives Here? Adopting a Plant, Animal, or Fungus, make sure all student presentations are completed before you do this activity.
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**Teacher Background:** Forests change over time in the process called succession. Fire is a dramatic force for change, but change occurs without fire, too. Some plants need sunny openings to grow well, so they thrive in the first years after fire, and some animals thrive in the habitat they provide. Other plants may thrive in deep shade, in places not burned for a long time, and the animals that depend on them are present only in old, unburned forests. Some plants and animals can live almost anywhere, regardless of when a fire occurred or how the forest changes.

It is best to spread this activity out over 3 days, presenting one feltboard story each day. Students help assemble the feltboard and provide sound effects as the teacher or another adult reads the story.

Once students in the **upper elementary grades** have seen at least 1 of the feltboard stories, they may be able to read the narrative it themselves, practice presenting the story with the felt materials, and then present the story to an audience - possibly in a classroom of younger students or in a program for parents.

**ANOTHER OPTION FOR OLDER STUDENTS:** If you used Activity E08-2. Who Lives Here? Adopting a Plant, Animal, or Fungus, have teams of students take 1 of the 3 forest ecosystems and write their own script using the feltboard materials to tell the story. Then have them present it to the class or to younger students.

**Materials and Preparation:**

1. Find the 3 feltboard backgrounds and the 3 looseleaf notebooks: *Creepy, Crawly Fires; Roaring Treetop Fires; and Rollercoaster Fires* (all in the trunk).

2. Find the small container of pins. You will probably need them to secure felt pieces to the backgrounds.

3. Hang the feltboard backgrounds in the classroom.

**Procedure FOR EACH OF THE 3 STORIES:**

1. Gather the students, perhaps in a circle, and prepare them for a story about a forest ecosystem. Explain: They will all help tell the story by placing pieces on the feltboard and making sounds when you ask for them.
2. Ask students to watch and listen for these special things as you go through the stories:
   - The kind of fire that is portrayed
   - Which plants and animals really like just-burned forests
   - Which plants and animals really like forests that haven’t burned for a long time

   Write a couple of words for each of these topics on the board as reminders. You will return to them at the end of each story.

3. Read the story:
   - Take out the 8”x11” felt sheets with felt pieces from the notebook. Keep the sheets and pieces stacked in order, so students can come up and place the pieces on the background as you cue them.
   - As you read the story, direct student helpers to place the pieces on the feltboard according to the cues in the narrative. (When students attach the felt pieces to the background, have them pat the pieces onto the board firmly. If they won’t stick, attach them with pins – but know that they may have to be removed during the course of the story.)
   - Ask for lots of sound effects; the narrative contains cues for these, but you can add more. Students love these.

4. After you complete the story, discuss the 3 points under Step 2 above with the class. Note that each ecosystem contains a streamside (riparian) area, and the plants and animals there generally like habitat that hasn’t burned for a long time.

5. Use pins to attach the felt pieces to the background for long-term display.

Assessment:
   - Keep the feltboards on display in the classroom, and keep the narratives out so students can refer to them.
   - Explain: Pick 2 of the 3 forest ecosystems covered by the feltboard stories (Creepy, Crawly Fires or Roaring Treetop Fires or Rollercoaster Fires). Create a pair of comic strips or drawings that show how the 2 ecosystem stories are the same and how they are different. Your work should include these items (write them on the board):
     - Some of the plants that live there (label them with their names)
     - Some of the animals that live there (label them)
     - Kind of fire that was most common in the past
     - What usually happened after fire
**ALTERNATIVE OPTION:** Have students write 2 paragraphs instead.

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<td>Comic strip/Drawing Option</td>
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<td>-Student addressed &lt;3 of the 4 requirements.</td>
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<tr>
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<td>-Student indicated a clear understanding of fire and succession in the 2 forest stories.</td>
<td>-Student did not indicate an understanding of fire and succession in the 2 forest stories.</td>
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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.

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.
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.

\(^1\) Appendix 3 lists scientific names for all plants and animals mentioned or shown in this activity.
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/).

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

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

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.
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.

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.

<table>
<thead>
<tr>
<th>Information and cues for studying “Carrying Fire the Pikunii Way”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Background:</strong></td>
</tr>
<tr>
<td>Speaker</td>
</tr>
<tr>
<td>Location</td>
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<tr>
<td>Art work</td>
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<tr>
<td>Sound</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Cues for the video:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>0:45</strong> Interviewer asks, “How did they do that [carry fire], and why? You could stop here and have students answer the question.”</td>
</tr>
<tr>
<td><strong>1:06</strong> 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.</td>
</tr>
<tr>
<td><strong>1:23</strong> Shows plains prickly-pear, a type of cactus.</td>
</tr>
<tr>
<td><strong>1:40</strong> Mr. Weatherwax says that, after fire, the land will “renew.” You could stop the video and ask students what that might mean.</td>
</tr>
<tr>
<td><strong>1:43</strong> Shows quaking aspen sprouting from a top-killed tree after fire.</td>
</tr>
<tr>
<td><strong>1:49</strong> Mr. Weatherwax refers to “pharmacies,” meaning materials that can be used for health and healing. For more information about his and others’</td>
</tr>
</tbody>
</table>
remarkable work in healing, see http://nativenews.journal.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

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:24</td>
<td>Shows several buffalo. The one on its back is wallowing in dust to</td>
</tr>
<tr>
<td></td>
<td>reduce parasites and soothe bites on the skin.</td>
</tr>
<tr>
<td>9:45</td>
<td>Shows sarvisberry leaves and berries (also called Saskatoon</td>
</tr>
<tr>
<td></td>
<td>serviceberry)</td>
</tr>
<tr>
<td>10:07</td>
<td>Shows common chokecherries</td>
</tr>
<tr>
<td>10:12</td>
<td>Shows blue huckleberries</td>
</tr>
<tr>
<td>10:14</td>
<td>Shows limber pine cones. The seeds of these trees and of whitebark</td>
</tr>
<tr>
<td></td>
<td>pines are very large and nutritious.</td>
</tr>
<tr>
<td>10:25</td>
<td>The interviewer asks, “Do the Pikuni still carry fire?” Maybe stop the</td>
</tr>
<tr>
<td></td>
<td>video and ask students if they think it is still important to carry fire.</td>
</tr>
<tr>
<td>11:31</td>
<td>The interviewer mentions “Sharing knowledge about the Pikuni way.”</td>
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<tr>
<td></td>
<td>Ask students how they have learned about their own way of life. Have</td>
</tr>
<tr>
<td></td>
<td>they had a special family member or teacher who was especially helpful?</td>
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<tr>
<td></td>
<td>How might they go about learning so they could become elders for their</td>
</tr>
<tr>
<td></td>
<td>school, family, community, or country?</td>
</tr>
</tbody>
</table>

**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:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Full credit</th>
<th>Partial credit</th>
<th>No credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building a campfire</td>
<td>Worked safely and carefully. Listened respectfully to other team members. Contributed suggestions. Helped team work together.</td>
<td>Worked safely and carefully. Listened respectfully to other team members. Contributed suggestions.</td>
<td>Ignored safety precautions, did not participate with others on team, or dominated project without input from other team members.</td>
</tr>
<tr>
<td>Examining fire carrier, listening to video</td>
<td>~~~Handled fire carrier gently. ~~~Offered 1 observation or question. ~~~Listened respectfully to video.</td>
<td>Met 2 of the 3 criteria under Full credit.</td>
<td>Met 0-1 of the 3 criteria under Full credit.</td>
</tr>
<tr>
<td>Cumulative listening activity</td>
<td>~~~Repeated previous 2 speakers’ statements. ~~~Contributed 1 sentence with accurate information.</td>
<td>Met 1 of the criteria under Full credit.</td>
<td>~~~Did not repeat previous 2 speakers’ statements accurately. ~~~Did not contribute 1 sentence with accurate information.</td>
</tr>
</tbody>
</table>
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. **Closing and sealing the fire carrier:** 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.

13. 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.

14. Cut leather into 5 strips, each about 14” long. These will be used to secure the cover.

15. Tie ends of four leather strips onto the fifth piece, which goes around the horn.

16. 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

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>buffalo</td>
<td><em>Bos bison</em></td>
</tr>
<tr>
<td>sarvisberry/Saskatoon serviceberry</td>
<td><em>Amelanchier alnifolia</em></td>
</tr>
<tr>
<td>arrowleaf balsamroot</td>
<td><em>Balsamorhiza sagittata</em></td>
</tr>
<tr>
<td>glacier lily</td>
<td><em>Erythronium grandiflorum</em></td>
</tr>
<tr>
<td>blue huckleberry</td>
<td><em>Vaccinium membranaceum</em></td>
</tr>
<tr>
<td>common chokecherry</td>
<td><em>Prunus virginiana</em></td>
</tr>
<tr>
<td>limber pine</td>
<td><em>Pinus flexilis</em></td>
</tr>
<tr>
<td>whitebark pine</td>
<td><em>Pinus albicaulis</em></td>
</tr>
<tr>
<td>willow</td>
<td><em>Salix species</em></td>
</tr>
<tr>
<td>western yarrow</td>
<td><em>Achillea millefolium</em></td>
</tr>
<tr>
<td>elk</td>
<td><em>Cervus elaphus</em></td>
</tr>
<tr>
<td>cottonwood</td>
<td><em>Populus species</em></td>
</tr>
<tr>
<td>quaking aspen</td>
<td><em>Populus tremuloides</em></td>
</tr>
<tr>
<td>pine</td>
<td><em>Pinus species</em></td>
</tr>
<tr>
<td>Fir, Douglas-fir</td>
<td><em>Abies species and Douglas-fir (Pseudotsuga menziesii)</em></td>
</tr>
<tr>
<td>birch</td>
<td><em>Betula species</em></td>
</tr>
<tr>
<td>buffaloberry</td>
<td><em>Shepherdia canadensis</em></td>
</tr>
<tr>
<td>prickly-pear</td>
<td><em>Opuntia species</em></td>
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</table>
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 to assessment of photos of wildland homes, ask how “firewise” the homes are, make recommendations to the home owners, and justify their recommendations.

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

Objectives: Students can:

• assess the fire hazards on and around homes in wildland settings.
• recommend steps to improve their protection from wildland fire.
• give reasons for their recommendations based on their understanding of wildland fire.

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

Duration: one class period

Group Size: Whole class

Setting: Indoors

Vocabulary: firewise

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<td>4, 7, 10</td>
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<td></td>
<td></td>
<td>ETS1.B</td>
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<tr>
<td>Earth’s Systems</td>
<td></td>
<td></td>
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<td>ESS2.D</td>
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</table>
Teacher background: This activity challenges students to apply their knowledge about fire science to a real-world problem – the safety of homes that are adjacent to 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 and associated fire behavior principles that apply to the photos used in this activity:

- Are there any ways that a surface fire could spread from the edge of the forest right up to the home? Why does it matter? Surface fires need continuous fuels for spread, 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 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 to get to the house? This point is not likely to emerge from their study of fire science, but it is surely worth bringing out in discussion.

Materials and Preparation:

- Download and project E16_FirewiseHomes1.pptx. This presentation contains photos of 4 homes for class discussion. If you want additional material, download E16_FirewiseHomes2.pptx, which has another 8 photos. The slides are shown in the Appendix at the end of this lesson.

- Make copies of Handout E16-1: Work to do on this home? for half of the class, and copies of Handout E16-2: Work to do on this home? 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 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, what might be done to reduce risk. Try to get to the idea that people can take action to reduce the risk of injury or damage to their homes from wildland fire.

5. Let’s list some ways to protect a house and property from wildland fire. These are called “firewise” practices. In the middle of the board, write “Firewise Rules.” For each suggestion, get an explanation of why it should reduce risk based on students’ understanding of fire and fuels. If the suggested rule and rationale are valid, list it on the board. This table shows some examples:

<table>
<thead>
<tr>
<th>What to do:</th>
<th>Why it works!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep litter and dead branches and other burnable stuff cleaned off the roof and porch and anyplace else next to the house.</td>
<td>An ember could ignite any of these fuels and then spread to the whole house.</td>
</tr>
<tr>
<td>Safe driveway</td>
<td>The driveway needs to be wide and clear so a fire engine can get to the house.</td>
</tr>
<tr>
<td>Limit surface fuels (vegetation)</td>
<td>Vegetation near the house creates opportunities for embers to catch and fire to spread.</td>
</tr>
<tr>
<td>No Trees overhanging house</td>
<td>Trees that overhang the house can drop burning branches onto the roof. They could also fall and break through the roof!</td>
</tr>
<tr>
<td>Green lawn</td>
<td>Moist fuels are unlikely to ignite and spread fire.</td>
</tr>
</tbody>
</table>
6. Explain: Now let’s apply our rules to some homes that are right next to wildlands or mixed in with wildland fuels. We’ll decide what makes these homes wise to fire – or firewise - and what could be improved.

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

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

9. Go through *E16_FirewiseHomes1.pptx*. With each photo, ask students to apply their firewise rules to the home. Add to or change the rules if appropriate. List their thoughts under “Good job!” and “Needs work”:

   **Slide 1**
   
   How firewise are these homes?
   
   **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.

   **Slide 2**
   
   **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.

   **Slide 3**
   
   **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.
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.

10. If you want to evaluate more photos, use E16_FirewiseHomes2.pptx, shown in the Appendix at the end of this lesson. The slides and notes are listed at the end of this activity.

11. Ask: Now that we’ve looked at some real homes, can you think of anything that should be changed in our list of firewise rules or added to it. Discussion.

12. Work with the class to turn the list of rules into a simple “Firewise home quiz,” 5 or more questions that anyone can use to evaluate a home’s protection from wildland fire. Example questions:
   a) Is the rooftop free of burnable materials, such as leaves and fallen branches?
   b) Is there a strip of unburnable material separating vegetation from the house?
   c) If there are trees and shrubs close to the house, are they short (not hanging over the roof)?
   d) Is there space between the surface fuels and the tree branches, so flames can’t get from the ground up into the tree crowns?
   e) If there is a lawn, is it kept green?
   f) Is there a road wide enough for a fire engine to get in while people are getting out?

Assessment:

1. Give each student either Handout E16-1 or E16-2.

2. Have them complete their individual handouts.

3. Then have them team up with someone who completed the other version, trade handouts, and try to improve both.
**Evaluation:**

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

<table>
<thead>
<tr>
<th>Handout E16-1</th>
<th>Good Job!</th>
<th>Needs Work.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Clean roof</td>
<td>• Embers can get under the deck</td>
</tr>
<tr>
<td></td>
<td>• Wide gravel driveway with turnaround</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No vegetation right next to house</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Woods near house are open, tree crowns are not continuous</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Handout E16-2</th>
<th>Good Job!</th>
<th>Needs Work.</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>• Clean roof</td>
<td>• Embers can get under the deck</td>
</tr>
<tr>
<td></td>
<td>• Woods near house are open, tree crowns are not continuous</td>
<td>• Mow grass near house.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Water grass. Get it green if possible.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Can’t see any way for a fire engine to get in or out.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Worry about burning stuff rolling down the hill into all that dry grass.</td>
</tr>
</tbody>
</table>
Handout E16-1: Work to do on this home?

Name: _______________

1. Good job!

2. Needs work:

3. This will help because...
Handout E16-2: Work to do on this home?

Name: ________________

1. Good job!

2. Needs work:

3. This will help because...
Appendix.
Additional photos of homes for “firewise” assessment
(*E16_FirewiseHomes2.pptx*)

Slide 1
More homes: How firewise are they?

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.

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.

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.

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.
Slide 6

Good job! Clever the way rocks have been used to landscape around the foundation. It looks like there’s green lawn on the other side of the sidewalk. It looks like trees in the background are spaced far apart.

Needs work: Can’t think of anything other than maintenance.

Slide 7

Good job! It looks like there’s some green lawn in the foreground.

Needs work: Are those bark chips next to the foundation? Replace them with something nonflammable, like rocks or gravel. Keep the landscaping shrubs watered and moist.

Slide 8

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

Needs work: Hard to find anything to suggest other than maintenance.

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.
17. Revisiting Wildland Fire

Use this activity only if you used Activity E01. Visiting Wildland Fire.

**Lesson Overview:** Students view the same photo presentation they saw in Activity E01, which shows wildland fires in a variety of plant communities and ecosystems, and some of the plants and animals that they learned about in the curriculum. When they first saw this presentation, it was accompanied by a short narrative. This time, they narrate the presentation themselves. Afterward, they discuss their feelings about wildland fire and whether they have changed from the feelings recorded in Activity E01. Finally, in the **Assessment**, they consider how difficult a fire manager’s job might be.

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

**Objectives:** Given a series of photos that they have seen before,

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

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**Teacher background:** This activity provides a way to briefly review concepts covered throughout the curriculum and an opportunity for students to articulate and validate their feelings about wildland fire.

**Materials and preparation:**

- Download *E017_VisitingWildlandFire.pptx* for presentation. The photos are the same as those used in *E01_VisitingWildlandFire*, but the narrative has been fleshed out so you can use it to prompt students or check their comments for accuracy. Try to avoid using it as a narrative.

- Find the flipchart with questions that students asked about fire in *Activity E01. Visiting Wildland Fire*. Post it in the classroom.

- Find the flipchart with students’ feelings recorded at the end of *Activity E01*. Don’t post it just yet.

**Procedure:**

1. Explain: For our final activity studying wildland fire, we’re going to go back to the first activity we did to discover what we have learned about fire and to describe our feelings about it.

2. Go through the questions that came up in *Activity E01* (recorded on a flipchart). Ask students to answer them now that they are experts on wildland fire. If they can’t, you can either help or suggest that they consult a local expert or do some research to find answers.
3. Explain: Now we will watch the same presentation that we saw at the start of our study of wildland fire. Last time, we had a short narrative about each photo. This time, you will explain what’s going on in each photo, as if you were explaining about wildland fire to a friend or family member.

4. Go through the presentation E17_VisitingWildlandFire.pptx. Ask students to provide information about each slide. When you get to the slides that show fire behavior, ask students to describe the kind of fire shown. **Try to avoid narrating the slides yourself. Instead, use the notes provided below and with the slides to draw out ideas from the students.**

**Slide 1**
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**
Here is a “creepy crawly” surface fire burning in a ponderosa pine/Douglas-fir forest. Surface fuels are burning: 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**
This is what the land looks like after that kind of 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.
The ponderosa pine tree on the left has survived many fires. Frequent surface fires were typical in this kind of forest up until about 1900. Since then, there have been few surface fires. As a result, lots of undergrowth has developed. These plants are now ladder fuels that could help a surface fire get into the crowns of the big old trees.

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.

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 surface fires removed the young trees growing beneath them. This removed ladder fuels and competition for moisture from understory plants.

This is a “roaring treetop” crown fire 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. They often run through the tree crowns, which grow close together and are sometimes even interlocking. The fires occur every hundred years or so, killing most of the trees.

Crown fires kill most of the trees in a stand. Unburned patches may be left, although this photo doesn’t show any. The photo shows that the ground is covered by ash, which means that there is no surface vegetation or litter left to protect the soil from the impact of raindrops and subsequent erosion. However, the fire probably only top-killed many plants, leaving their “buried treasures” intact and able to sprout new growth.
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 in big, severe burns. 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. This environment provides protection and food for the larvae. We also studied the mountain pine beetle in this class; the pine beetle feeds on the cambium of mature pines and kills the trees.

Here is a black-backed woodpecker. This bird arrives soon after severe fires to eat the insects (eggs, larvae, and adults of various species) under the bark of the dead trees. It will nest in the area and stay around for a few years. As food supplies decline, it will move on to a newly-burned area.

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 produces millions of seedlings and flowers.

Here are thousands of 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. That opened the cones, and 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).
Here is a “rollercoaster fire” in a high-elevation forest that has some whitebark pines and some subalpine firs. Fires don’t occur often in this kind of forest because it is cool and summers are short. Fires spread from one tree patch to another through the surface fuels, which are often discontinuous. The forest doesn’t have continuous tree cover, like lodgepole pine forests do, so it can’t support crown fire — although fires do torch in occasional patches of trees.

Here is a stand of whitebark pine where most of the trees are dead. They may have been killed by mountain pine beetle or white pine blister rust 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 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 mountain pine beetle and white pine blister rust that there are no seeds available for generating a new whitebark pine forest.

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 spread to reach it.

Here is a Clark’s Nutcracker. This bird harvests the seeds of whitebark pines and buries many of them underground so it can eat them later. It really likes to bury seeds in burned areas where lots of landmarks are visible. But it 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.
Here is a clump of whitebark pine seedlings that grew from seeds that nutcrackers buried. Whitebarks often occur in groups of 3 to 5 or more, because they originated in seed caches made by nutcrackers.

Wildland fires can burn for days or weeks after the flames have passed. They may burn in tree trunks, roots, duff, or 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. Ask: Do you want to answer any more of the flipchart questions? Do you want to add more questions? Record these and suggest a way to answer any new questions.

6. Display the flipchart on which you recorded their feelings about fire in Activity E01. Remind students: People’s feelings often differ without being “right” or “wrong,” so all of the feelings from class members in the past are valid and deserve respect. If they have new or changed feelings, those also deserve respect. Ask if they want to add to the list or discuss changes in their feelings.

Assessment: Ask the students to answer these 5 questions on a sheet of paper:

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

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