FireWorks Curriculum

Featuring the Sagebrush Ecosystem

Grades 4 - 8+

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For curriculum materials: www.frames.gov/partner-sites/fireworks/curriculum/sagebrush-ecosystem

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Contents

Introduction to the FireWorks Curriculum
Featuring the Sagebrush Ecosystem

Photo courtesy Gerrit Vyn, from *Nature's* *[The Sagebrush Sea]*

Welcome! This version of the *FireWorks* educational program (Smith and McMurray 2000) features the sagebrush ecosystem, the largest in North America. It is targeted to middle school students in grades 6-8, but can be adapted to meet the needs of all learners, including younger and older students. The ecology of southern and eastern Idaho is highlighted, but it is applicable to the sagebrush ecosystem areas found in 10 other western states, as well: Oregon, Washington, Wyoming, Montana, Utah, Nevada, California, North Dakota, South Dakota, and Colorado.

We extensively revised select lessons from the original curriculum to work with the sagebrush ecosystem and meet the new learning standards, as explained below. Note that we kept the numbers of the lessons the same as the original versions, to make it easier to cross-reference them. The original *FireWorks* focused on forest ecosystems can be found here: www.frames.gov/partner-sites/fireworks/curriculum.

Goals

FireWorks aims to increase understanding that:

- Properties of physical science explain combustion, including that of wildland fuels.
- Ecosystems have many kinds of organisms, which change over time and influence one another.
- Fire is an important natural process in many ecosystems.
- Native plants and animals have ways to survive and/or reproduce after fire.
- People influence the fire-dependent ecosystems where they live.

Meeting these goals helps implement the recommendation from the *Guidance for Implementation of Federal Wildland Fire Management Policy* (U.S. Dept. of the Interior and U.S. Dept. of Agriculture 2009) to transmit a clear message about the important role of fire as a natural process.

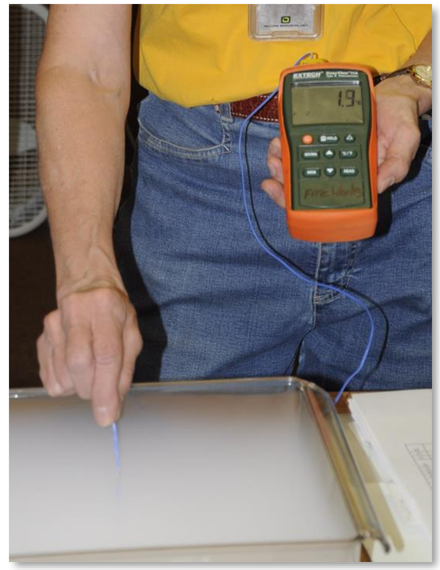
Why *FireWorks*?

FireWorks provides students with interactive, hands-on materials to study the forces that cause change, an integral part of healthy, enduring ecosystems in most temperate regions of the world. Based on the science of wildland fire, a highly interdisciplinary field, 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.

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 verbally and in writing
- identifying and expressing responses to science-related questions
- working in teams to solve problems and
- critical listening and reading.



Students using *FireWorks* ask questions, gather information, analyze and interpret data, 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).

The concepts and skills listed above are important in the Next Generation Science Standards (NGSS) and other state standards, including Idaho's new science standards which are based on the NGSS standards. These skills are crucial for developing an adult citizenry literate in science and attracting students to professional work in the sciences.

Lesson Plan Format

Each lesson has the following sections:

Overview
Lesson Goal(s)
Objectives
Alignment to Standards
Teacher Background
Materials + Preparation
Procedure
Assessment
Evaluation

Subjects: Science, Writing, Speaking & Listening, Art

Duration: 30 - 50 minutes

Setting: Laboratory or outdoors

Vocabulary

- ecosystem
- ecological community
- fire behavior

Each lesson also includes a text box (example above) that lists subjects covered, the average duration of the lesson, setting (laboratory, outdoors, etc.), and vocabulary (list of terms in the *FireWorks* Glossary that are **first** introduced in the lesson). ***Note:*** *FireWorks* Trunks are available free from BLM offices to support the curriculum, but most materials are also readily available elsewhere or can be downloaded if you do not have a trunk on loan.

Materials meant for teachers all begin with bold-face headers in **white** or **red text**. Handouts and other materials meant for students all begin with a large, bold-face header in **blue text**. Exceptions are listed in the Appendix, such as the glossary, which is a resource for both teachers and students.

Alignment to Standards

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

- the **Next Generation Science Standards (NGSS)**
- the **Common Core State Standards** in English Language Arts (ELA) and Math
- the **Excellence in Environmental Education: Guidelines for Learning (K-12) standards (EEEGL)**.

A chart like the one below is included in each lesson plan which lists the standards met.

Standards		Middle School (Grades 6-8)
NGSS	**Crosscutting Concepts**	• Stability and Change • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions ETS1.A: Defining and Delimiting an Engineering Problem
Common Core ELA	**Writing**	4, 7, 10
	Speaking & Listening	1, 2, 4, 6
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
EEEGL	**Strand 1**	A, B, C, E, F, G

Note:

- Numbers and letters listed for the standards correspond to those in the respective sections of the standards. Links to the standards are provided in the **References** section at the end of this introduction.
- Lessons are designed to meet multiple standards, but due to space considerations, those listed may not be completely comprehensive. Educators are encouraged to reinterpret standards and lessons and adapt lessons to meet their educational objectives and particular standards.

Safety

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

The following steps will help make a safe environment and assist your students in growing in responsibility and competence regarding lab safety and fire:

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

Place-Based Learning in the Sagebrush Ecosystem

Students learn best about ecology when it is close to home—when they can study the plants, animals, and fire regimes typical of local ecosystems (Lindholdt 1999; North American Association for Environmental Education 2010). This version of the *FireWorks* program focuses on the sagebrush ecosystem located close to many students throughout the West, a vast and diverse area containing 350+ species.

A large component of the ecosystem is the **sagebrush steppe** (also known as the high desert), which occurs mainly in the high elevation flat lands of the western United States. It contains dense patches of shrubs, grasses, and forbs (wildflowers), as well as patches of timber, such as juniper. Historically, the steppe was a vast area with bunch grasses and shrubs with open spaces between.

Due to this open spacing between vegetation, intense fires were rare in the high desert, and a stand replacement fire occurred only about every 50 – 100 years on average. Low intensity fires were common between stand replacement fires. These fires typically remained on the ground, cleaning up litter and duff, not harming the larger shrubs.

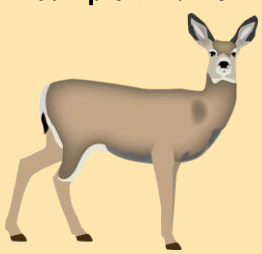
The table below lists historic fire regimes by group. Sagebrush steppe has historically been in Group 4.

Historic Fire Regimes				
Group	**Frequency**	**Severity**	**Description**	**Example**
Group 1 Frequent, low severity fires	0 – 35 years	Low / Mixed	Burns 25-75% of vegetation in mosaic pattern	Ponderosa pine forest
Group 2 Frequent, stand replacement fires	0 – 35 years	High / Stand replacement	High severity fires that burn over 75% of vegetation	Prairie grassland (Great Plains)
Group 3 Moderate to low frequency, low severity fires	35 – 200 years	Low / Mixed	Like Group 1, but with a longer return interval	Salt desert shrub
Group 4 **Moderate to low frequency, stand replacement fires**	**35 – 200 years**	**Stand replacement**	**High severity fires that replace over 75% of vegetation**	**Sagebrush steppe**
Group 5 Low frequency, mixed severity fires	200+ years	Mixed / Stand replacement	Generally stand replacement, but may include mixed severity	Coastal spruce – cedar – hemlock

The **high desert floor** is characterized by big sagebrush, low sagebrush, and salt-desert shrub systems. With increasing elevation, the higher plateaus and rocky areas support western juniper and curlleaf mountain mahogany communities. Aspen communities grow along streams and drainages in the mountain gorges and riparian zones, providing an important source of forage for deer and other wildlife. The **subalpine zone** supports low-growing shrubs, grasses, and wildflowers such as white mountain avens. Isolated stands of Douglas-fir and whitebark pine also occur in the mountains.

Wildlife species of concern include greater sage-grouse, mule deer, elk, pronghorn, pygmy rabbit, snowshoe hare, and golden eagle. Important habitats in the ecoregion include migration corridors and areas for overwintering pronghorn, as well as seasonal habitats for greater sage-grouse. Human-influenced changes in the ecoregion have affected fire frequency, severity, and seasonality. Additional effects are expected in the future from climate change influences, as well as a new awareness of allowing fires to burn, utilizing controlled burns, and new sources of ignition (e.g., more people moving into the Wildland Urban Interface).

The presence of **invasive species**, especially **cheatgrass**, in the ecoregion has made fire more problematic. In the sagebrush ecosystem areas, the primary woody species are not fire-adapted or fire-dependent. In the most dry, fuel-limited systems, fire may have almost never occurred. In other areas, fire may have occasionally burned these ecosystems (e.g., every few hundred years or more on average), especially after periods of significantly above-average moisture that may have increased fuel loads.

Summary of Sagebrush Ecosystem Ecology	
Sample Wildlife 	Greater sage-grouse, burrowing owl, pronghorn antelope, coyote, harvester ants, mule deer, golden eagle, pygmy rabbit, ferruginous hawk, American badger, sage sparrow, and prairie rattlesnake
Sample Plants 	Sagebrush, arrowleaf balsamroot, bluebunch wheatgrass, Idaho fescue, juniper, Indian paintbrush, Great Basin wild rye, bitterbrush, rabbitbrush, penstemon, tapertip hawk's beard, western yarrow, and wild onion
Sample Disturbances 	Invasive and noxious weeds (especially cheatgrass and medusahead), fire, fragmentation of the ecosystem (especially from roads and other development), and infrastructure associated with energy development
Traditional Native American Uses of Sagebrush 	Tea made from various parts of the plants and used extensively in medicine, for example to treat wounds and sore throats because of its antiseptic properties; wood used as fuel; stringy bark used to make ropes and baskets

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1. Wildland Fire in the Sagebrush Ecosystem

Subjects: Science, Writing, Speaking & Listening, Art

Duration: 30 – 50 minutes

Setting: Classroom

Vocabulary
- ecosystem
- ecological community
- fire behavior
- wildland
- wildland fire
- species
- succession

Overview Students view a narrated photo presentation that shows wildland fire and some of the plants and animals in the sagebrush ecosystem. During the presentation, students record observations about fire behavior. Afterwards, they compare and contrast the kinds of fire they observed, and describe their feelings about wildland fire.

Lesson Goals Increase students' understanding that wildland fire is a complicated process and it can sometimes benefit ecosystems

Objectives

- Students will sketch different kinds of fire behavior in various wildlands based on a photo presentation.
- Students will compare and contrast the different kinds of fire behavior in writing.
- Students will describe their feelings about wildland fire.

Standards		Middle School (Grades 6-8)
NGSS	**Crosscutting Concepts**	• Stability and Change • Systems and System Models
	Science & Engineering Practices	Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	LS2.C: Ecosystem Dynamics, Functioning, and Resilience
Common Core ELA	**Writing**	4, 10
	Speaking & Listening	1, 2, 4, 6
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
EEEGL	**Strand 1**	A, E, F, G

Teacher Background

As an introduction to the study of wildland fire, the photo presentation which accompanies this lesson highlights variation in **fire behavior** and its relationship to specific **ecosystems**. If you walk through a recently burned **wildland** area, you might encounter some places where all the vegetation looks dead and other places that still have a lot of green vegetation. You might see deep holes in the ground where roots have burned away, or even patches of leaf litter that are 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 forested areas with trees close together are more likely to support crown fires (spreading through the tree canopy) than forests where the trees are far apart.

This version of the *FireWorks* program focuses on the sagebrush ecosystem, the largest ecosystem in North America, which contains 350+ species. A large area of the ecosystem is the sagebrush steppe (also known as the high desert), which is found in the higher elevation plains of the Western United States. It contains dense patches of shrubs and grasses, as well as patches of timber, such as juniper. Historically, the steppe was a vast area with bunch grasses and shrubs with open spaces between. Due to this open spacing between vegetation, intense fires were rare, and a stand replacement fire occurred only about every 50-100 years. Low intensity fires were common between stand replacement fires. These fires typically remained on the ground, cleaning up litter and duff, not harming the larger shrubs.

Materials + Preparation

1. *Wildland Fire and the Sagebrush Ecosystem* PowerPoint presentation available here: www.frames.gov/partner-sites/fireworks/curriculum/sagebrush-ecosystem
2. Computer with Microsoft PowerPoint software and Internet access; projector and display screen
3. Copies of the "Wildfire in the Sagebrush Ecosystem" handout for each student (at end of lesson)
4. Write on the board: "**ecosystem**" and "**ecological community**"
5. ***Note:*** If you plan to teach the units on fire ecology (Units V and VI), consider giving the assignment from Activity 11 at the end of the lesson, so students have time to prepare for that activity, and so you can spread out student presentations over several days instead of having them all at once. See Activity 11 for more information.
6. ***Optional:*** Read additional sources such as the following for background, or make copies for students to read / discuss:
   - "Born of Fire—Restoring Sagebrush Steppe." USGS Forest and Rangeland Ecosystem Science Center: fresc.usgs.gov/products/fs/fs-126-02.pdf
   - "Big Wildfires in the West: Why, How, What to Do?" Lily Whiteman, National Science Foundation. livescience. July 31, 2013: www.livescience.com/38572-western-wildfires-causes-nsf-bts.html
   - Joyce, Christopher. "In Arid West, Cheatgrass Turns Fires into Infernos." NPR. Dec. 5, 2012. www.npr.org/2012/12/05/166574589/in-arid-west-cheatgrass-turns-fires-into-infernos
   - Schimel, Kate. "The art – and science – of forecasting wildfires." Mar. 13, 2015. *High Country News*. www.hcn.org/articles/the-art-and-science-of-forecasting-wildfires
   - "Science Connections: Western Wildfires & Climate Change." Infographic. Union of Concerned Scientists: www.ucsusa.org/global_warming/science_and_impacts/impacts/infographic-wildfires-climate-change.html

Procedure

1. *Optional:* Ask students an essential question to engage them and prime them for learning, such as "In what ways is our classroom (or school or town) a community?" Direct them to discuss the question with a neighbor while you circulate to answer any questions. After a couple minutes, ask for a volunteer to share their thoughts. Then ask students: "Do plants and animals live in communities like people? If so, what types of natural communities might be best able to adapt to change?" Explain that you will explore that question in class today and in the weeks ahead.

2. Explain to students that they will view a short presentation that shows fires in **wildlands**, natural areas without people living in them. In particular, they'll see fires in three different **ecological communities**. Explain that an ecological community includes all of the living things in an area—plants, animals, fungi, and microorganisms. An **ecosystem** includes the living AND nonliving things—soil, water, air, sunlight, etc. Ask for examples of **community** members (living things). Ask which is more inclusive or "larger": a community or an ecosystem? (An ecosystem is more inclusive, because it includes the community and also nonliving things.)
3. Explain that you will stop several times during the presentation and ask students to record something. After the presentation, you will ask them to compare and contrast different kinds of **fire behavior** and also to describe their feelings about the presentation.
4. Pass out copies of the "Wildfire in the Sagebrush Ecosystem" handout. Explain that you'll let students know when you'd like them to use it to record observations.
5. Show the presentation. You can use the narrative in Table 1 (below) or give your own narrative, but keep it brief. If questions arise, record them 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**.
6. When you come to the four photos that show fire behavior, pause. Ask the students to look carefully at the flames in the photo—how long they are and what parts of the plants they are burning—and then sketch the flames on their handout. They can also write a few words in the margin to describe the fire behavior. Give them a couple of minutes for each sketch.
7. After the presentation, have a brief discussion with the class about variety in fire behavior and how different ecological communities can respond to it differently. Also discuss their experiences with and feelings about wildland fire. This discussion need not be long; it is a warm-up for the writing assignment (see Assessment, below).

Table 1
Suggested narrative for *Wildland Fire and the Sagebrush Ecosystem* photo presentation:

Slide 1: Here is a bird's-eye view of some of the wildlands of the sagebrush ecosystem. We're going to spend the next few days/weeks/months learning about fires in this land.
Slide 2: Here is a fire burning the sagebrush ecosystem. Observe and sketch the fire under "A" on the handout.
Slide 3: This is what the land can look like after that kind of fire.
Slide 4: Here are some plants and animals that live in the sagebrush ecosystem after fire: Idaho fescue
Slide 5: Wildflowers (forbs), such as arrowleaf balsamroot; **Slide 6:** Western yarrow; **Slide 7:** Rabbitbrush; **Slide 8:** Sagebrush
Slide 9: Greater sage-grouse are one of many species which depend on sagebrush for survival. A male is shown doing his impressive mating display on the left, a female on the right.
Slide 10: Pygmy rabbits also depend on sagebrush for survival.
Slide 11: The sagebrush lizard is one species of reptile which can survive in the sagebrush ecosystem.
Slide 12: Here is another kind of fire in the sagebrush ecosystem, where there are some native plants from the sagebrush ecosystem with invasive cheatgrass. Observe and sketch the fire under "B."
Slide 13: This is what the land looks like after that kind of fire, which burns hotter.
Slide 14: Here are some plants and animals that live in that ecosystem after fire: Cheatgrass with some native species returning; bunchgrasses and brush

Slide 15: Here is a third kind of fire in the sagebrush ecosystem. Observe and sketch it under "C."

Slide 16: This is what the land can look like after that kind of fire, after it has been completely taken over by cheatgrass.

Slide 17: Here are some plants and animals that live in the area after fire: cheatgrass with little to no native species. Explain how systems respond to fire depending on what plants were found on the site and its disturbance legacy; e.g. a relatively intact site will respond more favorably (release of native plants, especially grasses and forbs) versus a site that is all cheatgrass prior to a fire.

Slide 18: **Succession** is the normal process of plants growing after a disturbance like wildfire. Native plants like bunchgrasses and wildflowers recover fastest, with shrubs eventually dominating the sagebrush ecosystem.

Slide 19: Invasive plants like cheatgrass regrow and spread very quickly after fire. Then fires spread faster and burn hotter. This fire cycle is difficult to break.

Assessment

1. Ask students to write on the back of the handout—or on a clean sheet of paper—responses to the prompts at the bottom of the handout:
    a. A paragraph in which they compare the kinds of fire they observed, giving at least two examples of how the kinds of fire are the same
    b. A paragraph in which they contrast the kinds of fire, giving at least two examples of how the kinds of fire are different
    c. A list of three words or phrases that describe their feelings about wildland fire, especially based on what they observed in the presentation. Explain that people's feelings often differ without being "right" or "wrong," so all of the feelings are valid. Also, a person's feelings can change over time, and they will have a chance to record their feelings again after they've learned more about fire.
2. *Optional:* Keep the handouts so they can be used again at the end of the wildland fire unit.

Evaluation

Task	Good	Fair	Poor
1. Fire comparison paragraph	• Complete paragraph • Contained two examples of similar fire behavior	• Incomplete paragraph • Contained one example of similar fire behavior	• Incomplete paragraph • Did not contain examples of similar fire behavior
2. Fire contrast paragraph	• Complete paragraph; • Contained two examples of different fire behavior	• Incomplete paragraph • Contained one example of different fire behavior	• Incomplete paragraph • Did not contain examples of different fire behavior.
3. Fire feelings list	• Three words or • phrases about personal feelings about wildfire	• Two words or phrases • about personal feelings about wildfire	• One word or no words or phrase about personal feelings about wildfire

Name: _______________________________ Period: ____ Date: _______________________

Wildfire in the Sagebrush Ecosystem

I. Color each sketch to show a typical fire in each ecological community.

A: Heathy sagebrush ecosystem

B: Some native plants from the sagebrush ecosystem with invasive cheatgrass

C: Cheatgrass with very few native plants

II. Please write:

1. **One paragraph comparing the kinds of fire behavior** and how they are similar. Give at least two examples.
2. **One paragraph contrasting the kinds of fire behavior** and how they are different. Again, give at least two examples.
3. **Three words or phrases that describe your feelings** about wildland fire.

5. Using Matchstick Models to Explore Wildland Fires

Subjects: Science, Writing, Speaking and Listening, Math

Duration: Two or three 30 – 45-minute sessions, or one block of 75 minutes or more

Setting: Laboratory or outdoors

Vocabulary
- fire triangle
- fire behavior triangle
- hypothesis
- slope
- stand density
- standing fuels
- crown fires
- controlled experiment
- variable
- fuel continuity

Overview

In this lesson, students use matchstick models to investigate two of the variables that affect the spread of wildland fire:

- slope (a feature of topography) and
- density of trees, shrubs or other standing fuels.

While this activity is especially well-suited to studying tree density, the principles apply equally well to any vertical fuel arrangement, including the tall shrubs and other native plants found in the sagebrush ecosystem.

Lesson Goals

- Increase students' understanding of the relationship between slope and stand density on fire spread
- Develop student skills in using models, experimentation, and written/oral communication

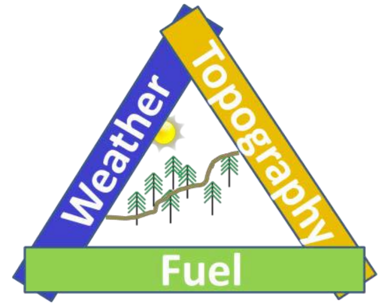
Objectives

- Students will create models of tree stands / shrubland to test the effect of slope and stand density on fire spread.
- Students will explain how slope and fuel density affect fire spread verbally and in writing.

Standards		Middle School (Grades 6-8)
NGSS	**Crosscutting Concepts**	• Stability and Change • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Constructing Explanations and Designing Solutions • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	ETS1.B, ETS1.C: Chemical Reactions EST1.A, ETS1.B, ETS1.C: Engineering Design
Common Core ELA	**Writing**	4, 7, 8, 10
	Language Standards	1, 2, 6
	Reading Standards Science & Technical Subjects	3, 9
	Writing Standards Science & Technical Subjects	4, 10
EEEGL	**Strand 1**	B, C, E, F, G

Teacher Background

After students understand the basic principles of combustion as described by the Fire Triangle (see units 2 – 4 in the original *FireWorks* and/or the lesson "Fire! Impacts on the Sagebrush Ecosystem and Human Communities" in the sagebrush ecosystem curriculum from the U.S. Fish and Wildlife Service: www.fws.gov/greatersagegrouse/education.php), they can apply that understanding specifically to how fires behave in the wildland environment. Fire professionals use a second triangle model, the "**fire behavior triangle**" shown to the right, to describe the complexities of wildland fire behavior.



In this lesson, trees and/or shrubs and other standing fuels are represented by individual matches. **Controlled experiments** are used to test hypotheses, meaning only one variable is changed at a time. In Experiment 1, for example, the **slope** (the degree of incline) is changed, but the **stand density** is not. Separate experiments would be needed to investigate other variables.

In general, the steeper the slope, the more quickly the fire will burn uphill. If a fire is burning on a hillside, the fuels above it tend to be dried and warmed by its convective heat, and the flames are quite close to the fuels above, while the fuels below are affected very little—unless burning materials roll downhill and ignite new fires. Thus, fires tend to spread upslope, and a fire that starts at the bottom of a hill is likely to spread faster than one that starts on a hilltop. Downhill burns are less intense, so even ground fuels are often not fully consumed. Regrowth tends to occur very quickly in these areas.

If a fire is burning in dense forest, it may spread from treetop to treetop (a **crown fire**). Crown fires may not fully consume all fuels if the fire just burns through the crowns, leaving a lot of understory. The fire might also follow topographical features or be wind-driven, leaving adjacent trees or shrubs virtually untouched. In more open forests, crown fires are less likely.

Wind also affects fire spread by bending the flames and the heat plume to lean toward the downwind fuels, helping the fire to spread faster. Surface fires may spread more rapidly in open stands than dense ones, however, because the wind speed is usually greater in openings. The effects of wind can be investigated according to a mathematical model as explained in unit 8 of the original *FireWorks* program.

Table 2 (below Materials section) describes the experiments included in this activity. Use Experiment 1 to help students investigate the effect of slope on fire spread. Then use Experiment 2 to learn about the effect of **stand density** (how close together the trees or shrubs are) and **fuel continuity** (how close together all the available fuel is).

These experiments apply to all kinds of plant communities subject to fire (and all kinds of forests, woodlands, shrublands, and grasslands around the world). The optional Experiment 3 uses more involved models for students to explore the effects of stand density and fuel continuity on the sagebrush ecosystem.

Additional information which you may want to share with students at the end of the lesson:
Fires that burn with varying intensity and for variable durations will leave a **mosaic** pattern across the landscape. This is desirable for habitat, as well as rejuvenation. It leaves open areas where grasses and forbs will return quickly; it also leaves more dense stands that animals can use for shade, shelter, and protection. Variations in the weather, available fuels, and landscape can lead to mosaics, including topographical features and the amount of moisture in different areas. If a fire burns hot enough and long enough through an area, it will consume all available fuels and the area will likely take longer to recover.

Materials + Preparation

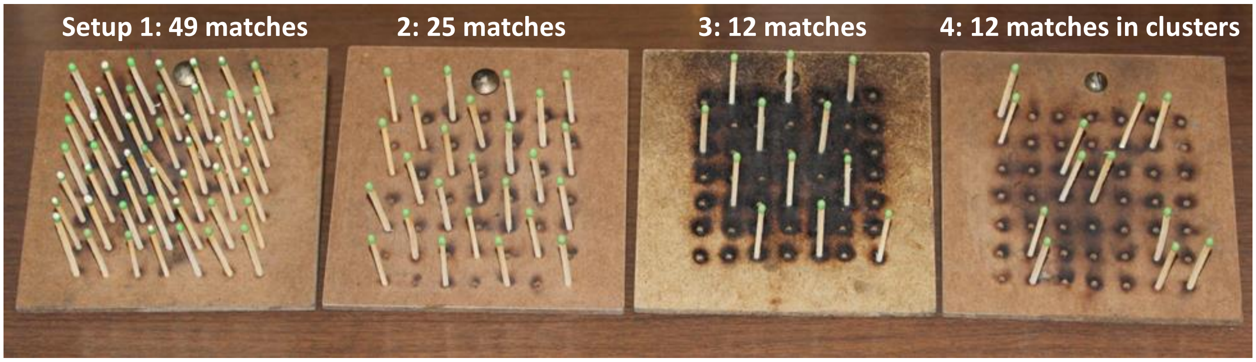
- Four boxes of wooden kitchen matches (not provided in the *FireWorks* trunk)
- Prepare to show the **Fire Behavior Triangle** diagram to students. Use the poster from the *FireWorks* trunk (Box B) or draw one on the board. You can also project one from online, such as: learn.weatherstem.com/modules/learn/lessons/121/12.html.
- Set up the teacher's area with this equipment:
  - Fire extinguisher, fully charged (Box B)
  - Two spray bottles filled with water (Hardware Box in Box A)
- Set up a lab bench or other safe space for each student team, using the equipment below (4 sets are provided in the trunk):
  - 1 metal tray (i.e., cookie sheet) (Box A)
  - 1 ashtray (Hardware Box in Box A)
  - 1 box of matches
  - 1 matchstick board (Hardware Box in Box A)
  - 1 ruler (Hardware Box in Box A)
  - A short and long bolt and 1 nut from the matchstick forest kit (Hardware Box in Box A). These are attached to the boards to adjust the slope.
  - 1 pair safety goggles (Hardware Box in Box A; the trunk is supplied with 4 pairs of safety goggles – for each person who lights matches. In many laboratories, however, every student must wear goggles to conduct experiments. Thus, you may need to supply more.)
- 1 copy of the "Matchstick Models" handout for each student (found at the end of the lesson)
- Have a metal trash can without a plastic liner available.
- The day before doing this activity, remind students to follow safety guidelines about clothing and hair when they get ready for school tomorrow. Flames in the experiments can reach up to a foot high, so please plan accordingly.
- Package of hair bands to give out as needed (not provided in trunk)
- Choose your location for the experiments carefully. Can you do it safely in your laboratory/classroom without setting off a smoke alarm? Can you take your students somewhere it will be safer? The activity should be done in an area with good ventilation and a hood or high ceiling. If your laboratory hood is not adequate, consider igniting the matchstick models outdoors—but not on a windy day. Use a large area far from dry grass, bark chips, and other fuels. Have a bucket of water and a hose available, with the water on.
- 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.
- Have students work in teams to setup the matchstick models for this activity, then ignite them one at a time so all students can observe all fires. You could also have student volunteers setup the matchstick forests ahead of the experiments.

Table 2

Experiments for investigating the effect of slope and density of standing fuels on fire spread:

Experimental Question	Potential Hypothesis & Explanation	Experimental Setup
Experiment 1 How will slope affect fire spread?	Fires on steeper slopes will spread faster. **Explanation:** Fires moving uphill tend to spread faster and burn more completely than fires moving downhill, because fuels above it tend to be dried and warmed by its convective heat, and the flames are closer to the fuels above than those on level ground.	Arrange 3 boards at different slopes with 49 matches/board (one in each hole): 1. Lay 1 board flat to model a fire on flat ground. 2. Use a short bolt to model a forest or shrubland on a moderate slope. 3. Use a long bolt to model a forest on a steep slope. Ignite an entire row of matches along the same edge of each board. The sloped boards should be lit along the bottom edge.
Experiment 2 How does stand density affect fire spread?	Fires will spread faster and combustion will be more complete in models with denser standing fuels. Thus, crown fires will be more likely in dense than sparse arrangements. Clumping of fuels will also increase the potential for crown fires. **Explanation:** In a dense stand, heat and flames are more likely to reach nearby fuels.	Use long bolts for 4 models to create a uniform steep slope for each. Use the following matchstick densities for each of 4 boards (see image below): 1. 49 matches (one in each hole) 2. 25 matches, distributed evenly (about 50% of holes filled) 3. 12 matches, distributed evenly (about 25% of holes) 4. 12 matches in clusters Ignite all boards from the bottom row.

Setup of matches for Experiment 2
(all on boards with steep slopes)

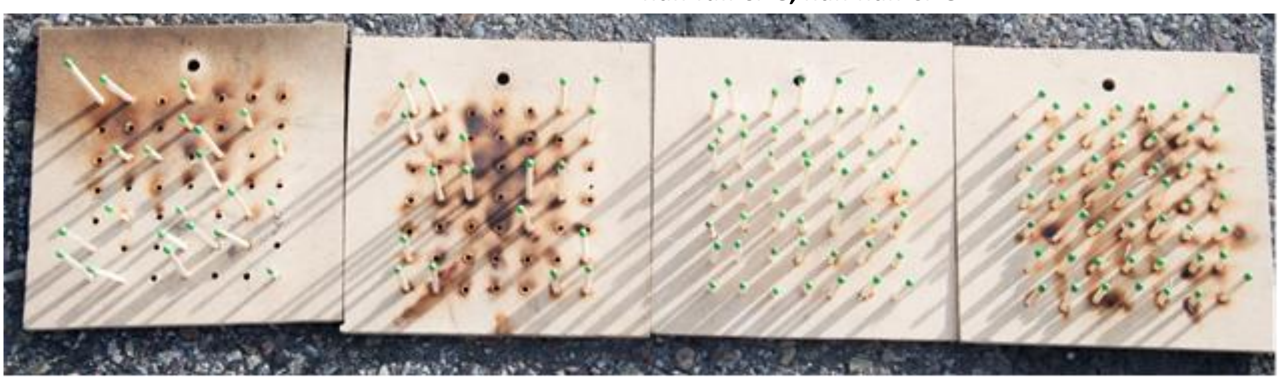


***Optional:* Experiment 3** How does stand density in specific kinds of fuels affect fire spread?	Fires will spread faster and combustion will be more complete when stand density is higher. Thus, crown fires will be more likely in dense than sparse arrangements. Clustering of fuels will also increase the potential for crown fires, but may not ignite nearby clusters. **Explanation:** When fuels are close together, as in a dense forest or clump of shrubs where fuel density is high, heat and flames are more likely to reach the fuels nearby. Shrubs and trees growing at different heights carry fire from the lowest grasses to the tree crowns.	Use long bolts for all models. Use the following matchstick densities for each board (see image below): 1. 10 full matches, placed in clumps of 2 – 3 and 10 matches broken in half and spaced throughout the board, representative of a healthy mix of vegetation on the sagebrush-steppe. 2. 18 matches in clumps of 3 to represent brush or trees with no understory, such as grasses or forbs, indicative of a healthy community. 3. 49 matches, half full-size and half broken in half to represent dense overgrowth 4. 43 half matches (to represent invasive cheatgrass), with 6 full matches scattered throughout (to represent sagebrush)

Setup of matches for optional Experiment 3

Setup 1: 10 full and 10 half-size matches

Setup 3: 49 matches, half full-size, half half-size

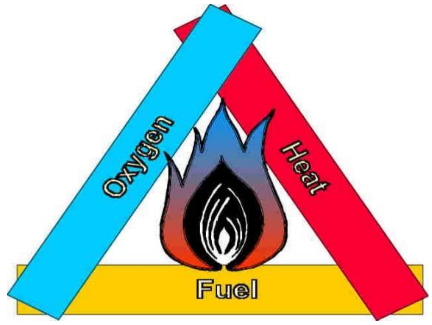


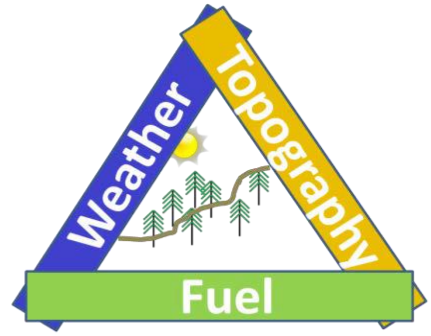
Setup 2: 18 matches in clumps of 3

Setup 4: 43 half-size & 6 full-size matches

Procedure

1. *Optional:* Ask for one or more volunteers to draw the "**fire triangle**" (oxygen, heat, and fuel) on the board and explain it as a review/warm-up.





2. Show students the "**fire behavior triangle**" and explain that it is an aid to remind fire managers in wildlands of three things that control how fires behave: fuel, weather, and topography.

3. *Optional:* Ask students to turn to a neighbor and discuss their ideas for how weather, topography of the land (how flat or hilly it is), and the amount, arrangement, and moisture of fuel can affect wildland fires.

4. Explain that today the students will get to investigate the effect of some of these factors on fire spread by creating fire models with matchsticks. Before beginning the experiments, discuss experimental design with the class, including the nature of a **controlled experiment***,* in which only one variable at a time is changed*.* Explain that a **variable** is whatever effect is being investigated—in this case, slope, or how much the land or model is on an incline (Experiment 1) or stand density—how close together trees or shrubs (or matches) are (Experiment 2).

4. Ask a student volunteer to help pass out the "Matchstick Models" handout and project it or write Questions 1 – 8 on the board. We suggest doing Experiment 1 as a class and recording observations on the board or projected handout. You can also do Experiment 2 as a class, with students recording observations on the handout. Or students can do Experiment 2 in teams.

5. Show students the matchstick forest/shrubland model (masonite board, nuts and bolts) and discuss some variables that can be investigated with it. Explain that the model is most often used to investigate **crown fires**—fires that burn through the tops of trees or shrubs—as opposed to fires that burn on the forest floor or in the organic material of the soil. Explain that grass fires are not thought of as crown fires, but the matchstick model results can be applied to these **standing fuels**, too.

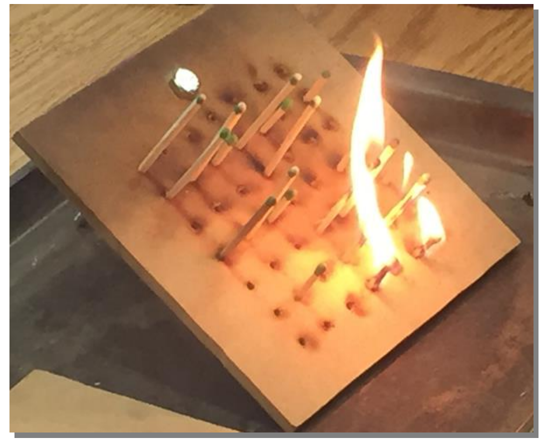
6. Explain that the class will first investigate the effect of **slope** on fire spread. This is the answer to Question 1 on the board. Ask students to develop a hypothesis for Experiment 1—a prediction of what might happen, or more than one—and write it on the board (Question 2).

7. Discuss with students what observations would be helpful to test the hypothesis. Observations should include the following, which should be listed on the board (Question 3):
   - Time of ignition and time when fire goes out (used to calculate fire duration) **or** fire duration measured by stopwatch
   - Number of match tips burned
   - Approximate maximum flame length (estimated at a safe distance from flames)

8. Group students into teams and assign each group to create an "experimental setup" from Experiment 1. (These are listed in the right-hand column of Table 2). Instruct students to wait until everyone is ready to ignite their setup. The matchstick models will be ignited one at a time, so the whole class can observe and record data.

9. Do a **safety checkup** with students using the *FireWorks Safety* poster. Remind students to dispose of burned matches in the ashtray or on the metal tray.

10. Have each team assign roles:
    - Igniter (unless you want to do this yourself)
    - Timer
    - Flame measurer
    - Data recorder
11. When all teams are ready, have each team, one at a time:
    - Describe their setup and write it on the board (Questions 4a, 5a, 6a, and 7a).
    - Ignite the boards and make observations one board at a time, recording their answers on their handouts.



12. After all four boards have been burned, direct students to complete any calculations (such as duration of burning if a stopwatch was not used), and discuss questions 9 and 10. Then discuss: "Using your understanding of the heat plume and the fire triangle, explain how **slope** affects fire spread." (This is like question 10 on the handout, except it refers to slope rather than stand density.)
13. Ask students to discuss the shortcomings of the models in their teams:
    - How is a matchstick model different from a real forest or area of sagebrush ecosystem? Explanations can include . . .
        - **the lack of weather**—especially the absence wind, unless you perform the experiments outside. Even if you do the experiments indoors, it is important to stress the role of natural elements such as wind, precipitation, and moisture content of fuels on fire behavior. For these reasons, conducting one or more of the experiments outside can help students understand that reality. For example, even on the steepest slope, fires might not burn "up the hill" if the wind is blowing crosswise to either a natural or model forest or shrubland.
        - **the absence of surface fuels** in the models.
        - **extremely ignitable "crowns"** (match tips) in the models.
        - **uniform "tree" or "shrub" distribution** in the models.
    - How is a board different from a real patch of land? Explanations can include how the terrain is uniform and trees tilt with the slope, unlike in nature, where trees grow straight up.
14. **Clean up:** Remind students to make sure all burned materials and matches are completely out before disposing of them; there should be no smoke and no heat being released. Remind them to use the metal trash can. If in doubt, students can first dump them in a bucket of water.

Assessment

1. Students should each complete the Matchstick Models handout on their own or in teams for Experiment 2 investigating the effect of **stand density** on fire spread.
2. Repeat steps 11 – 12 above, *one team at a time.* This way, EVERY student gets to observe EVERY fire and must answer the "a" part of Questions 4-7 before each ignition and the "b" part after the burn.

Evaluation

Questions 8-10 on Matchstick Models handout (credit/no credit):

Question 8	Question 9	Question 10
Student clearly explained why they either accepted or rejected the hypothesis and included examples from their observations to justify their decision.	Fires spread faster and burn more completely in dense standing fuels because heat and flames are more likely to reach nearby fuels.	The denser a stand of fuels, the easier it is for fire to spread because heat and flames can reach nearby fuels. In denser forests, more fuel is available and fuel continuity is more complete.

Adaptations / Extensions

1. Have some or all students do the optional **Experiment 3** listed in the table. If desired, another Matchstick Models handout could be completed for the experiment.

2. Have some or all students develop and test their own hypotheses using the models. Here are some questions that they could explore using these materials:

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

3. Discuss the concept of the **fire mosaic** with your students (explained at the end of the Teacher Background section). Students could illustrate the concept or create 3-D models of it and how fire mosaics can benefit wildlife habitat and rejuvenation of ecosystems.

4. Have students illustrate or create a 3-D model of a hilly area of sagebrush ecosystem and/or forest. Provide one or more images to help them, or, even better, visit a suitable natural area. Then have them show how a wildland fire might move through the area. Arrows and captions could be added to show the possible movement of fire, and which areas might burn less intensely or not at all, forming a mosaic.

Name: ______________________________ Period: ____ Date: ______________________

Matchstick Models

1. **Experimental question:**
   What is the effect of _____________________ (slope, stand density, etc.) on fire spread?

2. **Hypothesis:**

   ____

   ____

3. Measurements needed: _______________________ _______________________

   _______________________ _______________________

   Calculations needed (if any): ____

4. **Setup 1:**
   a. What is the condition of the experimental variable? (For example, in Experiment 1, is the slope flat, medium, or steep?): ____
   b. Observations: ____

   ____

   Calculations, if any: ____

5. **Setup 2:**
   a. How is the experimental variable different? ____
   b. Observations: ____

   ____

   Calculations, if any: ____

6. **Setup 3:**
   a. How is the experimental variable different? ____
   b. Observations: ____

   ____

   Calculations, if any: ____

7. **Setup 4:**
   a. How is the experimental variable different? ____
   b. Observations: ____

   ____

   Calculations, if any: ____

8. **Based on your observations, do you accept or reject the hypothesis?** ________________________

Discuss the following questions and write your answers on the back in complete sentences:

9. **What is your answer to the experimental question** (question 1)?
10. **Explain the effect of stand density on fire spread** using your understanding of the Fire Triangle, etc.

6. Ladder Fuels & Fire Spread: The Tinker Tree/Shrub Derby

Subjects: Science, Writing

Duration: 40 - 60 minutes

Setting: Indoor laboratory or outdoors

Vocabulary
- ladder fuels
- crown fires
- surface fires

Overview

In this activity, students use a physical model to learn how the vertical arrangement of fuels (ladder fuels) affects the potential for fires to spread into tree and shrub crowns. Teams create "tinker tree" models and compete by lighting simulated surface fires under the "trees." Those with unburned "foliage" advance to a final round with more surface fuel. Students use a handout to guide their inquiry and analysis.

Note: This activity applies to sagebrush ecosystems, as well as forests. For example, invasive plants like cheatgrass can act like ladder fuels, since they are fine, dry, and burn intensely; this allows surface fires to spread to the tops of large shrubs. Also, juniper and pinyon pine have been encroaching into sagebrush ecosystem areas. And forests containing a number of tree species can be found at higher elevations and in riparian areas adjacent to sagebrush ecosystem areas.

Lesson Goals

- Increase students' understanding of the relationship between fuel arrangement and vertical fire spread
- Develop student skills in making predictions, engineering, experimentation, and written communication

Objectives

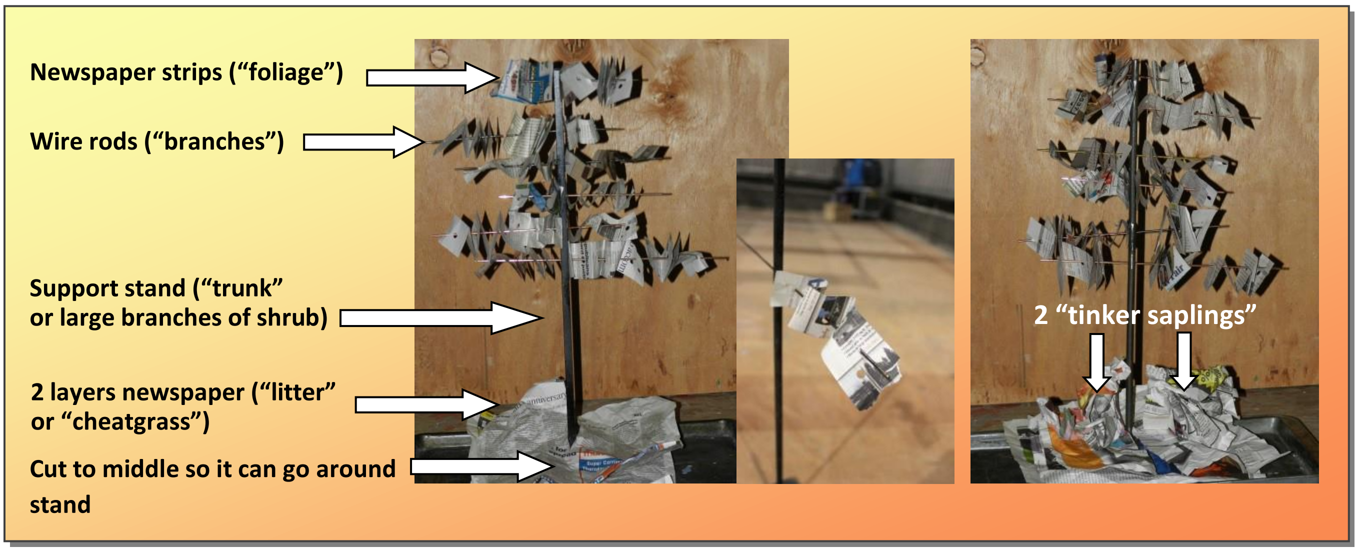
- Students will design a model tree/shrub and assess its ability to "survive" a surface fire.
- Students will analyze the role of different types of surface vegetation and litter in forest and sagebrush ecosystem fires.

Standards		Middle School (Grades 6-8)
NGSS	**Crosscutting Concepts**	• Stability and Change • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Constructing Explanations and Designing Solutions • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	ETS1.B, ETS1.C: Chemical Reactions EST1.A, ETS1.B, ETS1.C: Engineering Design LS2.C: Ecosystem Dynamics, Functioning, and Resilience
Common Core ELA	**Writing**	4, 7, 8, 10
	Language Standards	1, 2, 6
	Reading Standards Science & Technical Subjects	3, 9
	Writing Standards Science & Technical Subjects	4, 10
EEEGL	**Strand 1**	B, C, E, F, G

Teacher Background

This activity explores the potential for a **surface fire** (burning of vegetation on the forest floor or shrubland surface) to spread up into the crowns of overhanging trees and/or shrubs. The more continuous the fuels, the more likely this will happen. The fuel that allows fire to climb from the forest/shrubland floor to the crowns of trees/shrubs is known as **ladder fuel**. Once fire is in a tree or shrub crown, it can spread directly from one tree or shrub crown to the next; such **crown fires** are usually more dangerous and harder to control than surface fires.

The Tinker Tree Derby is a competition among student teams. Each team constructs a "tinker tree" from a support stand, wire rods, and newspaper fuels. The goal is to design a tree that can withstand fire passing beneath (surface fire), but that also has plenty of leaves so it can photosynthesize, grow, and produce seeds. A team's success is tested by experimental burning. The tree/shrub that survives burning with the greatest potential for photosynthesis is the winner. Photosynthesis potential is quantified by the length of the "branches" with unburned "foliage" (newspaper strips on branches) after the fire.



The Derby has two phases, which enable students to see the effects of two different levels of surface fuels (and hence the effects of time between fires in allowing more fuels to accumulate). However, you should only tell students ahead of time about Phase 1 (the Qualifying Round), which uses relatively light fuels. Any trees that survive Phase 1 will then be tested in Phase 2 (the Championship Round), with more than twice as much fuel and greater vertical continuity, as might occur in forest **succession**.

While this version of the *FireWorks* program focuses on the sagebrush ecosystem, juniper and pinyon pine have been **encroaching** into these areas. While it is only half the size it was in the early 1800s, the sagebrush ecosystem is still the largest in North America, with 350+ species. A large area of the ecosystem is the sagebrush steppe (also known as the high desert), which is found in the higher elevation plains of the Western United States. It contains dense patches of shrubs and grasses, as well as patches of timber, such as juniper and pinyon pine. Historically, the steppe was a vast area with bunch grasses and shrubs with open spaces between. Due to this open spacing between vegetation, intense fires were rare, and a stand replacement fire occurred only about every 50-100 years. Low intensity fires were common between stand replacement fires. These fires typically remained on the ground, cleaning up litter and duff, not harming the larger shrubs. Changes in the ecosystem have resulted in larger and more intense fires.

Materials + Preparation

- Make copies of the "Tinker Tree Derby" handout (found at the end of the lesson) for each student.
- Work with students to prepare newspaper:
  - 4 bags, each containing about 30 strips of newspaper approximately 40 cm long and 4 cm wide. Each strip should be folded accordion-wise so it can be threaded onto a wire rod to represent tree/shrub foliage.
  - 24 half-sheets of newspaper, 25 x 35 cm. These will represent litter.
  - 8 quarter-sheets of newspaper, approximately 25 x 20 cm. These will represent saplings.
  - About 20 narrow strips of newspaper, cut into strips
  - 4 half-sheets of newspaper, 25 x 35 cm
- Set up 4 work stations. Each station should have:
  - 1 pair of safety goggles (Hardware Box in Box A)
  - 1 metal tray (Box A) with a support stand on it (Tinker Trees bag in Box A)
  - 10 – 15 segments of wire rod (Tinker Trees bag in Box A)
  - 1 ashtray (Hardware Box in Box A)
  - Paper towels for clean-up
- In addition, you should have:
  - 2 or more spray containers, filled with water (Hardware Box in Box A)
  - 1 measuring tape (Hardware Box in Box A)
  - 1 fire extinguisher (make sure it is charged, and know how to use it) (Box B)
  - 1 "Tinker Trees" kit which has pendants for awards in each phase (Box C)
  - 1 box of kitchen matches
  - 1 or more hole punches, in case students need them to push newspaper on rods
  - A handful of hair ties, in case students need them.
  - A *metal* trash can *without a plastic liner*
- The activity should be done in an area with good ventilation and a hood or high ceiling. Smoldering pieces of newspaper can rise as high as 20 feet on the heat plume. If your laboratory hood is not adequate, consider igniting the Tinker Trees outdoors—but not on a windy day. Use a large area on concrete or asphalt far from dry grass, bark chips, and other fuels. Have a bucket of water and a hose available, with the water on. Have another adult or responsible students help "patrol" for burning materials.
- The day before doing the activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.
- Copy this results table onto the board (or a sheet of paper if you're burning outdoors):

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

Procedure

1. Project an image of a fire showing **ladder fuels** for students, such as:
   - http://mediad.publicbroadcasting.net/p/nwpr/files/styles/x_large/public/201603/ladder_fuels.jpg
   - https://en.wikipedia.org/wiki/File:Ladderfuels.png
   - https://goo.gl/jxV2oO

   You could also draw a simple illustration on the board illustrating the concept. Use the visual(s) to help explain that ladder fuels are the arrangement of fuels from the ground to the tree and/or shrub tops, which fire can climb like a ladder.

2. Explain the student challenge: to design a "tinker tree/shrub" model, with "foliage" high enough to withstand **surface fire**. It should avoid fire climbing up ladder fuels from surface to tree/shrub tops, and at the same time maximize the length of branches covered by foliage. (Surface fires burn in the vegetation on the ground surface, including fallen leaves, grasses and shrubs, small trees, and fallen twigs and branches. In the sagebrush ecosystem they often burn surface plants, such as cheatgrass.)

3. Ask each team to choose a team name while you pass out the "Tinker Tree Derby" handouts. Read the handout together and answer any questions. Ask them to tell you one thing that will disqualify their team from the competition. (Answer: Adding moisture to their model.)

4. Do a safety briefing in preparation for handling matches in these experiments. Use the *FireWorks Safety* poster as a visual aid, and review the location of spray bottles and a fire extinguisher. Display the poster prominently for the remainder of the activity.

5. Direct students to construct their trees. After about 10 minutes, have them ignite the trees one team at a time, so everyone gets to see every fire.

Phase 1 - Qualifying Round

6. Direct student teams to come forward one at a time:
   - Ask for the team name and have a student write it on the board in the table.
   - Check and modify the surface fuels to make them similar among trees so this variable will not confound the results.
   - Have a student on each team start the fire by igniting two corners of newspaper along one long edge of the metal tray. If they all use the same ignition pattern, this variable will not confound the results. The student lighting the fire should wear safety glasses, and others nearby can, too.
   - When the fire is out, use the measuring tape to determine the tree's score: the length of branch, in centimeters, that still has unburned newspaper ("live foliage") on it. Have a student record this on the board under "Qualifying Round" for that team.

7. After all teams have completed a burn, determine the winner of the Qualifying Round, that is, the entry with the greatest total branch length with "foliage."

8. *Optional:* Award Tinker Tree Derby Champion badges to the winning team. Explain that they get to wear the badges until the end of class.

Phase 2 – Championship Round

9. For all teams whose tinker trees/shrubs survived the Qualifying Round, have students leave the surviving foliage intact, but gently remove the ash of the burned surface fuels and replace it with **four** new layers of surface fuel (crumpled half-sheets of newspaper). Teams with trees/shrubs that did not survive the Qualifying Round (zero centimeters of unburned foliage) should observe.
10. Explain that accumulation of surface fuel often occurs in forests after many years of **succession** without surface fire.
11. Have each team take two smaller pieces of newspaper (quarter-sheets), crumple them up, and place one on each side of their tinker tree trunk/shrub under the branches. These are “tinker saplings,” young trees that grow up under the old survivor. Explain that this, too, often happens in forests after many years of succession without surface fire.
12. Repeat step 6 above for each tinker model. Determine the score and the winner, if any. Award Tinker Tree Grand Champion badges to the winning team. Explain that they get to wear these until the end of class.
13. Direct students to finish their answers to the questions on the handout, discussing the questions as a group while they each record their answers.
14. Lead a closing discussion with the class about their conclusions, and how these dynamics of wildland fire might impact the sagebrush ecosystem. For example, you could talk about how encroaching cheatgrass, as well as encroaching juniper and pinyon pine forest, can add to the potential severity of fires in sagebrush ecosystem areas.

Assessment

Review completed handouts for each student.

1. Check for at least 2 reasonable changes to the tinker models.
2. Some possible answers for how the tinker model is not real:
    - Its metal “trunk” cannot be damaged by fire.
    - It has no roots that could be damaged by fire.
    - It does not grow taller, gain new branches, or shed old ones as years go by.
    - It has flat, very dry “foliage.”
3. Compare fire spread potential:

    “A” has:

    - More surface fuels; larger surface fuels
    - More ladder fuels
    - More continuous crowns than “B.”
    - Thus, A is more likely to have severe surface fire and/or crown fire than “B.”

- An additional point not covered in this activity: “B” is more open than “A,” so the wind at the ground surface is likely to be stronger. Thus, surface fire is likely to spread more quickly in “B” than in “A.”

Surface fire: a burn in vegetation on ground surface, including fallen leaves, grasses and shrubs, small trees, and fallen twigs and branches

Ladder fuel: arrangement of fuels from forest floor to the tree tops; fire can climb like ladder

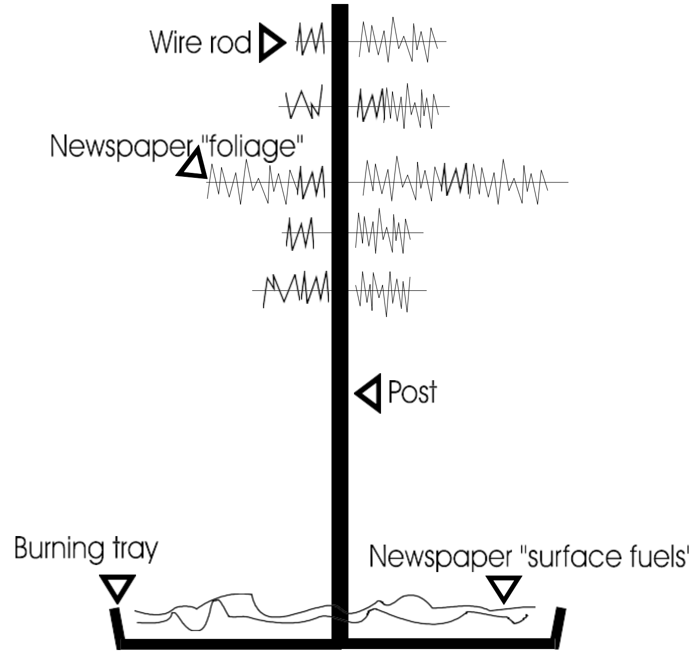
Evaluation

Task	Very Good	Fair	Poor
1. Changes to tinker model	• 2 or more changes	• 1 change	• 0 changes
2. How tinker model is not real	• 2 or more examples	• 1 example	• 0 examples
3a. Compare fire spread potential	• Explained 2 or more fuel differences • Explained 1-2 differences in fire behavior	• Lists 1 fuel difference or mentions crown fire potential	• Does not address question or include terms
3b. Define surface fire and ladder fuel	• Correctly explained surface fire and ladder fuel within explanation	• Included surface fire and ladder fuel, but did not explain terms	• Does not include terms
4. Compare fuels in “A” and “B”; incorporate role of encroaching species like cheatgrass in answer	• Correctly explained how dry, fine fuel, especially invasive grasses like cheatgrass, act like ladder fuels in the forest which can help fire climb beyond surface fire to shrub crowns to kill the shrubs	• Included surface fire and ladder fuel, but did not incorporate role of cheatgrass	• Does not include terms

Name: ______________________________ Period: ____ Date: ______________________

Tinker Tree Derby

A tinker tree is a model of a tree, as shown to the right. Its "trunk" is a lab support stand. Its branches are wire rods stuck through holes in the trunk. Its "foliage" (leaves) are strips of newspaper. Your goal is to design and build a tinker tree that has foliage which survives a fire that burns the surface fuels beneath it. You have to decide how much foliage to use and how to arrange it so that the tree can survive a surface fire. The tree with the most foliage left after the fire burns wins!



Procedure

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

Scoring

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

Rules

- Do not add moisture to your tinker tree or experimental setup before it is burned, or it will be disqualified.
- Do not move or remove your tree's foliage after the fire has burned.

Tinker Tree Analysis

1. List at least two changes you would make to your tinker tree or the surface fuels in this experiment to increase the tree's chances of surviving a surface fire. Explain why you would make each change.

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____

____

2. List at least two ways in which the Tinker Tree model does NOT resemble a real tree.

____

____

____

3. Study the two photographs below. How are the fuels in "A" different from those in "B"? How would that be likely to affect the kind of fire that could occur if conditions are dry and windy? Explain the terms **surface fire** and **ladder fuels** and how they impact wildland fires to support your explanation.

A.

Dave Powell, USDA Forest Service, Bugwood.org

B.

Photo courtesy of Rick Trembath

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____

4. Now compare fuels in the **sagebrush ecosystem**. Studying the two photos below, how are the fuels in "A" different from those in "B"? How does this fuel type compare to forest fuels when taking into consideration ladder fuels? Incorporate an explanation of how **encroaching** species like **cheatgrass** affect fire behavior in your answer.

A. Sagebrush ecosystem (without cheatgrass)

B. Sagebrush ecosystem with cheatgrass

7. Fuel Properties: The Campfire Challenge

Subjects: Science, Speaking & Listening, Writing

Duration: 40 – 60 minutes

Setting: Outdoors or laboratory with a hood and good ventilation

Vocabulary
- fuel moisture
- fineness
- fluffiness
- ground fire

Overview In this lesson, students explore how different properties of fuels affect fire behavior – especially how easy or difficult it is to ignite fires and how long they are likely to burn. Students consider various combinations of fuels (“fuel recipes”), predict how they will burn, and test their hypotheses by building safe “campfires.”

Lesson Goal Increase students’ understanding of fuel properties, ignition, and fire duration in wildland fuels

Objectives

- Students will demonstrate understanding of how fuel properties influence fire behavior.
- Students will select and arrange fuels that will be easy to ignite and burn a relatively long time.

Standards		Middle School (Grades 6-8)
NGSS	**Crosscutting Concepts**	• Stability and Change • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions ETS1.A: Defining and Delimiting an Engineering Problem ETS1.B: Developing Possible Solutions
Common Core ELA	**Writing**	4, 7, 10
	Speaking & Listening	1, 2, 4, 6
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
EEEGL	**Strand 1**	A, B, C, E, F, G

Teacher Background

Anyone who has built a successful campfire knows that one has to choose fuels wisely and arrange them carefully. A variety of **fuel properties** influence fire behavior, including the amount, size, moisture content, fluffiness, and spatial arrangement of the fuel.

The four properties of fuels listed below determine how flames heat the fuels, how much oxygen is in contact with them, and thus how quickly they will ignite and how long they will burn.**Amount** The more fuel, the longer a fire can burn and the more heat it can produce . . . if the fuels can be ignited.

- **Fineness**
  - **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 a new layer of fuel to oxygen.
  - The smaller the fuel particles, the more easily the heat plume can engulf them and heat them to ignition temperature. For example, consider the challenge of igniting a big log versus a thin pine needle.
- **Moisture**
  - The drier the fuels, the less heat needed to dry them out, so the more easily they will ignite and the more completely they will burn.
  - Moisture makes fuels hard to ignite and also makes them burn slowly. This is because the moisture must be removed before a particle can be heated to ignition temperature. See the "Steps to Combustion," below, for details; you may want to share these details with more advanced students.
- **Arrangement**
  - The **fluffiness** of fuels determines how much oxygen is available for combustion. An important skill in building a campfire is to get the spatial arrangement of fuels "just right," so lots of heat and oxygen are right next to the unburned fuels.
  - Fuels have to be somewhat near each other for fire to spread from one piece to another. The pieces can be too loosely packed for heat to reach from one particle to the next, making it hard for fire to spread. For example, if one crumples up 20 pieces of newspaper and scatters 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. A land owner who wants to prevent crown fires notices heat's tendency to rise too, and makes sure there are big gaps between the surface fuels and the tree crowns. If the gaps are small, the fire can spread up the "ladder fuels" provided by young trees, shrubs, and low branches – and reach the crowns.
  - If easy-to-ignite fuels are placed below hard-to-ignite fuels, the rising heat helps ignite the upper fuels. We use this principle in building a campfire when we place fine fuels (kindling) near the bottom of the fuel bed and then place layers of coarse fuels above.

Steps to Combustion

1. Temperature of moisture rises to boiling point (~100° C (212° F). This includes all moisture inside living cells, plus the moisture that comes from rain and humidity.
2. Moisture is changed from liquid phase to gas phase and stays at 100° C (212° F).
3. Temperature of fuels rises to the point where carbohydrates **pyrolize** – that is, break down into small molecules (200 – 300°C; 400 – 600°F).
4. **Combustion!** Small carbohydrate molecules combine with oxygen. This produces a lot of heat, which may engulf and ignite nearby fuels.

Note: This activity investigates one aspect of the Fire Behavior Triangle directly: **fuels***.* Indirectly, it also investigates **weather***,* since weather impacts the moisture and oxygen (because of wind) in fuels.

Materials + Preparation

- This activity is best done outdoors because it can be messy and smoky. However, do not do it outdoors on a windy day. Use a large area that is far from dry grass, bark chips, and other fuels. Have a bucket of water and a hose available, with the water turned on. Have another adult and/or responsible students help "patrol" for burning materials.
- If you do this activity indoors, use a laboratory with a hood and good ventilation.
- At least two days ahead of time, obtain about a dozen "handfuls" of each of these fuels:
  - cheatgrass (Box B in *FireWorks* trunk)
  - sagebrush and/or bitterbrush (Box B)
  - juniper needles (Box B)
  - juniper branches/twigs (Box B)

  Spread out the fuels in a dry place so they are uniformly dry by the time you use them.
- Make sure you have enough peat moss (**duff**) to do the activity (Fuels Box in Box B). You could also substitute small, thin strips of newspaper, if necessary.
- During the class before you do the activity, remind students to dress appropriately for burning. Post and refer to the **FireWorks Safety poster** (Box B or download from www.frames.gov/partner-sites/fireworks/curriculum/sagebrush-ecosystem).
- Copy the ingredients for the fuel recipes onto a table on the board (or a poster if you plan to go outdoors).

Recipe	Ingredients
1	• Dead cheatgrass • Duff • Sagebrush/Bitterbrush
2	• Dead cheatgrass • Juniper needles • Thick juniper branches
3	• Juniper needles • Duff • Thick juniper branches
4	• Duff • Thick juniper branches • Sagebrush/bitterbrush

- Setup your teacher area with:
  - The Fuel Recipe box (Box C, or download from the website above).
  - 5 boxes or grocery bags containing dry fuels:
    - peat moss (duff)
    - cheatgrass

- sagebrush/bitterbrush
    - juniper needles
    - juniper branches
    - ***Note:*** You can label the bags or boxes by writing on them or using tie-on labels in the Fuel Properties Kit (Box C, or download from the website above).
  - Fire extinguisher (Box B)
  - 2 spray bottles, filled with water (Hardware Box in Box A)
- Other water (bucket, charged hose, etc.) to ensure you can easily put a fire out
- Set up 4 student work stations, each with:
  - 9" diameter aluminum pie tin with tilted edges
  - match box with 7 matches
  - ashtray (Hardware Box in Box A)
  - pair of safety goggles (Hardware Box in Box A; *Note:* The trunk is supplied with 4 pairs of safety goggles – one pair for each student who lights matches. However, in many schools, every student who conducts experiments must wear goggles. Thus, you may need to supply more.)
- Have a **metal** trash can **without a plastic liner** available.

Procedure

1. Explain to students that they will work in teams to build small "campfires" using specific combinations of fuels. The experimental questions are:
    - What kinds of fuels are easiest to ignite?
    - What kinds of fuels burn longest?
2. Explain what **duff** is: partly decomposed plant and animal matter lying on or in the soil.

   There can be a huge amount of duff on the ground, such as under an old tree or in a peat bog that may have "organic soils" a meter deep or more. Or there can be very little duff – as in dry places where plants grow slowly. A fire burning in the duff is called a **ground fire**. In this experiment, dried peat moss is used to represent duff.
3. 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?
    - Which will burn out in the **shortest** time?
    - Which will burn **longest**?

Record the votes on the board in the table. These are the students' hypotheses.

4. Group students into 4 teams.
5. Explain the procedure and note that **the whole team is responsible for safety. If any student is injured, the team must alert the teacher and use water to put out their campfire.**
   Each team will:
    - Draw a recipe from the "Recipe Box."
    - Collect the three ingredients on their "recipe" from the labeled ingredient bags. Fuels are

      "measured" by the "handful," which is subjective, but the point is to use about the same amount of each fuel in a campfire.

- 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 matches can be used to ignite the campfire or added into the fuel array. Obviously, at least one must be used for ignition.
- Have a teacher or other adult verify that they have met the requirements before ignition.
- After ignition, groups **may not** rearrange the fuels, but they **may** blow on the fire.
- Dispose of burned matches in the ashtray or in the campfire.

6. Direct the students to ignite their campfires. Monitor their progress, watching for safe practices.
7. 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.
8. **Safe clean up:** Direct students to make sure all burned materials and matches are completely out before disposing of them:
    - There should be no smoke and no heat being released. They (and you) should especially check juniper sticks and duff, which may smolder for a long time. Stir the fuels and feel for heat.
    - When fuels are completely cool, dispose of them in a metal trash can without a plastic liner. If in doubt, dump fuels in a bucket of water and leave them there overnight before putting them in the trash can.

9. Discuss the results with students, and how they compared to their hypotheses; include fuel properties, heat transfer, and the fire triangle concepts. This can be done as a whole class or in groups, but one option to involve students more fully in discussion is through an engaging speaking and listening activity called a "**dynamic Socratic circle**" (also called a "Socratic seminar") with a "**brilliance board**":
    - Divide the class into three groups; consider naming the groups "Heat," "Fuel," and "Oxygen" to reinforce the fire triangle concept (or just A, B, and C, as described below).
    - Arrange the chairs in the room as to have an inner circle of chairs (enough for each student in group A) and an outer circle of chairs (enough for each student in group B).
    - Each student in group C should stand by the chalk or dry erase board with a piece of chalk or dry erase marker. The individuals in the inner circle will be given a question that they should discuss in the form of a conversation. Tell students that they are not to dominate the conversation and they are not to remain silent. All must contribute to the discussion; they could participate by adding information, asking another question, encouraging a peer to speak, or building upon a peer's response.
    - During this time the teacher is to remain silent—tell your students to pretend that you are not there. Also, warn your students that there may be periods of awkward silence from which you will not rescue them—tell them that silence means thinking and you will wait for something to be said. If there is little left to be said or information is being repeated, change the question.

Each group should go through at least three questions. The conversation will end when the teacher asks a new question, changes the groups around, or says the activity is over.

- Once a student in the inner circle has contributed to a conversation, a student from the outer circle can tap them on the shoulder, switch places, and join the conversation.
- While groups A and B are speaking and listening, the group at the board writes down brilliant and important points and questions that come up during the conversation. Tell this group that it is okay to repeat points and questions. In fact, it is preferred because after the discussion the class will analyze the board for trends.
- Rotate the groups so that each has had a turn at each station.
- Tell students to use their observations from the experiments and their knowledge of the fire triangle and heat transfer in the conversations. Possible questions for the inner circle include:
    - Were any of your hypotheses incorrect?
    - Were any of your hypotheses correct?
    - Which was the easiest to start on fire?
    - Which was the hardest to start on fire?
    - Which burned out the quickest?
    - Which burned the longest?
    - How did fuel fineness affect fire?
    - How did fuel moisture affect fire?
    - How did fuel size affect fire?
    - How does fuel fluffiness affect fire?
    - Discuss the fuel properties of duff and how it would burn (you may need to define duff as the dead parts of vegetation, such as leaves, branches, bark, and stems that exist in various stages of decomposition above the soil surface).

Assessment

Options include:

1. Participation in the dynamic Socratic circle with brilliance board or other type of discussion.
2. Ask students to use their knowledge about starting fires to write a description of each fuel property (amount, size, moisture content, and spatial arrangement) and how it affects fire.
3. Ask students to write down the "recipe" they used, then use the four fuel properties to explain why their recipe burned as it did (easy or hard to ignite, burning out quickly or slowly).
4. Ask each student to write down his or her favorite three ingredients for a successful campfire. During another class period, have students select a handful of each of their favorite ingredients and build a campfire that ignites easily and burns long.

Evaluation

1. If the class used a dynamic Socratic circle with brilliance board:

	Excellent	Good	Fair	Poor
Inner Circle	• Built upon peer's comments • Greatly contributed to conversation • Encouraged others to speak.	Constructively contributed to conversation	Did not contribute, but was actively listening	Disruptive to conversation
Outer Circle	• Tapped in once a student had spoken • Encouraged others to tap into the inner circle.	Willingly left inner circle when tapped out	Did not contribute, but was actively listening	Disruptive to conversation
Brilliance Board	• Consistently wrote brilliant points and questions on board	Actively listened and occasionally wrote on board	Did not participate, but was actively listening	Disruptive written remarks

2. Information that can be included about the four fuel properties includes:
    - **Amount:** The more fuel, the longer your fire can burn and the more heat it can produce.
    - **Fineness (size):** The smaller the fuel particles, the more easily they will ignite because it is easy to heat them up to ignition temperature.
    - **Moisture:** The drier the fuels, the more easily they will ignite and the more completely they will burn because little heat is needed to remove moisture.
    - **Fluffiness** determines how much oxygen is available.
    - **Spatial arrangement:**
        - The best arrangement is fluffy enough to let air and heat circulate, but not so fluffy that heat and flames can't easily reach from one particle to the next.
        - It is usually best to put fine fuels below coarse ones; the fine ones will ignite more easily and may produce enough heat to get the larger ones to ignition temperature.

3. Explanation of their recipe: The student used the fuel properties to explain how and why the fire started (or didn't start) and how well or poorly it burned.

11. Adopting Organisms of the Sagebrush Ecosystem

Subjects: Science, Reading, Writing, Speaking & Listening

Duration: 1 – 2 class periods for student preparation; 3 – 5 minutes each for presentations

Setting: Classroom / lab

Vocabulary
- adaptations
- biodiversity
- succession

Overview

In this activity, students teach each other about some of the species that live in the sagebrush ecosystem. Each student "adopts" an organism, prepares a mask or costume, and presents his or her organism to the class. Students can use the essays in the *FireWorks Encyclopedia: Sagebrush Steppe Ecosystem Field Guide* to conduct research, and/or other sources. Each student presentation should address the ways the organisms are impacted by fire, both positive and negative.

Lesson Goals

- Students will deepen their understanding of ecological communities, ecosystems, and biodiversity by learning about some of the plants, animals, and fungi that live in the sagebrush ecosystem.
- Students will understand that individual species have specific ways to survive fires.

Objectives

- Students will conduct research about an organism and create a mask, costume, or puppet to represent it.
- Students will give a 3- to 5-minute presentation to the class that describes their organism, including its adaptions to the sagebrush ecosystem and its relationship to fire.

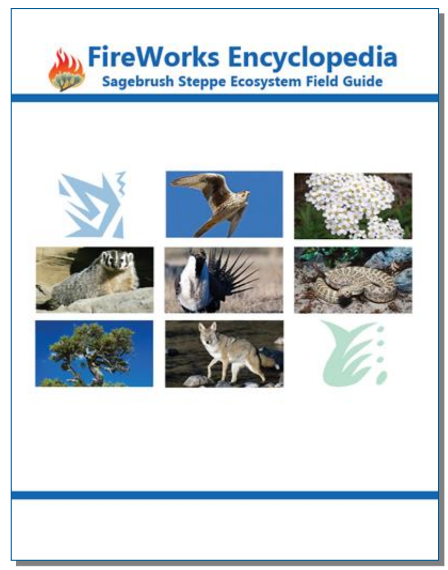
Standards		Middle School (Grades 6-8)
NGSS	**Crosscutting Concepts**	• Systems and system models • Stability and Change
	Science & Engineering Practices	Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	LS1.B: Growth and Development of Organisms LS2.A: Interdependent Relationships in Ecosystems LS2.C: Ecosystem Dynamics, Functioning, and Resilience
Common Core ELA	**Writing Standards** Science & Technical Subjects	4, 7, 10
	Language Standards	1, 2, 3, 6
	Reading Standards Science & Technical Subjects	3, 7
EEEGL	**Strand 1**	A, C, E, F, G

Teacher Background

Different kinds of organisms have different needs. Some of these living things are adapted to grow well only in sunny openings, for example, while some grow well in shade and others require special soil conditions or large amounts of water. Different species that live in the sagebrush ecosystem have different ways to survive fire and thrive afterward. These traits—or **adaptations**—are sometimes specific to a certain kind of fire, so changes in the kinds of fire or their frequency may make life difficult for the organism.

Students should discuss the organism's adaptations in their presentations, including those that allow them to survive fire. A rubric to assist with student self-evaluation and teacher evaluation is provided at the end of the lesson.

Materials + Preparation



- *FireWorks Encyclopedia: Sagebrush Steppe Ecosystem Field Guide* (Box C in the trunk and online at www.frames.gov/partner-sites/fireworks/curriculum/sagebrush-ecosystem)
- Art supplies for making masks, costumes, or puppets
- Copies of the "Organism Presentation Rubric" for each student (at the end of lesson)
- Decide how to assign species to students. Ideally, students will be able to choose to increase motivation, or you can speed up the process by assigning them each an organism or having them draw the names from a hat. Print a copy of the table **"**Species Featured in the *Fireworks Encyclopedia . . .*" (below) for recording assignments.
  Note: The organisms marked with * are key species which should be assigned first.
- Apart from class time, allow for sufficient time outside of class for all students to complete the project.

Procedure

1. Explain to students that they will each be able to "adopt" an organism that lives in the sagebrush ecosystem. He or she will each:
    - Learn about their adopted organism from the fun essay about it in the *FireWorks Encyclopedia.* These are written from the organism's point of view.

      Optional: If time allows, students can conduct additional research using sources such as those listed at the end of the essays.

    - Give a 3- to 5-minute presentation about the organism that includes a basic description of it and how it is adapted to survive in the sagebrush ecosystem. They should include how it meets its needs and how it deals with fire. Review the concept of **adaptations** with students, and ask them for examples to demonstrate their understanding. They should also discuss the other organisms it interacts with, including the organisms it eats—or that eats them.

    - Prepare a mask, costume, or puppet to use in the presentation.

    - A written summary of the content will be submitted before presenting.

2. Pass out copies of the **"**Organism Presentation Rubric" and read through it will students. Answer questions to ensure students understand that they will be learning about the organisms'

characteristics AND their relationship to fire in preparation to give a 3- to 5-minute presentation about it to the class—complete with a mask, costume, or puppet as a visual aide.

3. Have students work on the assignment for 1 – 2 class periods—or potentially longer if they are doing more in-depth research. They should complete their rubric and turn it in to you when they are ready to present, along with the written summary of the content they plan to present.
4. Ask students who appear to have done an excellent job preparing to present—and on their mask, costume, or puppet—to present first as models for other students. There is no need to finish all of the presentations before doing further lessons in the curriculum. In fact, it may be helpful to spread the student presentations over multiple class periods.
5. After the presentations are complete, have a brief discussion about the many interactions between organisms highlighted in the presentations, and how everything in the sagebrush ecosystem—like all ecosystems—is interconnected. Discuss the concept of **biodiversity**, and how it is critical for healthy ecosystems.
6. *Optional:* Students can work together to create and perform a play that illustrates the sagebrush ecosystem's relationship with fire, incorporating all of the organisms they researched. This could be a project for the whole class, for student groups, or for a smaller group of students.
7. *Optional:* For more activities which increase student understanding of the concept of biodiversity and how it is critical for the health of the sagebrush ecosystem, see the *Inquiry, Exploration, and Service Learning in the Sagebrush Ecosystem* curriculum from the U.S. Fish and Wildlife Service, such as "The Sagebrush Sea's Web of Life" lesson: www.fws.gov/greatersagegrouse/education.php

Assessment

Have a few students give their presentations at the start of each class until all are complete, using the rubric to assess their proficiency. Tell them to keep their costumes handy because they will be needed later—or store them in one place in the classroom after they have presented so they cannot be lost or damaged.

Evaluation

You and the students can use the "Organism Presentation Rubric" below to assess proficiency with meeting the goals for the assignment.

Table: Species featured in the *FireWorks Encyclopedia: Sagebrush Ecosystem Field Guide*

* denotes some of the key species in the sagebrush ecosystem

Species	Student Name
Arrowleaf Balsamroot*	
Badger	
Bitterbrush*	
Biotic Crust*	
Buckwheat	
Cheatgrass*	
Chokecherry	
Coyote	
Cutworm	
Douglas Fir	
Ferruginous Hawk*	
Fringed Sage	
Globemallow	
Golden Eagle*	
Great Basin Wild Rye*	
Harvester Ant*	
Idaho Fescue*	
Indian Paintbrush	
Juniper*	
Lupine	
Mormon Cricket	
Mountain Mahogany	
Mule Deer*	
Pinyon Pine*	
Ponderosa Pine	
Prairie Falcon	
Prairie Rattlesnake	
Pronghorn Antelope*	
Pygmy Rabbit*	
Quaking Aspen	
Rabbitbrush*	
Sagebrush*	
Greater Sage-grouse*	
Sage sparrow	
Short Horned Lizard	
Tapertip Hawk's Beard	
Townsend's Ground Squirrel*	
Western Yarrow	
Wheatgrass*	
Wild Onion	

Name: ___________________________ Period: _______ Date: ______________________

Organism Presentation Rubric

Name of Organism: ____

Presentation Component	Maximum Points Possible	Self-Score (fill out before presentation)	Teacher Score
Part 1: Content			
Organism's key traits explained, including: • **Adaptations** which help it survive in the sagebrush ecosystem • What it eats and/or what eats it	10		
Interactions with fire clearly explained	10		
Part 2: Delivery / Audience Engagement			
Speech delivered clearly at appropriate volume and speed (not too fast, slow, loud, or soft)	5		
Speed, volume, and voice inflection are varied to engage audience and emphasize key points	5		
Speaker connects with audience through eye contact and does not spend too much time looking at notes or screen	5		
Speaker demonstrates enthusiasm for topic throughout presentation; audience is persuaded by speaker	5		
Part 3: Visual(s)			
• Well-made mask, costume, and/or puppet helps to explain about organism • *Optional:* Other visuals increase understanding of organism and role(s) in ecosystem	10		
Part 4: Writing Conventions			
Grammatical / spelling conventions followed in written summary and any text used in presentation	10		
TOTAL:	**60**		

Teacher Comments:

12. Tree/Shrub Structures and Fire

Subjects: Science, Writing, Reading, Speaking & Listening, Art

Duration: Two 30- to 45-minute class periods or one block of 60 minutes or more

Setting: Classroom and/or outdoors

Vocabulary:

- bark
- biological soil crust
- branch
- cone
- duff
- ground fire
- litter
- mineral soil
- snag
- resprouting
- seed dormancy

Overview In this lesson, students learn to name the parts of trees and shrubs, describe their functions, and describe some of the ways they are adapted to survive fire and/or reproduce after it. Students first research ecological terms and concepts and make presentations about them to the class. Then the class breaks into teams to play an enjoyable Jeopardy-style game which reinforces the concepts.

Lesson Goal Increase students' understanding of how trees and shrubs function and how they may be affected by different kinds of wildland fires

Objectives

- Students will make class presentations about tree/shrub structures and their functions, elements of the organism's environment, and/or ways they are adapted to different types of fire.
- Students will prepare visual representations of concepts to aid in their presentations and reinforce their learning.
- Students will demonstrate understanding of important concepts in a Jeopardy-style game.
- Students will describe how specific tree/shrub characteristics enable them to better survive surface fires, crown fires, and/or ground fires.

Standards		Middle School (Grades 6-8)
NGSS	**Crosscutting Concepts**	• Structure and Function • Stability and Change • Systems and System Models
	Science & Engineering Practices	Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	LS2.A: Interdependent Relationships in Ecosystems LS2.C: Ecosystem Dynamics, Functioning, and Resilience LS4.C: Adaptation
Common Core ELA	**Reading Standards** Science & Technical Subjects	3, 9
	Speaking & Listening	1, 2, 4, 6
	Language Standards	1, 2, 3 6
	Writing Standards Science & Technical Subjects	4, 7, 10
EEEGL	**Strand 1**	A, E, F, G

Teacher Background

To understand how fire affects organisms and shapes plant communities, it is helpful for students to learn how tree and shrub structures help them to survive. This activity challenges students to master and use a number of terms and concepts, many of which they already have some familiarity with, while others may be entirely new.

The lesson consists of two parts. In Part 1, students teach their classmates about:

- tree and shrub structures and the relationships between them
- the forest and shrubland environment, and
- types of fire and how trees and shrubs are adapted to survive them.

Part 2 is an engaging Jeopardy-style game which reinforces the terms/concepts and encourages students to think critically about them.

Throughout the lesson students should gain a better understanding of how different **adaptations** can enable trees, shrubs, and other plants to survive specific kinds of fire and/or reproduce and thrive after it. For example:

- Thick **bark** (the outermost layer of stems and roots of woody plants like shrubs and trees) can protect a woody plant's sensitive phloem and cambium from the heat of surface fires. However, it does not protect against crown fires.
- If a tree tends to shed its low branches, fires are less likely to climb from the forest floor into the tree crowns than if the branches are continuous from ground to crown.
- If young trees of a species can grow really fast, getting their leaves and branches high above the ground, they may be able to survive surface fires even when young.
- Roots that grow deep in mineral soil are protected from the heat of surface and ground fires. However, deep roots don't prevent damage to the cambium from surface fires or damage to the leaves and buds from crown fires.
- If trees, shrubs, and other plants can protect their seeds from fire, new plants can become established afterwards. Tightly sealed **cones** can protect the seeds of trees and shrubs in the conifer family from crown fire. Burial protects seeds from all kinds of fire – unless they are in duff or organic soil, which can burn if it dries out.
- If a tree or shrub can sprout from its roots after its top is killed, it can survive surface and crown fire; its ability to survive ground fire depends on soil properties and how deeply its roots are buried.

Materials + Preparation

- Download the Jeopardy game PowerPoint "M12_Tree-Shrub_Jeopardy.pptx" from www.frames.gov/partner-sites/fireworks/curriculum/sagebrush-ecosystem. Practice working with the game to prepare to play it with students and obtain prizes for the winning team(s) if you plan to award them.

- Print 1 copy per student of the handout "Tree/Shrub Structures and Fire" found at the end of the lesson. Pass them out to students at least 1 day before doing this activity and ask them to study it to prepare for a class game.
- Copies of the "Trees/Shrubs and Fire Presentation Rubric" for each student (at end of lesson)

- Reference books and/or Internet/library access for students to conduct research.
- *Optional:* Blank paper and colored pencils for students to create visual models of the concepts and/or clay and other materials for students to create 3-D models of them.

Procedure

Part 1

1. *Recommended:* Take students outside to the schoolyard or nearby natural area to carefully observe trees, shrubs, organic litter, and soil. Discuss some of the terms and concepts on the "**Tree/Shrub Structures and Fire**" handout, then explain that students will have the opportunity to become an expert about one of them so they can teach the class more about it.

2. Ask students to review the tree/shrub structures and other terms on the handout and choose the ones they would most like to research more in-depth. Walk around with another copy of the handout and write down student names next to their choices, helping them to make another selection, if necessary. Allowing student choice increases intrinsic motivation, but you could also choose to assign the 25 terms for efficiency.

3. Pass out the "**Trees/Shrubs and Fire Presentation Rubric**" and tell students that they will develop a 1- to 2-minute presentation to teach the class more about their chosen concept. The presentation must include an illustration, 3-D model, or another type of visual or digital component such as part of the organism, a PowerPoint presentation, a photograph, or a short video (no longer than 60 seconds). They should also include information about how the structure or other concept is adapted to and/or impacted by fire (if applicable).

4. Explain to students what additional resources are available for research, such as reference books, the Internet, and/or a visit to the school library. Tell students much time they will have to research their presentations and prepare a written summary of it, an outline, or note cards. They should fill out the rubric and hand it to you when they are ready to present.

5. Have students teach their concepts to the class using their visual aid(s). Encourage the other students to record additional notes and/or simple illustrations on the "**Tree/Shrub Structures and Fire**" handout or a separate sheet while they listen. Another option is to ask students to create one complete labeled illustration showing as many of the terms as possible, as shown on the "**Example of a Simple Labeled Diagram**" at the end of the lesson. This is a great way to help students make connections between the concepts, and a rough illustration could be followed by a more detailed and/or beautiful one after all the presentations are complete. Students can also write down 3 or more adaptations that can help trees/shrubs survive or grow after ground, surface, and crown fire on their diagrams or a separate sheet.

   NOTE: It is best to have **branch** presented before **leaf**, **bud**, and **cone**, followed by **seeds**. **Roots** should ideally be presented before **resprouting**.

6. Congratulate the students on their presentations and ask them to take their handouts and any other notes home to prepare for the Jeopardy! game.

Part 2

7. *Note:* If you only have one class period available, or your class already has a good understanding of the terms/concepts, you can skip Part 1 and have students simply review the handout before starting the game.

8. After students have had the opportunity to study the terms/concepts, ask them to put their handouts and other notes away and form groups of 4 – 5 students. *Optional:* Tell the groups that you will allow them to refer to their handouts and any other notes during the game for half points.

9. Open the "M12_Tree-Shrub_Jeopardy.pptx" PowerPoint presentation and explain to students that they will compete for points based on their understanding of tree and shrub structures and how they are adapted to survive fire and other challenges in the environment.

10. Before beginning, ask them teams to decide on a team name and ask for one member of each team to volunteer to keep score (for all of the groups). That way all the groups (and not you) are responsible for the correct totals, no one needs to miss out on playing the game to keep score, and more students practice quick mental math skills.

11. Ask students if there any final questions about the concepts.
    Optional: Award bonus points to the group(s) that can answer the questions.

12. Advance through the "Category" slides, reading the names for the class in a fun, dramatic way. Explain how the game is played and tell students that Jeopardy! answers should always be given in the form of a question. (Decide if they will only be given half points—or no points—if they forget to do that.) Be sure to tell students that they will lose the dollar amount shown for each question if they give an incorrect answer or raise their hand(s) to give an answer and they cannot do so within the time limit.
    Note: You can click the "Start Timer" link in the red bar at the bottom of the slides when you are waiting for an answer. (Be sure your audio is turned on if you want to hear the buzzer at the end of the time limit and/or use the sound effect buttons shown in the lower-right.)

13. *Optional:* Tell students that you are thinking of a type of fire, and the first group to raise their hand and guess the type gets to choose first.

14. Play the game until all the clues have been given, using the "Home" button at the bottom of the screen after each question. Then click the link in the lower-right to advance to Final Jeopardy. Advance to the Category slide and ask the groups to write down how much of their dollar totals they want to wager. When all the groups have done that, tell they groups they must quietly discuss and write down their answer after you read the question. Advance to the next slide, read the question, and then click the "Start Timer" link in the red bar at the bottom. (Be sure your audio is turned on if you want to play the classic tune while the groups record their answers.)

15. If time allows, move to the "Bonus Question!" Category slide and ask students to wager one last time.

16. Present award(s) to the winning team(s), if desired, and congratulate everyone on a well-played game. You can encourage teams to shake hands if you'd like to reinforce good sportsmanship and sportswomanship, too. ☺

    Note: You can reset the main game screen and turn all the dollar values back to yellow by closing the PowerPoint presentation and reopening it.

Assessment / Evaluation

Task	Full Credit	Partial Credit	Less than Partial Credit
Presentation Have students fill out the "**Trees/Shrubs and Fire Presentation Rubric**" rubric at end of lesson or use the criteria to the right	• Student presented accurate information in clear and concise way • Visual/digital component was relevant and helpful	• Student presented information that contained some misinformation (*which the teacher corrected*) • Visual/digital component was present, but only slightly relevant	• Student presented mostly misinformation • Visual/digital component was distracting or missing
Jeopardy Game	Student participated consistently in game by contributing to group discussions to determine answer, presenting answer for the group, listening, and giving other group members a chance to speak.	Student participated sporadically in game by listening, occasionally contributing to group discussion, and presenting the group's answer at least once.	Student did not participate in game by listening to or engaging in group discussion or presenting group's answers.
Labeled diagram (if applicable)	• Student correctly labeled 10 or more terms on the diagram. • Student correctly described 3 adaptations that can help the tree or shrub survive or grow after ground, surface, and crown fire.	• Student correctly labeled 5-9 parts on diagram. • Student correctly described 1-2 adaptations that can help the tree survive or grow after different types of fire.	• Student correctly labeled less than 5 parts on diagram. • Student did not describe any adaptations that can help the tree survive or grow after fire.

Name: _________________________________ Period: ____ Date: ____________________

Tree/Shrub Structures and Fire

Visible Tree/Shrub Structures

bark: the outside covering of a tree or shrub's stems and branches; Thick bark on tree trunks can protect them from surface fire.

branch: limb of a tree or shrub that grows out from the trunk and holds leaves up in the light. Some trees drop their low branches as they age, which helps keep surface fires on the forest floor, so the tree can avoid crown fire.

bud: the cells that will grow next year's leaves and branches. Located at the tips of branches in trees and shrubs, as well as a tree's top. Similar cells occur at the tips of roots.

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

crown: the top of a tree, which holds most of its leaves, or the part of a shrub above the ground**.**

leaf: the part of a plant that is usually green which uses sunlight, water, and carbon dioxide to make "food" for the plant. Leaves of many plant species are also an important food source for many animals.

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

snag: a dead standing tree, often with a broken top; provides good habitat for wildlife, but also good fuel for fires

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

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

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

Hidden Structures

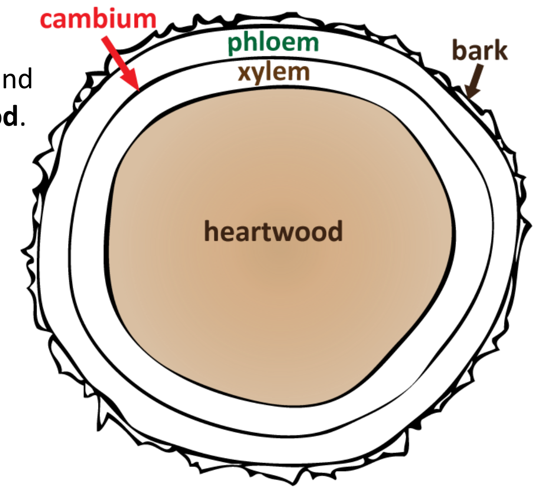
cambium: layer of living cells inside a tree or shrub that produces the xylem and phloem layers

heartwood: inner wood of trees and shrubs which gives strength and resists decay. It is often darker than the outer **sapwood**.

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

xylem (sapwood): layer of hollow wood cells inside the cambium that pumps water from roots to leaves

Simplified Trunk/Branch Cross Section



Forest + Shrubland Environments

biological soil crust: living surface of the ground in dry environments such as sagebrush ecosystems made up of organisms such as fungi, lichens, and algae; important for controlling **erosion** and preventing invasive grass species

duff: the layer of soil that is made up of decomposing plant and animal matter. Duff is below litter and above mineral soil. Deep duff can protect a tree or shrub's cambium and roots from fire until it dries out.

litter: the layer of dead leaves and other plant matter, not yet decayed, on the soil's surface, above the ground

mineral soil: soil that has no plant or animal matter, so it cannot burn. It can help roots and burrowing animals survive fire.

organic matter: material such as plant leaves or animal waste that was recently part of a living thing; Many organisms such as worms and bacteria can eat it, helping it **decompose**.

Types of Fire – and Adaptations to Survive It

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

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

ground fire: a fire that burns the organic material along the ground, including the **litter** and **duff** layer of the soil. Ground fires usually burn slowly, with lots of smoldering instead of long flames. They can produce intense heat, which can kill roots.

resprouting: an adaptation of some plants which lets them regrow from the top of their roots when the part above ground is killed (usually by fire)

seed dormancy: seeds of some plants can remain **dormant** (alive but not **germinating**) for long periods of time until the seed coat is damaged, causing them to **germinate** (start to grow)

Name: ____________________________ Period: _______ Date: ______________________

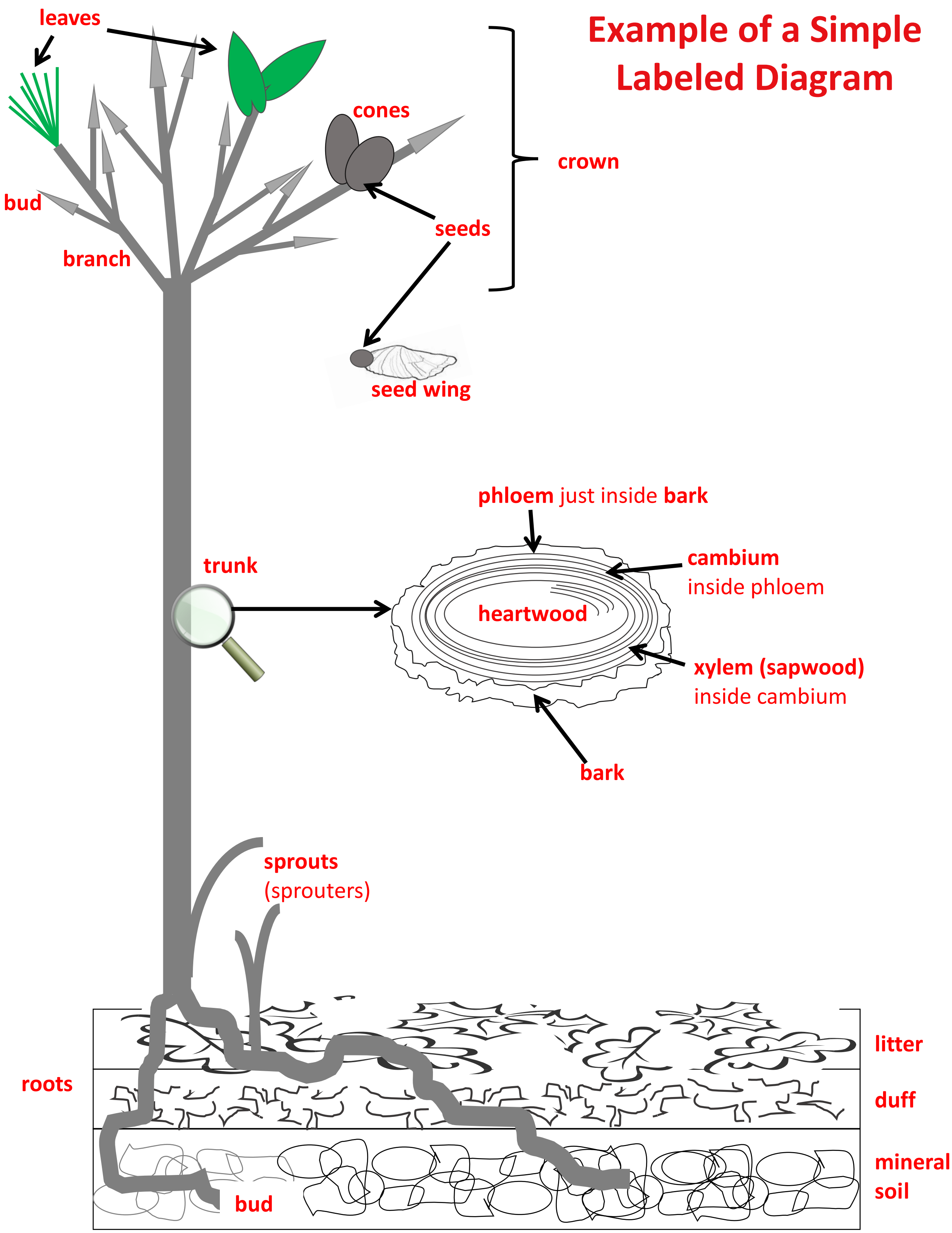
Tree/Shrub Structures and Fire Presentation Rubric

Name of Term/Concept: ____

Presentation Component	**Maximum Points Possible**	**Self-Score** (fill out before presentation)	**Teacher Score**
Part 1: Content / Visual(s)			
Important, accurate information explained, including: • **Adaptations** which help it survive fire (if applicable) • Interactions with other tree/shrub structures and/or the environment	10		
Accurate visual(s) clearly explain concept	10		
Part 2: Delivery / Audience Engagement			
Speech delivered clearly at appropriate volume and speed (not too fast, slow, loud, or soft)	5		
Speed, volume, and voice inflection are varied to engage audience and emphasize key points	5		
Speaker connects with audience through eye contact and does not spend too much time looking at notes or screen	5		
Speaker demonstrates enthusiasm for topic throughout presentation; audience is persuaded by speaker	5		
Part 3: Writing / Conventions			
Written summary, outline, or note cards complete and accurate	10		
Grammatical / spelling conventions followed in written summary and any text used in presentation	10		
TOTAL:	**60**		

Teacher Comments:

Example of a Simple Labeled Diagram



Traits for surviving fire and/or thriving after it:

- **ground fire:** seeds or roots in mineral soil
- **surface fire:** thick bark; seeds in duff or mineral soil
- **crown fire:** seeds in closed cones, duff, or mineral soil; ability to sprout; loses low branches

13. Mystery Plants of the Sagebrush Ecosystem

Subjects: Science, Writing, Reading, Speaking & Listening, Art

Duration: Two 30- to 45-minute class periods or one block of 60 minutes or more

Setting: Classroom or outdoors

Vocabulary

- adaptations
- biodiversity
- bunchgrass
- forb
- herbaceous
- leaf arrangements: alternate, opposite, whorled
- shrub

Overview Students make scientific observations of plants from the sagebrush ecosystem, recording their observations, illustrations, and measurements on a guided investigation sheet. After the teacher checks the sheets for accuracy, they are used by all the groups, along with other resources, to try to identify the plant species. These attempts at identification are recorded on a second handout, as well as student ideas about the plants' adaptations that help them to survive in the sagebrush ecosystem.

Lesson Goals Increase students' understanding of the diversity of plants in the sagebrush ecosystem and how the plants are adapted to their environment

Objectives

- Students will make scientific observations of plants from the sagebrush ecosystem and record their characteristics in writing.
- Students will create a detailed scientific sketch of a "mystery plant" to assist with making careful observations of the plant and its parts, such as leaves, buds, flowers, and seeds.
- Students will record their hypotheses about possible plant adaptations in writing and share them orally in groups and/or with the class.

Standards		Middle School (Grades 6-8)
NGSS	**Crosscutting Concepts**	• Patterns • Structure and Function • Stability and Change • Systems and System Models
	Science & Engineering Practices	Planning and carrying out investigations Obtaining, Evaluating, and Communicating Information
	Disciplinary Core Ideas	LS2.A: Interdependent Relationships in Ecosystems LS2.C: Ecosystem Dynamics, Functioning, and Resilience LS4.C: Adaptation
Common Core ELA	**Writing**	4, 10
	Speaking & Listening	1, 2, 4, 6
	Language Standards	1, 2, 3, 6
	Writing Standards Science & Technical Subjects	4, 7, 10
EEEGL	**Strand 1**	A, E, F, G

Teacher Background

This mystery plant species is a favorite food of many wildlife species, including deer, elk, and greater sage-grouse. Can you guess it? Keep reading the lesson to see if you are correct!

Wildland ecosystems are usually biodiverse, and the diversity of plant species is an important characteristic of sagebrush ecosystems. This is also true of forest ecosystems, which can be found adjacent to sagebrush areas at higher elevations, as well as riparian areas (wetter areas near streams) which can travel through sagebrush areas. To understand and appreciate the complexity of the ecosystems and fire's role in such communities, students should learn to distinguish among plant species.

In this activity, students use their observation skills to describe and identify important plants of the sagebrush ecosystem, such as:

1. Antelope bitterbrush (shrub)
2. Big sagebrush (shrub; multiple subspecies)
3. Scarlett globemallow (forb)
4. Arrowleaf balsamroot (forb)
5. Lupine (forb)
6. Western yarrow (forb)
7. Tapertip hawksbeard (forb)
8. Sulpher-flower buckwheat (forb)
9. Idaho fescue (bunchgrass)
10. Great Basin wildrye (bunchgrass)
11. Cheatgrass (invasive grass)
12. Western juniper (tree)

The 12 numbers listed in front of the species above are used to identify the mystery plant species in the "FireWorks Trunk for the Sagebrush Ecosystem."

Materials + Preparation

- Assemble 10 stations in the classroom, each containing a grocery bag with the following items from the FireWorks Trunk for each mystery species:
    - Plant specimen and any other plant parts, such as flowers (Box A)
    - Set of four photos of the species (Mystery Plants Box in Box B)
    - Ruler (Hardware Box in Box A)

- Did you guess the name of the important plant species shown on the previous page? It is mountain big sagebrush, one of the subspecies of big sagebrush *(Artemisia tridentata)*. The two other main subspecies of big sagebrush are basin big sagebrush and Wyoming big sagebrush.
- Make copies of the "Mystery Plants of the Sagebrush Ecosystem" investigation sheets (found at the end of the lesson) for each student. We recommend using separate pieces of paper for the two sheets.
- Make copies of the essays about the plants used in the activity from the *FireWorks Encyclopedia: Sagebrush Steppe Ecosystem Field Guide* found at www.frames.gov/partner-sites/fireworks/curriculum/sagebrush-ecosystem.
- Write these terms on the board to discuss with students:
  - Biodiversity
  - Adaptations
  - Forb
  - Herbaceous
  - Bunchgrass
  - Shrub

Basin big sagebrush

- Species name labels (Mystery Trees Box in Box B) for students to use at the end of the lesson
- *Optional:* Hand lenses for students to make even more careful observations of the mystery plants
- *Optional:* Read additional sources such as the following for background, and/or provide copies for students to read / discuss:
  - "Common Native Plants in the Sagebrush Ecosystem" guide, found in the free *Inquiry, Exploration, and Service Learning in the Sagebrush Ecosystem* curriculum from the U.S. Fish and Wildlife Service: www.fws.gov/greatersagegrouse/education.php
  - *Backpack Guide to Idaho Range Plants:* marketplace.uidaho.edu/C20272_ustores/web/product_detail.jsp?PRODUCTID=2705&SINGLESTORE=true
  - *Sagebrush Country: A Wildflower Sanctuary* by Ronald J. Taylor: www.goodreads.com/book/show/852674.Sagebrush_Country
  - *Great Basin Wildflowers: A Guide to Common Wildflowers of the High Deserts of Nevada, Utah, and Oregon* by Laird Blackwell: www.goodreads.com/book/show/1034849.Great_Basin_Wildflowers_
  - *Idaho Wildflowers* App from Stillinger Herbarium and other partners: www.highcountryapps.com/IdahoWildflowers.aspx
  - "What About Bunchgrass?" Pacific Northwest National Laboratory: workbasedlearning.pnnl.gov/pals/resource/cards/bunchgrass.stm

Procedure

1. *Optional:* Ask students an essential question to activate prior knowledge and help them to think critically about plants in the sagebrush ecosystem. For example, "What adaptations might plants from the sagebrush ecosystem have to help them to survive in their dry environment that is often very cold in the winter and quite hot in the summer?" Ask students to work with a neighbor to brainstorm their ideas, recording them on a piece of paper. After a couple minutes ask the groups to share a few of their ideas.
2. Explain to students that they will be making careful scientific observations of different plants from the sagebrush ecosystem. They will work in teams to describe mystery plant species using specimens and photographs.
3. Explain that there are twelve mystery plants (or however many you are including), but that this is just a very small sample of the many native species in the sagebrush ecosystem. Tell students that this plant **biodiversity** is one reason why so many different types of wildlife can live there, too.
4. Explain that there may be one or more mystery tree species, because trees are encroaching (moving in) to the sagebrush ecosystem and shading out sagebrush and other important species, but that most of the plants will be from 3 categories of plants: shrubs, forbs, and grasses. Ask students about each category of plant, pointing out the terms on the board and clarifying that:
    - **Shrubs** are woody, like trees, but they are usually smaller and have multiple main stems instead of one large trunk, like trees
    - **Forbs** have broad leaves and showy flowers; they do not have woody stems, so they are **herbaceous** plants
    - **Bunchgrasses** are the native grasses most often found in the sagebrush ecosystem. Like all grasses, they are herbaceous with narrow leaves (blades) and their flowers are hard to see.

   Ask students to think about why most of the grass species found in the sagebrush ecosystem grow in bunches. Discuss how it is an **adaptation** which helps them to survive in the dry environment by better using limited water resources, especially with their very deep roots (another adaptation). Explain that thinking about the amazing adaptations of all of the plants will be the focus of their second investigation—along with identifying all of the plants using their classmates' investigation sheets and other resources.

   Optional: Discuss how wildlife of the sagebrush ecosystem such as greater sage-grouse are adapted to eat plants found there, such sagebrush, which animals found elsewhere might not be able to eat. Also discuss why some species of plants are more palatable for wildlife than others (they are more herbaceous, they do not contain as many toxins, etc.)

This beautiful forb finds scarce water with its long, thick taproot, providing important forage for wildlife.
It blooms from May to August and is named for its large, pointy leaves.
Can you and your students name it and the important bunchgrass below?

5. Ask the students to form teams of 2-4 students and pass out the "Mystery Plants of the Sagebrush Ecosystem" investigation sheets, one for each student (or just one per group, if you prefer). Assign each group to one of the stations to begin observing their mystery plant. Explain to students that they should record as many details as possible on the sheets, because they will be important for the whole class to try to identify all of the mystery species during the second investigation.
6. As teams complete their handouts, they can show them to you to check for completeness and accuracy. Ask the students to revise the sheets, if necessary, so they will be as useful as possible for other students during the second investigation.
7. After you approve a team's mystery plant sheet(s), they can trade them with another group whose sheets have been approved if you want to start Investigation 2 during the same class period. If that is the case, you can pass out the "Investigation 2" sheet for students to record the names of the plants and their ideas about their adaptations in the table. If not, collect the Investigation 1 sheets, have the students place their plant specimens back in the grocery bags, and they can begin Investigation 2 during the next class period. Another option is to make copies of all the student-created sheets to put into guides for each group.
8. Students can use their classmates' Investigation 1 sheets and the essays from the *FireWorks Encyclopedia* and any other available resources to identify the mystery plants. As all the students have their Investigation 1 sheets approved, they can trade them with another group or leave them in the station and circulate through all of the stations to complete Investigation 2.
9. *Optional:* Students can use one or more plant identification guides or apps to help them check their identifications of the mystery plants and/or other plants out in the field. For example:
   - *Sagebrush Country: A Wildflower Sanctuary* by Ronald J. Taylor: www.goodreads.com/book/show/852674.Sagebrush_Country
   - *Great Basin Wildflowers: A Guide to Common Wildflowers of the High Deserts of Nevada, Utah, and Oregon* by Laird Blackwell: www.goodreads.com/book/show/1034849.Great_Basin_Wildflowers_
   - *Idaho Wildflowers* App from Stillinger Herbarium and other partners: www.highcountryapps.com/IdahoWildflowers.aspx
   - Good lists of apps can be found online, including: www.shareitscience.com/2016/05/plant-identification-apps-yard-mapping-kids-activity.html.
10. After the students all complete Investigation 2, hold up the species name labels one at a time. Ask the students to all read the name of the species in unison. Ask for volunteers to match each label with the specimens, and the rest of the class can show a "thumbs up" if they agree with the identification or a "thumbs down" if they disagree. Students can each correct their Investigation 2 sheets, and you can also discuss the students' ideas about each plant's adaptations—as a class, in groups, or in "pair shares" with individuals from different groups.

Assessment

1. Collect all of the completed Investigation 1 sheets after they have been used by the class to complete Investigation 2.
2. Collect the completed Investigation 2 sheets after the students have had a chance to use them during the closing activity in which the correct plant names are revealed. Students should correct their own sheets with the common names of the plants. You can also ask them to write the scientific names for practice writing scientific binomial names.
3. Observe levels of student participation throughout the activities and discussions.

Evaluation

Task	Good	Fair	Poor
1. Completion of Investigation 1	• Detailed illustrations showing careful observation • Completion of the rest of the sheet, including detailed written observations	• Illustration(s) do not reveal careful observation • Minimal written observations	Investigation sheet not completed
2. Completion of Investigation 2	• Table completed and student correctly identified all of the species (after the correct names are revealed at the end) • Careful thought about adaptations is apparent	• Incomplete table • Careful thought about adaptations not apparent	Investigation sheet not completed
3. Participation	• Worked well with group members to complete investigations • Shared ideas orally in groups, pairs, and/or with the whole class	Minimal effort to participate	Student did not work well with group or participate in class

Name: ______________________________ Period: ____ Date: ______________________

Mystery Plants of the Sagebrush Ecosystem

***Investigation 1**: Observations*

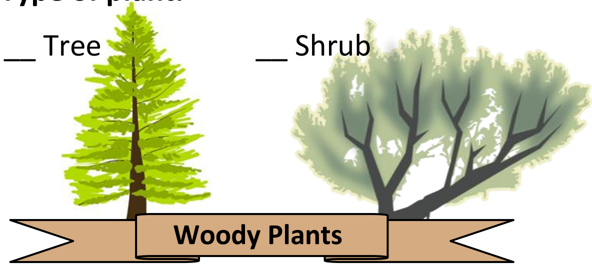
1. Mystery plant number: _____

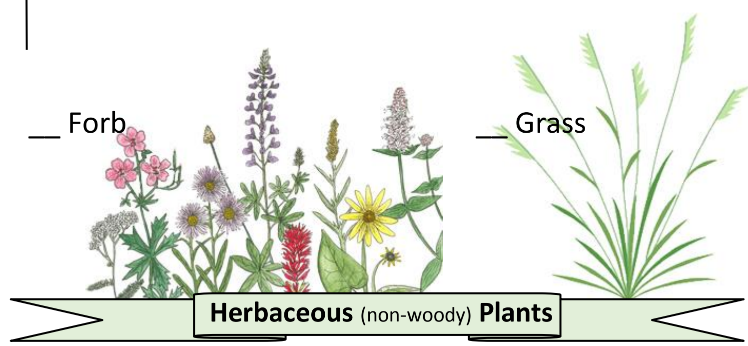
2. Illustration of plant (include roots, if present)

3. Close-up illustration(s)—leaves, flowers, etc.

4. Type of plant:

__ Tree __ Shrub __ Forb __ Grass





5. Leaf arrangement:

__ Alternate __ Opposite __ Whorled __ Other:

6. Measurements:

Height of plant: _____ cm

Width of plant: _____ cm

Length of leaves: _____ cm

Length of seed(s) (if present): ____ cm

Width of flower(s) (if present): ____ cm

7. Description of plant & plant parts (leaves, buds, bark, flowers, seeds, other ways to identify, etc.):

____

____

____

____

Name: ______________________________ Period: ____ Date: ______________________

Mystery Plants of the Sagebrush Ecosystem

***Investigation 2**: Identification & Adaptations*

Plant	**Type** (shrub, forb, etc.)	**Possible Name(s) of Plant** (circle most likely)	**Adaptations for Survival in the Sagebrush Ecosystem**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

15. Bark and Soil: Nature's Insulators

Subjects: Science, Math, Writing

Duration: 45 – 60 minutes

Setting: Classroom / lab

Vocabulary
- insulation
- cambium
- phloem
- soil
- xylem

Overview

In this activity, students work in groups to explore the use of insulation to slow the transfer of heat through materials. Bark (on trees and shrubs) and soil are two kinds of materials that insulate living things from the heat of fires.

Students simulate nature's insulation by covering a surface (a model of a tree/shrub or of soil) with quilting materials. They hypothesize about how it will affect temperature changes as they use a hair dryer to simulate the heat of a fire. They record the temperature pattern beneath the insulation as it heats up and cools off, and then graph the data. Finally, they analyze the data and relate it to how bark and soil may help protect trees and shrubs, including their roots and seeds, from fire.

Lesson Goal

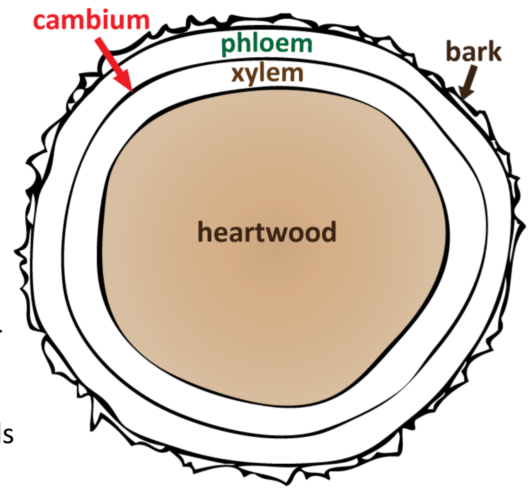
To increase students' understanding of heat transfer and the usefulness of insulation to slow the process and protect trees and shrubs

Objectives

- Students will hypothesize about how insulation will affect heat flow.
- Students will collect data, graph it, and analyze it to describe how insulation affects heat flow.
- Students will describe how bark and soil can protect living tissues from the heat of fires.

Standards		Middle School (Grades 6-8)
NGSS	**Crosscutting Concepts**	• Energy and Matter • Stability and Change
	Science & Engineering Practices	Analyzing and interpreting data
	Disciplinary Core Ideas	PS3.A: Structures/Properties of Matter
Common Core ELA	**Writing Standards** Science & Technical Subjects	4, 7, 10
	Language Standards	1, 2, 3, 6
	Reading Standards Science & Technical Subjects	3, 7
Common Core Math	Geometry	6.G
EEEGL	**Strand 1**	A, C, E, F, G

Teacher Background



Nature has ways to insulate living things from the heat of wildland fires. Many trees have thick bark, which slows the transfer of heat from fire to the crucial **cambium** layer beneath the bark that can make new cells and transport nutrients throughout the tree. The cambium is comprised of **xylem** and **phloem** cells. The xylem moves water and nutrients through the plant and provides woody support. The rings seen in cross sections of tree trunks and branches are xylem cells. Phloem cells carry sugars, minerals, and other substances throughout the plant. They are the only kind of cell that can deliver carbohydrates produced in the leaves to other parts of the plant.

Soil is another of nature's insulators. Soil protects small animals that stay in their underground burrows during fires. It also protects roots, buried seeds, and other underground plant parts.

In this activity, we assume that bark and soil will not burn, but that assumption is not completely accurate. Bark *can* burn if it gets dried out and is exposed to enough heat**.** High intensity fires are becoming more common due to factors such as climate change and the spread of invasive species like cheatgrass. This exposes plant life to high heat and reduces natural regeneration in the sagebrush ecosystem. At higher elevations and when soil has more moisture, the sagebrush ecosystem becomes more resilient to regeneration. Some materials in the soil can burn, too. Soil is composed of tiny particles of rock (minerals), which do *not* burn, plus partly decomposed particles of vegetation and animal matter, which *can* burn. When the dead, rotting organic matter is in a distinct layer on top of the mineral soil, we call it **duff** or **the organic layer**.

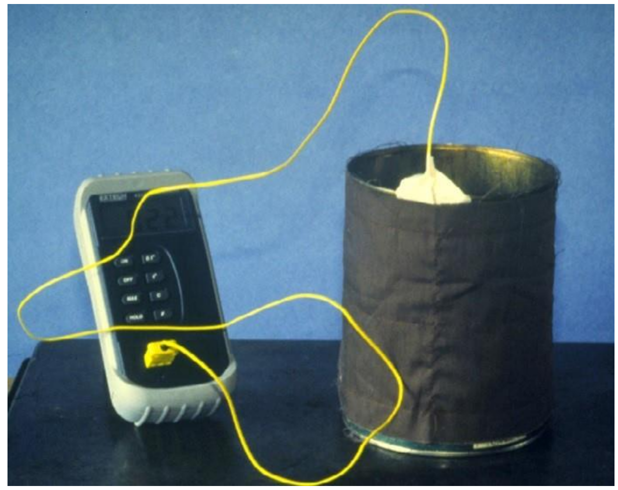
Students may be surprised to find that, while thick insulation prevents the temperature from rising rapidly, it also prolongs the heating process and slows the cooling process when compared with thin insulation. An analogy you could use with your students is how insulation in a home keeps it from heating up rapidly on a hot summer day and from cooling off rapidly on a cold winter night. Insulation may also slow the house's cooling *after* a hot summer day, which is why we might open the windows and use fans to bring more cool air inside.

Note: Unless your school has multiple sets of the materials required for this lab, only one student group will be able to work at a time. If that is the case, think of other work your students can be doing before and after the lab.

Materials + Preparation

- Hair dryer (Hardware Box in Box A)
- Digital thermometer (make sure it has a working battery) (Hardware Box in Box A)
- 1.5-pound coffee can (if simulating tree bark) (Hardware Box in Box A)
- Cover outside of can with newspaper
- 1 piece of lightweight fabric, approximately 15 X 30 cm
- 10 pieces of quilt batting, 1/8" to 1/4" thick (Box A)
- Ruler (Hardware Box in Box A)
- Masking tape
- Stopwatch or clock (must show seconds)
- Copies of the "Insulating Power" handout for each student (at end of lesson)

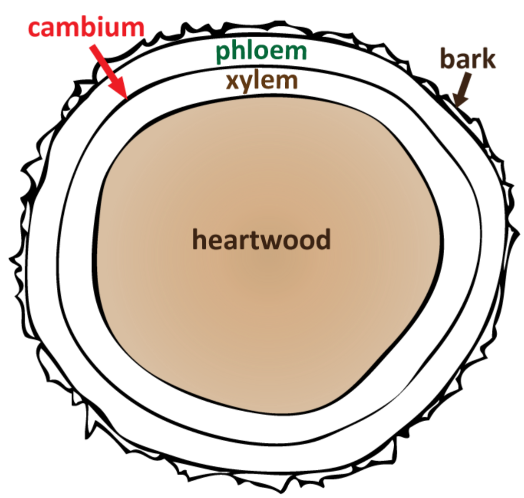
- Set up the first iteration of the experiment (no insulation) as a demonstration. Then have students work in teams of 2 to 4 to do the second (5 layers of insulation) and third (10 layers) iterations. The trunk has only one digital thermometer, so unless you have more of them, you will need to arrange for student teams to take turns completing the experiment.
- Use this activity to model *either* the insulating properties of tree/shrub bark *or* those of soil. After you have studied heat transfer into one material (either bark or soil), they should be able to predict heat transfer into the other material in the last question of the Assessment (see below). The photo and directions here are written for the tree/shrub bark model. If you're modeling the insulating properties of soil, simply measure temperatures on a tabletop instead of in a coffee can (or oatmeal box if a can is not available).



Procedure

1. Ask students how trees, shrubs, and other plants can avoid harm from wildland fires. Explain that this activity explores ways in which living tissues are insulated from the heat of wildland fires.
2. Go over the beginning of the "Insulating Power" handout with the class. Read the experimental questions. Write these terms on the board and explain with an illustration as shown below:
   - **cambium**: a thin layer of living cells beneath the bark that can produce new cells. Cambium produces two kinds of cells:
     - **xylem**: the cells inside the cambium that carry water and dissolved minerals from the ground to the plant's leaves. Most of the cells in the xylem layer are dead, but they are crucial for water transport. *Optional:* Show students the rings of xylem seen in the cross section of a tree trunk and/or branch. Pass these around for students to examine.
     - **phloem**: a thin layer of living cells at the boundary between the cambium and the bark. These cells carry sugars, minerals, and other substances throughout the plant. They are the only kind of cell that can deliver carbohydrates produced in the leaves to other parts of the plant. *Optional:* Show students tree sap on the outside of a tree cross section and/or branch which was transported in the phloem.

Simplified Trunk/Branch Cross Section

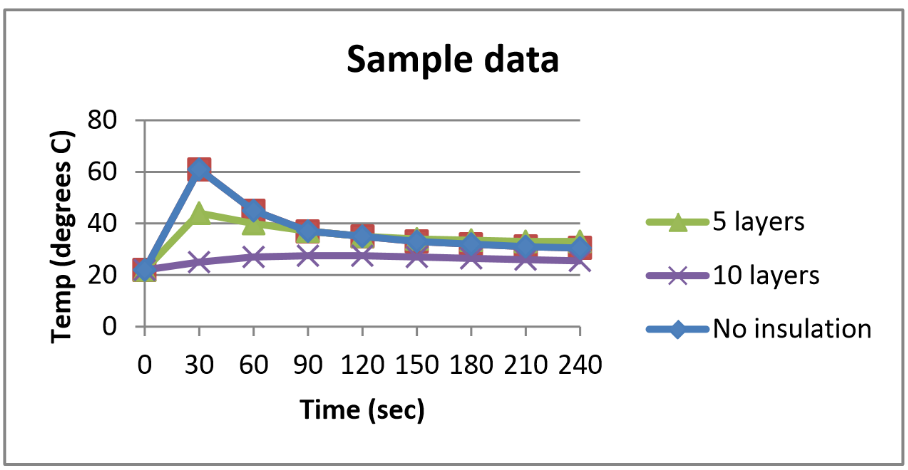


Note: Students can learn more about these layers of cells in lesson 12: "Tree/Shrub Structures and Fire."

3. Decide which question to investigate – insulating effects of tree/shrub bark or soil.
4. Get a team of 3 or 4 students to take on the roles described in the handout. Have them practice the timing of "Heat on" and "Heat off" before actually collecting data.
5. Set up the experiment and follow steps 1 – 7 of the procedures on the handout.
6. Have students graph the data on the handout OR you can graph it with their help on the board, then have them graph it on their handouts.
7. Read and discuss question #9 on the handout: "How do you predict the data may change if you add 5 layers of insulation?" Show how to draw a possible heating/cooling pattern on the graph. For example, show the temperature peaking at a lower level, rising and falling more slowly than it did with no insulation. Explain that their guesses are hypotheses that they will test with the next two experiments.
8. Explain that students will work in teams to get the second and third sets of data (5 and 10 layers of insulation).
9. Arrange the teams and complete the experiment.
10. Discuss the results with the students as a class, and give them the opportunity to revise their answers to the last question about the benefits of bark and soil for insulating trees and shrubs, including their roots and seeds, from the effects of fire.

Assessment

You can assess students on completion of the handout.
A sample of a graph of observed data is shown below.



Evaluation

Handout Question	Excellent	Good	Fair	Poor
#12	• The student clearly compared/contrasted the observed and predicted results. • The student cited specific examples from the data.	• The student contrasted the observed and predicted results. • The student did not cite specific examples from the data.	• The student wrote that the predictions were (or were not) accurate. • The student did not explain why.	• The student did not address the question.
#15	• The student clearly compared/contrasted the observed and predicted results. • The student cited specific examples from their collected data.	• The student contrasted the observed and predicted results. • The student did not cite specific examples from the data.	• The student wrote that the predictions were (or were not) accurate. • The student did not explain why.	• The student did not address the question.
#16 – 17	• The student wrote that bark/soil CAN insulate living tissues from the heat of wildland fire. • The student explained that bark/soil slows the transfer of heat, so the living tissues do not reach damaging temperatures unless the fire lasts a long time.	• The student wrote that bark/soil CAN insulate living tissues from the heat of wildland fire. • The student explained that bark/soil slows the transfer of heat.	• The student wrote that bark/soil CAN insulate living tissues from the heat of wildland fire.	• The student wrote that bark/soil CANNOT insulate a tree's seeds and roots.

Team Names: ________________________________ Period: ____ Date: ____________________

Insulating Power

Here are two experimental questions to investigate in this lab:

- Can bark insulate the cambium of a tree or shrub from fire's heat?
- Can soil insulate seeds and roots from fire's heat?

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

Choose team roles:

- **Timer**: calls out 15-second intervals and "Heat on/off!"
- **Heater**: turns hair dryer on/off
- **Observer**: watches thermometer; calls out temperature
- **Recorder**: writes down temperature observations

Setup

Setup the thermometer so the **observer** can see it.

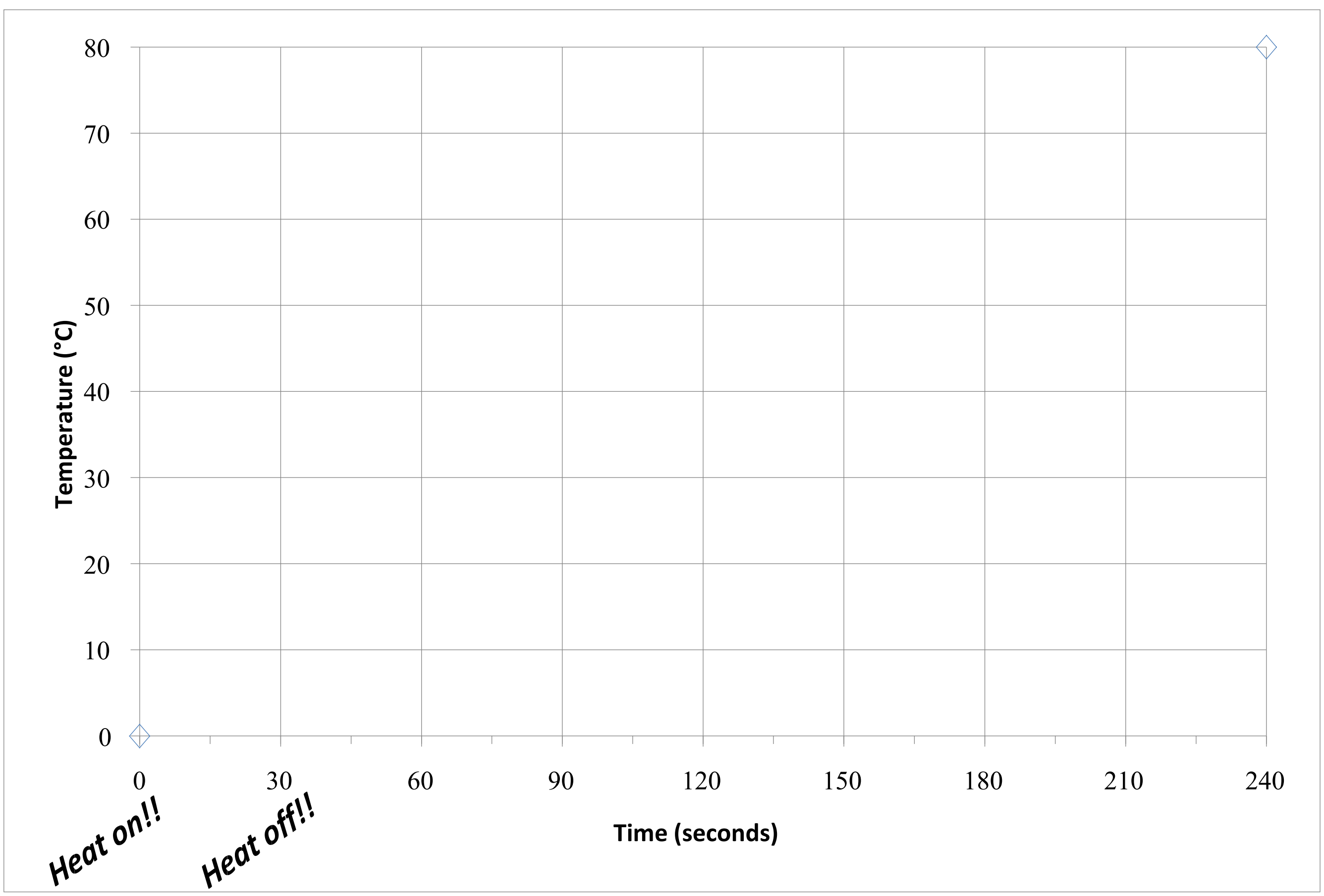
- **For a soil model**: Tape the thermocouple wire to a table top. Lay a thin layer of fabric on top. Do the first experiment with no insulation. Do the next ones with 5 or 10 layers of insulation on top of the fabric.
- **For a tree/shrub model**: Tape the thermocouple wire to the surface of an empty coffee can or oatmeal box. Do the first experiment with no insulation. Do the next ones with 5 or 10 layers of insulation wrapped on top of the fabric.

Procedure

1. The **heater** positions the hair dryer 20 centimeters from the table or coffee can, pointing at the thermocouple top (which you can't actually see because it's under cloth).
2. The **observer** turns the thermometer on. Set it to degrees Celsius. Report the temperature.
3. The **recorder** writes down the temperature at "0" seconds using the appropriate column in the table on the next page for the layers of insulation being tested (0, 5, or 10).
4. The **timer** calls out "Zero, heat on!" and the **heater** turns the hair dryer to "high."
5. The timer calls out "Fifteen" and the **observer** reports the temperature. The **recorder** writes it down in the table.
6. The **timer** calls out "Thirty. Heat off!" The **heater** turns the hair dryer off while the **observer** calls out the temperature and the **recorder** writes it down.

7. Repeat this process every 15 seconds until 4 minutes have passed.
8. Graph your results on the chart below.

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



9. How do you predict the data may change if you add 5 layers of insulation? Record your **hypothesis** below in a complete sentence.

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10. Use a light pencil line to draw the temperature pattern you predict on the graph above. Label the line "**Hyp 5**" to indicate your "hypothesized pattern with 5 layers."
11. Add 5 layers of insulation and repeat the experiment (steps 1 – 7). On the graph above, plot your data and label the line "**Obs 5**" to indicate your "observed pattern with 5 layers."
12. How do the observed results compare with the results you predicted in step 9? Use specific examples from your data and complete sentences to describe how accurate your predictions were.

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13. What do you predict will happen if you add 5 more layers of insulation, for a total of 10 layers? Pencil in a line on the graph to show your hypothesis and label it "**Hyp 10**."
14. Add 5 more layers of insulation and repeat steps 1 – 7. Plot your data and label the line "**Obs 10**" on the graph.
15. How do the observed results compare with the results you predicted? Use specific examples from your data and complete sentences to describe how accurate your predictions were.

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16. Can bark really protect a tree or shrub from fire? Does the thickness of the bark matter? Why or why not?

17. Can soil really protect underground seeds and roots? Why or why not?

Appendix

Glossary

adaptation: a trait of an organism that helps it survive and reproduce; an aspect of its form, function, or behavior that changes over many generations that helps it out-compete other organisms. *Example:* If plants have deep roots, they are more likely to survive and reproduce during dry years. In this way, future generations are more likely to have the adaptation of deep roots, as well.

alternate: leaf pattern in which one leaf grows from each node on alternating sides of the stem

animal: organism that eats or absorbs nutrients from other organisms, which typically has specialized sense organs and can respond quickly to stimuli

annual: a plant that completes its life cycle in one year

bark: the outermost layer of the stems and roots of woody plants (shrubs and trees)

biodiversity: the variety of life in a community, habitat, or ecosystem

biological soil crust: a combination of living organisms including algae, bacteria, lichens, mosses, liverworts, and fungi that grow on or just below the surface of the soil

biology: the study of living things

biome: the world's major ecological communities which cover large areas; examples are sagebrush steppe, desert, forest, and grassland

branch: a stem of a tree or shrub; the main stem of a tree is called the trunk-

bud: the cells that will grow next year's leaves and branches. Located at the tips of branches in trees and shrubs, as well as a tree's top. Similar cells occur at the tips of roots.

Bunchgrass: native grasses most often found in the sagebrush ecosystem that grow in bunches. Like all grasses, they are herbaceous with narrow leaves (blades) and their flowers are hard to see.

cambium: a thin layer of living cells beneath a tree or shrub's bark. The cambium layer produces two kinds of cells: those that carry water and minerals from roots to leaves (xylem), and those that carry sugars and other nutrients from leaves throughout the plant (phloem).

climate: the average weather conditions of a place, such as temperature and rainfall levels, over a long period of time

common name: a name by which a species is known, rather than its scientific name; can vary by region or country, unlike scientific names

community: all the organisms in a habitat, which interact in a complex food web

cone: the part of plants in the conifer family that protects the reproductive structures, such as seeds

contiguous: connected; meeting or joining at the border

controlled burn: a fire set intentionally, with specific vegetation and weather prescriptions, in order to achieve a specific resource objective

controlled experiment: a scientific test (an experiment) in which only one variable at a time is changed and others are held constant so they will not affect the experiment's outcome; this lets researchers isolate the results

crown: the top of a tree, which holds most of its leaves, or the part of a shrub above the ground**.**

crown fire: fire that spreads in the crowns (tops) of trees and shrubs. Crown fires are usually ignited by surface fire. They are common in coniferous forests and shrublands.

decompose: when organic matter (matter that was once living) breaks down

diversity: a variety of different things; the number of different species, communities, or habitats; can also apply to human communities

duff: the layer of soil that is made up of decomposing plant and animal matter. Duff is below litter and above mineral soil. Deep duff can protect a tree or shrub's cambium and roots from fire until it dries out.

ecological community: all of the living things in an area including plants, animals, fungi and microorganisms

ecosystem: a community of organisms (living things such as animals, plants and fung) and nonliving things (such as soil, water, air, sunlight), which interact with one another through a flow of energy and cycling of materials in the environment

fauna: the animal life of an area

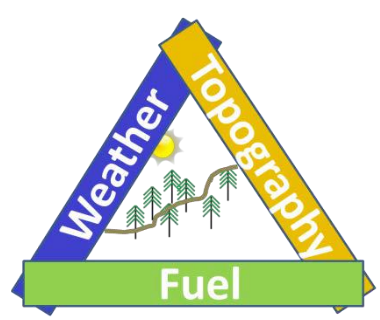
fineness: the quality of being very thin, light, or soft; the finer the fuel, the more quickly it can ignite and allow fire to spread

fire behavior: the manner in which fuel ignites, flames develop, and fire spreads. Fire behavior changes with the interaction of fuels, weather, and topography.

fire suppression: when natural or prescribed burning is not allowed

fire triangle: a model for understanding the three things most fires need to burn: heat, fuel, and oxygen

fire behavior triangle: a diagram (shown to the right) used by fire professionals to describe the complexities of wildland fire behavior; it includes weather, topography of the land, and fuel



flora: the plant life of an area

flower: the reproductive part of some plants; used to help make seeds

fluffiness: the measure of how light, soft, and/or puffed up something is; the more fluffy the fuel, the more quickly it can ignite and allow fire to spread

forage: food available to grazing animals

forb: a non-woody, broad-leaved plant (wildflower)

fuel continuity: the degree or extent of how uninterrupted fuels (vegetation) are, which affects a fire's ability to sustain combustion and spread

fuels reduction: using management techniques such as thinning, brush removal, and controlled burns to reduce the amount of surface fuels and prevent or lessen the severity of wildfires

fuel moisture: the measure of the amount of water in fuels (vegetation), expressed as a percent or fraction of oven-dry weight. (For example, a completely dry fuel has a fuel moisture content of 0%.) Fuel moisture is the most important fuel property controlling flammability.

germinate: when a plant starts to grow from a seed

ground fire: fire that burns fuels under the ground, mostly by smoldering combustion. These fires include duff like peat moss and dead roots.

habitat: the place or type of site where an organism lives

herbaceous: plants that do not have woody stems

heartwood: inner wood of trees and shrubs which gives strength and resists decay. It is often darker than the outer **sapwood**.

hypothesis: a prediction of what might happen in a scientific experiment

insulation: material that absorbs heat slowly and releases it slowly, so it can be used to protect an object from rapid heating or cooling

invasive species: a species, usually nonnative, that spreads and crowds out native species, causing harm to the environment, economy, and/or human health

ladder fuels: shrubs and small trees that fill the space between the forest floor and tree crowns with flammable material, so a fire might be able to “climb the ladder” from surface fuels into the treetops

landscape: the visible expanse of an area of land, made up of physical elements (landforms, water bodies), living elements (dominant flora and fauna), and human elements (buildings, roads, farms)

leaf: flattened, above-ground piece of a plant attached to a stem, which is usually green during the growing season; uses sunlight to make food for the plant through photosynthesis

leaflet: a division of a compound leaf that is similar to a leaf but is attached to a leaf vein instead of the plant’s stem

litter: accumulation of dead plant material on the soil surface

microscopic: so small as to be invisible without a microscope

mineral soil: soil that has no plant or animal matter, so it cannot burn. It can help roots and burrowing animals survive fire.

monoculture: area consisting almost entirely of a single plant species

mutation: a rare change in the DNA of genes that creates genetic diversity

natural selection: the process in which organisms better adapted to their environment survive to produce more offspring

noxious: harmful, poisonous, or very unpleasant

observation: the act of noticing or paying attention using one's senses

opposite: a leaf pattern in which two leaves grow across from each other at the same node on the stem

organic matter: material such as plant leaves or animal waste that was recently part of a living thing; Many organisms such as worms and bacteria can eat it, helping it **decompose**, and it can burn when it is dry.

organism: individual living thing that can react to stimuli, reproduce, and grow

perennial: a plant that lives for more than two growing seasons

phloem: the outer layer of cells produced by a woody plant's cambium. Phloem cells carry sugars and other nutrients from photosynthetic tissue (mainly leaves) to other parts of the plant.

photosynthesis: the process of using energy in sunlight to convert water and carbon dioxide into carbohydrates and oxygen

pioneer species: plant species that grow first in an area without vegetation

resprouting: an adaptation of some plants which lets them regrow from the top of their roots when the part above ground is killed (usually by fire)

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

sagebrush ecosystem: an interconnected community dominated by sagebrush with 350+ species; a landscape with shrubs, grasses, and forbs (wildflowers) with few trees; receives most of its water from snow melt

sagebrush steppe: a shrub community dominated by sagebrush; a landscape with shrubs, grasses, and forbs with few trees which is generally flat and found at higher elevations

sapwood (xylem): layer of hollow wood cells inside the cambium that pumps water from roots to leaves

scientific control: group in an experiment that is not changed so it can be compared with a similar group that is changed

scientific name: the two-part Latin name assigned to a species; system established by botanist Carl Linnaeus in the 1700s

seed: a very tiny, living plant—just waiting to grow—plus a package of nutrients and a protective covering; used by plants to reproduce

seed dormancy: seeds of some plants can remain **dormant** (alive but not **germinating**) for long periods of time until their outside is damaged, causing them to **germinate** (start to grow)

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

shrub: woody plants that are usually smaller than trees and have multiple main stems instead of one large trunk

shrub steppe: a landscape that is a mixture of shrubs, grasses, and forbs with few trees

slope: the measure of how much an area of land rises (its steepness). Fires usually spread more quickly on steep slopes.

soil: fine rock particles mixed with decayed organic matter and tiny living organisms which cover Earth's surface

species: a particular kind of living thing; the populations of organisms whose members interbreed under natural conditions and produce fertile offspring

snag: a dead standing tree, often with a broken top; provides good habitat for wildlife, but also good fuel for fires

stand density: the amount of vegetation in a particular area

standing fuels: any combustible material that is arranged vertically, such as brush, trees, etc.

stem: the part of a plant that supports the leaves and buds

steppe: an area of grass- and/or shrub-covered plains, generally without trees and found at higher elevations. The climate of steppe ecosystems are semiarid and dry.

succession: the process of change in a community. After a severe fire, this is the way succession often works: Grasses and wildflowers may be the most obvious plants for a few years; then shrubs dominate, and finally trees (in forest ecosystems). In sagebrush ecosystems, shrubs can continue to dominate.

surface fire: a fire that burns in the litter, duff, grasses, and wildflowers on the forest floor but does not burn in the crowns of trees. In *FireWorks*, we use the term to describe fires that usually do not kill the mature trees in a forest. (Big sagebrush in the sagebrush ecosystem can also sometimes survive surface fires.)

taproot: a large root that grows straight down and is important for tapping groundwater

trunk: the central stem of a tree

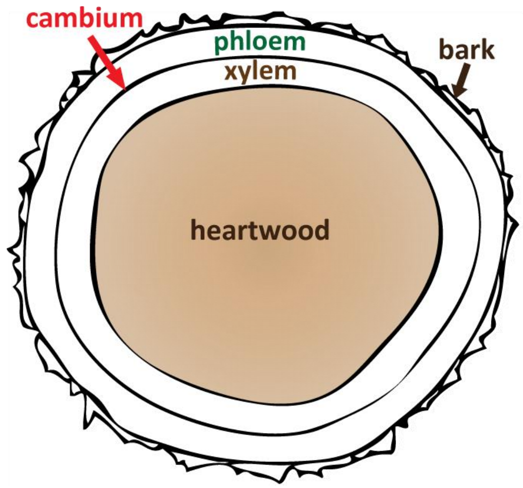
variable: the part of an experiment that changes during the investigation

wildland: an area where the species present and the processes occurring are relatively unchanged from times before settlement by European Americans. Wildlands are often contrasted with agricultural and urban lands.

wildland fire: any fire, other than prescribed fire, occurring in a wildland (large natural area)

xylem: the inner layer of cells produced by a woody plant's cambium, also called sapwood. Xylem cells carry water and nutrients (mainly minerals) from roots to leaves.

Simplified Trunk/Branch Cross Section



Name(s): ____ Date: ______________________

Presentation Rubric

Title: ____

Presentation Component	**Maximum Points Possible**	**Self-Score** (fill out before presentation)	**Teacher Score**
Part 1: Content			
Subject and purpose of presentation clearly introduced	10		
Key concepts identified and clearly explained in well-organized way	10		
Ideas supported by examples, data, graphs, etc.; All information accurate and obtained from reliable sources	10		
Conclusion summarizes key points in persuasive way; Questions answered thoroughly and accurately	10		
Part 2: Delivery / Audience Engagement			
Speech delivered clearly at appropriate volume and speed (not too fast, slow, loud, or soft)	10		
Speed, volume, and voice inflection are varied to engage audience and emphasize key points	10		
Speaker connects with audience through eye contact and does not spend too much time looking at notes or screen	10		
Speaker demonstrates enthusiasm for topic throughout presentation; audience is persuaded by speaker	10		
Part 3: Visuals			
Visuals help to clearly explain concepts	10		
Part 4: Writing Conventions			
Grammatical and spelling conventions followed	10		
TOTALS:	**100**		

Comments:

Youth Permission and Waiver Form

Field Trip/Site Location: ____ Date: ____________________

ALL PARTICIPANTS UNDER THE AGE OF 18 WHO ARE UNESCORTED BY AN ADULT MUST HAVE A PARENT OR GUARDIAN SIGN THIS PERMISSION AND WAIVER FORM. Escorted youth may be included by their parent, guardian or authorized adult on the adult registration and waiver form.

This is a waiver and release. Please read it carefully before signing. I am the parent or legal guardian of Participant named below and I, the undersigned, enter this Release and Waiver of liability and Assumption of Risk Agreement ("Agreement") on behalf of myself, the Participant, my personal representatives, next of kin, heirs, successors, and assigns and anyone else who may make any claim for or on behalf of the Participant.

- I will **cause the Participant to agree and comply** with the terms of the Agreement and not to take any actions that would assist or cause the Participant to invalidate, renounce, negate, revoke, or disclaim any part of the Agreement.
- I make this Agreement for the benefit of partner organizations, other individual volunteers, project coordinators, sponsors, suppliers, supporters, and all private and public land owners on whose property the project described above may be located (collectively the "Released Parties), including, without limitation, the Released Parties' employees, agents, personal representatives, next of kin, heirs, successors and assigns.
- I make this Agreement in consideration of the Released Parties providing Participant with the opportunity to **participate as a volunteer** in this project.
- I understand that the Project may include **dangerous or hazardous** activities and that the Project may take place on a location or under conditions that may be dangerous to Participant.
- Participant and I **accept full personal responsibility** for all risks arising from or relating to this Project.
- Participant's involvement in this Project is **completely voluntary** and neither participant nor I have received nor expect to receive any compensation for participation in it.
- Participant will read, listen to and follow all **safety instructions and procedures** presented in conjunction with this Project and **use best judgment** based upon physical and mental abilities at all times, and to immediately terminate participation in this Project if activities become too strenuous, difficult or hazardous.
- I agree to **waive all liability** of the Released Parties, **discharge them, and covenant not to sue them** for any liability, claims, sums, costs, or other expenses on my account that may be caused in whole or in part by Participant's involvement in the Project.
- I agree that this Agreement shall act as a **complete bar against all actions or claims** that I might otherwise bring against the Released Parties, including negligence claims, arising from or related to this project.
- I have read this Agreement, fully understand its terms, understand that I have **given up substantial rights** by signing it, and have **signed it freely** and without any inducement or assurance of any nature. I intend this Agreement to be a **complete and unconditional release of all liability** to the greatest extent allowed by law, and I further agree that if any portion of this Agreement is held invalid, then the balance of the Agreement shall continue in full force and effect.
- I understand that a photographer may be present to photograph the activities at the Project and that Participant may be photographed while participating in the Project. I agree that Participant will contact the photographer if he or she does not wish to be photographed.
- I hereby grant the irrevocable and unrestricted right to **use and publish photographs of Participant**, or in which Participant may be included. I hereby release Photographer and his/her legal representatives and assigns and partner organizations from all claims and liability relating to any such photographs.

Thank you for filling out the form below and signing to give permission for your student to participate in field work. Please print clearly. We would <u>never</u> sell or trade your information.

Name of Participant						
Name of Parent/Guardian						
Relationship to Participant		**Phone**	-	-	☐ **Home** ☐ **Business**	
Address						
City			**State**		**Zip**	
Age of Participant						
Signature of Parent or Guardian: ______________________________ **Date:** __________________						

Are you able to chaperone? ☐ **YES** ☐ **No** ☐ **Maybe**

If so, please indicate your preferred method(s) of contact.

☐ **Email, using address below** (please write your email address in the boxes below)	☐ **Mail, using address above**	☐ **Phone:**
		☐ **Home** ☐ **Business**

Student Feedback

FireWorks Program

We want your opinion about your experience! Help us find out what was good and bad about the program, and what difference it made for you. There are no right or wrong answers and no one will know your responses.

Please read each statement below and decide if you agree or disagree with the statement.
Put an X in one box in each row.

Statement	Strongly NO	Sort of No	I'm Not Sure	Sort of Yes	Strongly YES
What I did in this program was interesting.					
I think I will remember the things I learned in this program about fire and the sagebrush ecosystem.					
I see some things differently because of this project.					
I care more about fire and what happens to the sagebrush ecosystem after participating in this project than I did before.					
I can see the connection between this program and the other things I am learning in school.					
I might volunteer to help the sagebrush ecosystem.					
I might like to enter a career dealing with the land or conservation because of this program.					

Do you have any suggestions or comments about this program?

THANK YOU—Your input helps a lot!