

From Ponderosa to Prickly Pear

**Exploring the
Native Plants
of New Mexico**

**An ecoregional
curriculum for
grades 9-12**



**Institute
for
Applied
Ecology**

From Ponderosa to Prickly Pear:

Exploring the Native Plants of New Mexico

• An ecoregional curriculum for grades 9-12 •

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From Ponderosa to Prickly Pear: Exploring the Native Plants of New Mexico

• An ecoregional curriculum for grades 9-12 •

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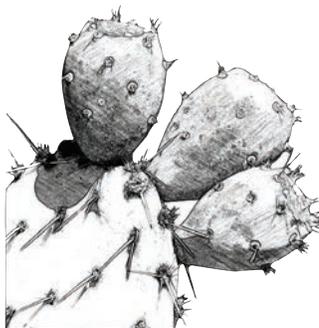
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About Institute for Applied Ecology

Founded in 1999, the Institute for Applied Ecology (IAE) is a non-profit organization established to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems and effective management strategies. IAE offers habitat restoration services complete with habitat management plans, site preparation, maintenance and monitoring. Our Native Seed Network connects buyers and sellers of native seed while our Conservation and Research division conducts native ecosystem research and monitoring and provides surveys for rare plants. The Ecological Education Program provides opportunities for K-12 students, teachers and the adult community in place-based education and service learning projects.

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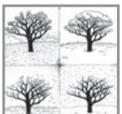
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Introduction

Getting Started

The Institute for Applied Ecology (IAE) is a non-profit organization with the mission to conserve native ecosystems through restoration, research and education.

In 2011, IAE published a native plant curriculum for the state of Oregon, "From Salmonberry to Sagebrush: Exploring Oregon's Native Plants." Due to the success of the Oregon curriculum, IAE has been provided the opportunity to develop native plant curricula for several other states, including New Mexico, using the Oregon curriculum model. Each of these curricula are intended to provide place-based learning for high school-aged students to improve their understanding and appreciation of their local flora and native plant conservation. While most of the lessons are intended for students at the high school level, a number of lessons have been successfully applied in junior high and college level classes.

The curriculum template was developed working with students through our in-school programs to meet a need for science based lessons focused on native plants. The goal is to introduce students to the phenomenal biodiversity of flora, and the connections between plants and their ecosystems. The lessons encourage students to study what is outside their door, or if adventuresome, learn about plants across the state. Along with the knowledge gained through these lessons, students will gain the skills to be informed and active citizens in local natural area issues and decisions in their future.

The native plant curriculum for New Mexico "From Ponderosa to Prickly Pear: Exploring New Mexico's Native Plants" emphasizes the flora, ecology, landscape management, and cultural plant relationships unique to New Mexico and the Southwest. The project overall has had expert guidance and insight from more than thirty advisors including teachers, students, science curriculum developers, natural resource agency, educators, artists, and field scientists. Subject matter specialists and science educators in New Mexico provided additional critical review of content. Much of the subject matter and organization of the curriculum comes from their collective suggestions.

Development of the lessons followed the principles of North America Association of Environmental Educators (NAAEE) Guidelines for Excellence incorporating fairness & accuracy, depth, emphasis on skills building, action orientation, instructional soundness, and usability. The overall curriculum goal is to lead students in the exploration and wonder of New Mexico's plant life. It is not intended to teach general skills such as photosynthesis, plant growth, evolution, and natural selection that high school students receive in biology class. Explore and enjoy!

Introduction

Our guiding principles:

- 1. Place-based:** The local community is the starting point for teaching concepts in science and culture; students learn about where they live
- 2. Hands-on:** Students actively use all of their senses to explore nature, stewardship, and science
- 3. Inquiry-based:** Students learn science by asking and answering questions as a guide to discovering the world around them
- 4. Experiential:** Students don't just learn, they DO
- 5. Service-learning:** Learning activities directly benefit community, motivating students by giving extrinsic value to their work
- 6. Education Standards:** Aligned with New Mexico Educational Content Standards with Benchmarks and Performance Standards for Science, English Language Arts, Mathematics and Social Studies and incorporates service learning methods. New Mexico Standards can be found at <http://www.ped.state.nm.us/standards/>
- 7. Fosters community partnerships:** Students forge relationships with peers and professionals by taking part in their community
- 8. Interdisciplinary:** Curriculum pieces integrate across disciplines teaching about native plants through science, math, social studies, art, and literacy
- 9. Developed within the framework of the NAAEE Guidelines for Excellence:** Fairness and accuracy, depth, emphasis on skills building, action orientation, instructional soundness, and usability



Introduction

Organization of Curriculum:

Lessons progress from basic plant identification into more advanced topics; the curriculum is designed to be a complete unit of study. We also understand that many teachers are unable to commit to the entire unit of study, so lessons can also be used individually. All lessons start with a Teacher Page; check there for the Teachers Hints section to find any essential skills or background needed from earlier lessons. Background information, study topics and curricula are included with each of the lessons for study.

Student pages are written for the students to be self-guided in their studies. What better way for them to practice their literacy skills than to read, interpret, and follow written directions.

As the teacher, you will need to be familiar with the background information and reflection activities found on the student pages.

Of course as the teacher, you maintain the control to use this student directed learning feature as it works best in your classroom.

All lesson data or work sheets provided will follow the Student Pages. Occasionally lessons will ask students to create their own data collection sheet. Lessons suggest ways to integrate student studies into service-learning and community projects.

References: Superscript numbers within the text link to references provided at the end of the document. References are organized by chapter and numbering starts at the beginning for every chapter. In addition to citations provided in the References, the Glossary has its own list of citations for definitions used (called Glossary Endnotes). Glossary Endnotes are provided at the end of the Glossary.

Anatomy of a Lesson

Planning: Time estimate and best season for the lesson

Time Estimate
60 minutes in the classroom

Best Season

	Fall
	Spring
	Summer

Teacher Hints: how to prepare the lesson successfully and other useful resources

Teacher hints

- This activity is a good introduction to plant studies because it highlights specialized terminology that might be useful in attempting to describe plants and that a system for identifying plants would be handy.
- If possible, choose plants with unique features to help students identify differences from one plant to the next.

Vocabulary: help familiarize students with language associated with the lesson

Vocabulary

herbarium
herbaria

Overview

This activity awakens basic plant observation skills as students examine and describe plants collected by the teacher. Students have fun making up descriptive common names for their species and getting up close and personal with their species to make a great description. Students present their species to their class.

Preparation

1. Prepare bouquets of wild plant species (native or non-native) from your area. You will need one bouquet for each group of students. Each bouquet needs to be made up of the same plants and contain one plant for each person in the group. Consider choosing plants from different families (refer to the Plant Family Chart in the "Plants Have Families Too" section for examples).
2. Divide the class into groups (adapt to fit your classroom making groups of 3-5 students) and give each group one of the bouquets.
3. Hand the students a hand lens or magnifying glass and instruct them to use it to get intimate with their plant.

Learning Objectives

1. Learn and demonstrate proper techniques for collection, drying, preserving, and cataloging plant specimens
2. Contribute to a classroom herbarium with a usable system of organization
3. Use botanical terminology as well as common and Latin names to correctly describe a plant specimen (review)
4. Practice plant identification skills (review)

Overview: General description of lesson plan

Preparation: simple instructions on how to plan ahead

Learning Objectives: students appreciate knowing expectations

Class Discussion: Suggestions and leading questions for class conversation

Student Directions

1. Assemble a personal plant press. You will need 5-6 pieces of heavy cardboard, several sections of newspaper, and 4 long, heavy rubber bands. Cut the cardboard pieces to the size of a folded newspaper. Use newspaper as your blotter paper to position your plant specimen, plus use additional layers of newspaper between each specimen to help absorb moisture. Use an 8 1/2 x 11 sheet of paper as a size guide; your finished specimen will be mounted on this size paper.
2. Make a weed collection from your home, roadside or vacant lot (follow the steps below). Collect 4-5 different weed specimens. Do not collect from parks, natural areas, or personal property without the owner's consent. BE RESPONSIBLE; do not spread weeds. Be sure to contain any seeds that may fall off your collections and dispose of extra weedy materials that you bring back to the classroom in the trash.

CLASS DISCUSSION

How does human activity impact your ecoregion now? How do you expect it to change in the next 10 years? The next 50 years? Include both negative impacts and positive impacts.

Reflection: exercises prompt students to think about, reflect on, and apply the concepts they have learned

Reflection

What sets your ecoregion apart from the others around it? What makes it a special place? Think about what you like about the different seasons: winter, spring, summer and fall. Are there things that you enjoy doing outdoors that are enhanced by or only possible in your ecoregion? Do you have a special place that you like to visit? Describe it. If you don't have a particular special place, think about characteristics that would make an outdoor place special to you—describe it.



Assessments: allows students to test their own understanding

Self Assessment

- 1 Name and describe one native and one invasive plant species found in your ecoregion.
- 2 Name and locate one (or more) natural areas in your ecoregion.



In the Field

Go on a field trip or go on your own time to a natural area in your own level III ecoregion. Bring a hand lens and your field journal. Find and observe several samples of different native plant species and take careful notes about each in your field journal. Use your knowledge of plant adaptations to explain how each species is adapted to your ecoregion. Where else might these species thrive? What factors do you think limit the range of each species?



EARLY FINISHERS

Design an experiment that will test control methods for an invasive plant species that is a problem in your area. Start by brainstorming possible ways to limit the further spread of the plant. Think outside the box to create new, more effective, environmentally friendly methods that could be used for control. Narrow your ideas to ones that you can test. Write a proposal and submit it to your teacher.

Directions: written step by step with the students in mind

In the Field: provides opportunities for students to apply learning out in nature

Early Finishers: enrichment or extension activities engage motivated students

Making the Most of this Curriculum

1. Create a student field journal at the beginning of the study.

Encourage students to use them throughout the course of study. Allow time for students to observe, explore, and document their discoveries in their field journals each time you take them outdoors. Over time their journal will become a handy reference for them to check back to when they are in the field. You will find the “In the Field” sections often reference journals. In addition, the journal can be used throughout the curriculum as an assessment tool and portfolio. See the activity Field Journaling; Observations from a Special Spot to get you started.

2. Purchase field guides specifically written for your ecoregion.

Check Appendix I for our recommended list of guides for your ecoregion. Field guides are an essential part of becoming familiar with local plant identification. Several of the lessons reference students using these field guides. Ideally your classroom will have one available for each pair of students. Grants are available to purchase field study equipment, including field guides. Challenge a group of your students to write a grant; this is good experience for the students and gives them buy-in on future projects. It would be very helpful to order the free Ecoregions of New Mexico pamphlet handout from the EPA. This pamphlet, a valuable resource especially for the ecoregion section, may be ordered by contacting the principal investigator at the EPA at <https://www.epa.gov>.

3. Plan ahead to take advantage of outdoor, hands-on learning opportunities.

Many of the activities lessons are outdoors-based. While many of these hands-on outdoor activities can be done in the schoolyard or an

empty lot, we believe it is a hugely beneficial experience for students to discover and explore a natural area. Some schools are lucky enough to be within walking distance of a wetland or other natural area, but many may need to take a field trip to incorporate this type of experience. If this is the case, plan ahead for lessons that would best be done at a natural area (for example, the Ecosystem Comparison lesson or the Measuring and Monitoring Plant Populations lesson). Buses may need to be ordered, schedules arranged, permission slips signed, and permission may need to be requested from whomever owns or manages the natural area you plan to visit. We recommend always being in touch with the manager of the natural area before visiting, as they may be able to provide valuable information or even meet your class there to provide a tour and answer questions.

4. Make community connections.

The best sources of knowledge about your specific area comes from those who live and work there. Reach out to local or regional groups including: conservation organizations; government land management agencies; watershed districts; soil and water conservation districts; the New Mexico Native Plant Society, land trusts; city, county, or national parks departments; colleges and university extension services. Contacts from these groups can provide a variety of assistance to your class, from recommending resources to helping to guide a native plant garden or restoration project. It is invaluable to have a go-to contact to answer questions and provide guidance as you teach about native plants.

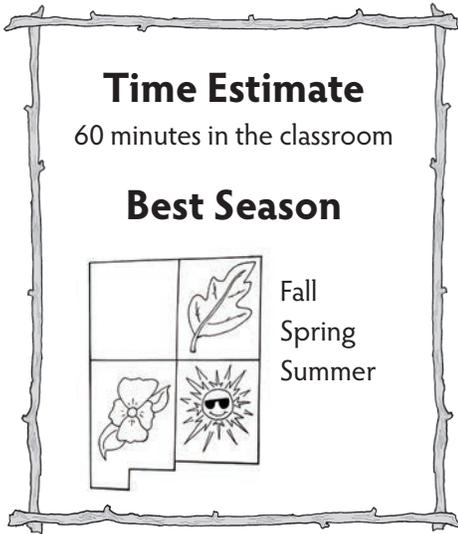
Section 1:
**Plant
Identification**





Botany Bouquet

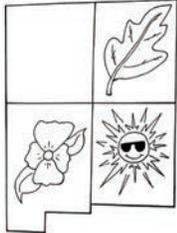
"You can observe a lot by just watching." -*Yogi Berra*



Time Estimate

60 minutes in the classroom

Best Season



Fall
Spring
Summer

Teacher hints

- This activity is a good introduction to plant studies because it highlights specialized terminology that might be useful in attempting to describe plants and that a system for identifying plants would be handy.
- If possible, choose plants with unique features to help students identify differences from one plant to the next.
- This activity also works as an "ice-breaker" among a group of students who do not know each other.



Overview

This activity awakens basic plant observation skills as students examine and describe plants collected by the teacher. Students have fun making up descriptive common names for their species and getting up close and personal with their species to make a great description. Students present their species to their class. The activity is followed by a discussion on the usefulness of a language of plant terminology to help with plant description.

Preparation

1. Prepare bouquets of wild plant species (native or non-native) from your area. You will need one bouquet for each group of students. Each bouquet needs to be made up of the same plants and contain one plant for each person in the group. Consider choosing plants from different families (refer to the Plant Family Chart in the "Plants Have Families, Too" section for examples).
2. Divide the class into groups (adapt to fit your classroom making groups of 3-5 students) and give each group one of the bouquets.
3. Hand the students a hand lens or magnifying glass and instruct them to use it to get intimate with their plant.
4. If you can, be prepared with the common and scientific name and description of the plants used in the bouquet for sharing at the end of this activity. You can ask experts or use field guides such as those listed in the Resources Section at the end of each lesson. Add an additional ecological or human use for each plant to make it memorable.

Assessments

- 1 Look for detail in group description of the plant, and names that are creative.
- 2 Did students make observations about every visible part of the plant?
- 3 Did the students make any creative interpretations about parts of the plants they cannot see or about the habitat, pollination method, or uses?



Botany Bouquet

"You can observe a lot by just watching." -Yogi Berra

Materials Needed

- Sample plant cuttings that are representative of the wild plants in or around your school grounds
- Hand lenses or magnifying glasses
- Several plant identification/field guides; See Appendix I: *Field Guide Recommendations*

Overview

Explore the usefulness of common plant language. Use your observational skills to examine and describe plants by getting up close and personal. Give your plants a made up name using their plant characteristics to guide you. Then share your new plant with your classmates.

Learning Objectives

1. Develop and use botanical observational skills
2. Examine different plants and compare how they differ structurally from one another
3. Increase understanding of plant diversity

Background

How can you tell one type of plant from another? **Botany** is the scientific study of plants. If you were a trained botanist (a person who studies plants) you would have the skills needed to identify plants through descriptions, keys, botanical drawings or photographs, and habitat knowledge. The first step for you to obtain these skills is to develop your powers of observation.

Observation is the act of noticing. Observational skills are very important in all fields of science and in all aspects of life. In this activity we are going to stretch our plant observational skills, using them to differentiate between local plants. Carefully examine the plant you have been given. Use your hand lens or magnifying glass to observe fine details. Notice not only the flower color, but the size and numbers of different parts. Are there other colors inside the flowers aside from the color of the petals? Do you see hairs on your plants? If so, where? When observing the leaf, compare the top and bottom. Look at the shape, number, and edges of your leaves. In addition to using your eyes for your observations, use touch and smell. Feel the texture of your leaves and stems. Crush the leaf tip and smell it. However, please do not taste your plant! Since you do not know its identification and natural history, you don't know if it may be poisonous. Once you are an adept botanist, the world of edible wild plants will be more accessible to you.

Use your observations to write a description of your plant. Draw your plant. Describe your plant with enough detail that someone could pick it out of a field of hundreds of other plants. Lastly, choose a name for your plant that will help describe something about its appearance or natural history. When you observe plants closely you will begin to notice how different they

Vocabulary

botany





Botany Bouquet

are. Scientists estimate there are over 300,000 species of plants in the world. The United States has around 19,000 known native plant species. New Mexico has 3,614 known native plant species.¹ This does not include landscape plants from other parts of the world, agriculture plants developed for food use, or invasive plants that were accidentally or purposely introduced to the country. The term native plant is usually used to describe a plant that naturally grew in its current habitat prior to European settlement.

As you work through this activity, you will get a better understanding of the need for a system of sorting and naming plants. It is not necessary for you to know the name of your plant. If you do know the name, keep it to yourself until the very end of the activity when you can share it with your classmates. For now, examine your plant as if you are a pioneering botanist who has never seen it before.

Student Directions

1. Form a group of 3-5 students. Each group should have a bouquet of flowers of the same species. Each student should take one plant from the bouquet to examine.
2. Take 3 minutes to look at your plant closely and give your plant a descriptive name (for example: wooly, tough-stemmed daisy).
3. Use your hand lens or magnifying glass as well as all your senses (except taste) to get to know your plant. Take turns pointing out your observations to others in your small group.
4. As a group, come up with a creative name for your plant based on your close observations. Then designate one student to write a description you come up with as a group. Make your description detailed so a stranger could pick out your plant from a field of many plants. Be sure to describe all the parts of the plant if they are present including: roots, leaves, stem, flowers, fruits, and seeds.
5. If you have time, flip through a field guide and try to find the real name of your plant. Look at the description and see if you can learn something about the uses of your plants or something you did not notice in your observations. What kind of habitat does your plant live in?
6. Present the name and description of your plant to the rest of the class. Hold up your plant and pass it around to other students so they can examine your plant.
7. If your group knows the real common and scientific name of your plant, you can share it now with the class (you do not need to know this piece of information).
8. If your small group does not know the name, ask the class if anyone knows it. Your teacher can help with this if needed.

CLASS DISCUSSION

Explore the need for botanical terminology:

1. Did anyone have trouble describing any part of their plants for lack of a word to describe what they were observing? What parts of the plants were hard to describe?
2. Did the class understand the small group presentations? Is there anything else they would have liked to know about the plants they saw?
3. Discuss the need for a common plant vocabulary that all can understand.
4. Would it be helpful to have another way to identify plants other than flipping through the pages of a field guide?
5. Do you have any ideas of another way to identify plants?
6. Do you think any of the plants from the bouquet are closely related to one another? What makes you think that? (Point out similarities on the plants).
7. Based on your observations, do you think any of the plants perform similar functions? For example, perhaps there were two sticky plants, and both sticky plants might deter insects and other creatures from eating them.



Botany Bouquet

Reflection

Write a short story or poem that describes your plant, its characteristics, human and/or wildlife uses, adaptations related to habitat, and the root words of the plant's scientific name.



Self Assessment



- 1 Look for detail in group description of the plant, and names that are creative.
- 2 Did you make observations about every visible part of the plant?
- 3 Did you make any creative interpretations about parts of the plants you cannot see or about the habitat, pollination method, or uses?

EARLY FINISHERS

Repeat the activity with other plants from the bouquet. Research a plant species; describe its characteristics, habitat where the species is most likely to be found, and common human uses.



Resources

- Global Strategy for Plant Conservation: <http://www.bgci.org/worldwide/gspc/>
- Ivey, Robert D. (2003) *Flowering Plants of New Mexico*. RD and Ivey Publishers.
- Littlefield, Larry J. and Pearl M. Burns. (2015) *Wildflowers of the Northern and Central Mountains of New Mexico: Sangre de Cristo, Jemez, Sandia, and Manzano*.



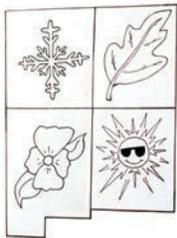
Botanical Terms Challenge

"Learn a new language and get a new soul." -Czech Proverb

Time Estimate

60 minutes with additional time required for the crossword puzzle and In the Field!

Best Season



Winter
Fall
Spring
Summer

Overview

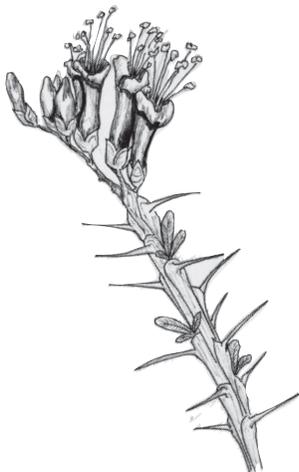
In this lesson students will study basic and advanced botanical vocabulary and create a Botanical Terms Self-Study Sheet. This activity will introduce students to plant anatomy and function and ease plant identification and lead to a better understanding of plant biology. Students can test their knowledge by completing the crossword puzzle.

Preparation

1. Some students may have learned these terms in grades K-8 while others may be learning them for the first time. The words learned in this section are used throughout the curriculum. Student will create a Botanical Terms Self-Study Sheet to supplement the illustrations following this chapter and familiarize themselves with botanical terminology. The crossword included in this lesson is designed to practice this new terminology.
2. Assemble sufficient references for student teams to work on definitions independently. Field guides, the next chapter "The Secret Life of Flowers" the curriculum glossary, internet resources, and biology/botany textbooks listed in the "Resources" section are good options. Discuss how to determine if a source of information is reliable, especially if students are using the internet.
3. For the "In the Field!" section, collect twigs with more than one leaf to show twig attachment patterns. (Be sure students are aware of - poison ivy, poison sumac, poison hemlock, stinging nettle, or other plants that cause rashes.) Each team should use a different species and label them with a number.

Teacher hints

- Supplement the student's field journals with vocabulary words from this lesson for a handy reference on field trips and during outdoor activities.



Assessments

- 1 Give students a stem with leaves, flowers, or fruits attached and ask them write a description using at least 4 new vocabulary words.
- 2 Have students sketch a whole plant or a plant part of a particular species from only a written description from a field guide.



*Student
Project*

Botanical Terms Challenge

Botanical Terms Challenge

Crossword Answers Teacher Key

Across

1. cordate
3. opposite
5. rhizome
6. sessile
7. ovary
12. pinnate
13. node
14. filament
16. bulb
17. lobed
22. stigma
24. palmate
25. receptacle
26. leaflet
30. inflorescence
34. taproot
35. corolla
38. solitary
39. umbel
41. ovule
42. panicle
45. spike

Down

1. composite
2. lanceolate
4. vein
8. root
9. petiole
10. sepal
11. indehiscent
12. pistil
15. dehiscent
18. style
19. bract
20. basal
21. whorled
22. stamen
23. margin
27. entire
28. anther
29. stem
31. flower
32. ovate
33. simple
35. compound
36. alternate
37. bud
40. leaf
43. calyx
44. fibrous



Botanical Terms Challenge

"Learn a new language and get a new soul." -*Czech Proverb*

Materials Needed

colored pencils for drawings
(optional)
field journal

Overview

In this lesson you will study basic and advanced botanical vocabulary and create a Botanical Terms Self-Study Sheet. This activity will introduce you to plant anatomy and function and lead to a better understanding of plant biology. Test your knowledge by completing the crossword puzzle.

Vocabulary

Basic plant anatomy:

root	leaf margin
rhizome	bud
bulb	flower
fibrous root	fruit
taproot	seed
stem	node
vein	internode
petiole	spine
axil	

Leaf types & patterns:

simple	lobed
compound	entire
opposite	sessile
alternate	leaflet
whorled	cordate
basal	lanceolate
palmate	ovate
pinnate	

Basic flower and fruit parts:

sepal	ovule
petal	corolla
tepal	calyx
bract	bract
pistil	indehiscent
ovary	dehiscent
carpel	inflorescence
style	solitary
stigma	composite
peduncle	spike
stamen	umbel
filament	panicle
anther	
receptacle	

Learning Objectives

1. Understand basic botanical terminology
2. Increase botanical vocabulary to assist with describing and identifying plants
3. Relate plant structure to function

Background

One of the most formidable tasks of the aspiring botanist is to learn the vast terminology required to use a typical plant identification guide. Botanists love to make up new words that are rarely used outside of the world of botany. The experience of trying to properly identify a plant without a working botanical vocabulary can be challenging and frustrating for the beginning plant lover. The purpose of this lesson is to teach you basic botanical terms and introduce some more complicated terminology.

Botanists commonly use several different words to describe similar things. For example, if a plant has hair on its leaves, there are several possible words that you may use to describe the type of hair you see. A leaf that is tomentose has dense short, woolly hairs; a leaf that is pubescent has short, soft hairs; and a scabrous leaf is rough to the touch, resulting from the presence of stiff short hairs. And the list goes on and on. One might question the need to differentiate between types of hair. The easy answer to this is that different hairs serve different functions. For example, tomentose leaves are nearly white in appearance making them able to reflect solar radiation in high light environments so they do not burn. Scabrous leaves may serve to deter insect predators and herbivores. The leaves of plants such as cacti, ocotillo, and barberry are modified as spines. The reduction of leaf surface reduces water loss and also may deter predators. When you are learning these new terms, try to think a bit about how the form you are learning about may serve a useful function to the survival of a plant.

Often, botanical terms can be best described with a simple illustration rather than words. Utilize the websites and books listed in the "Resources" section to find pictures of the words in your vocabulary list.

It is important that everyone in your group develop a similar basic foundation in plant anatomy and terminology. This activity is self-guided; you can proceed at your own speed, or you may choose to work with a partner. Your goal should be to become familiar with all the terms listed in this activity.



Botanical Terms Challenge

Student Directions

Part 1: Botanical Terms Self-Study Sheet (used to build new vocabulary)

1. Work individually or in pairs.
2. Complete vocabulary sheets by writing one new word in the box. In the appropriate columns, write a definition and the botanical reference. The botanical reference should be a reference to the function of the plant part or something else about the word that will help you to remember it. Fold your paper to cover all but the word column; this will line up a drawing box on the back of the sheet with each word. In this box, draw a simple illustration of the vocabulary word. Use field guide glossaries, textbooks, or internet sources to complete the definition and function boxes.

3. Use your completed sheet to test yourself. Fold the paper so that the vocabulary word and drawing are visible. Can you give a definition and function for this plant part? If you need a clue, uncover the botanical reference column. Check your answer by uncovering the written definition.

Part 2: Crossword (use for terminology review)

1. Work individually or in pairs to complete the Botanical Terminology crossword. The words in this puzzle are basic terms that you will need in future lessons. Use your new Botanical Terms Self-Study Sheet, the glossary, field guides, textbooks, or internet sources to complete your crossword.

In the Field

Each team should collect a plant with leaves attached and attach a number label to it. Be sure each team works with a different species.

1. Use unlined paper and fold it in half width-wise to make 2 – 5.5" x 8.5" sections. Record team member names and your plant's number on the back of your paper.
2. On one half of the front of your paper, sketch your twig and leaves showing important details. Be sure to show the leaf attachment, shape, margin, and anything that would help others to identify your plant. If you have them, use a magnifying glass or a hand lens to look closely at the hairs and textures on the leaves and stem of your plant.
3. On the other half of the front of your paper, write a detailed description of your plant. Make sure the description matches your drawing and is as complete as possible. Use terminology from the vocabulary list.
4. Collect the twigs and description papers. Display the twigs with the numbers visible so that teams can rotate around to view them. Fold the description papers in half. Shuffle and hand out the description papers to the teams with the description side visible and the drawing hidden. Try to use only the written description, not the drawing, to make the match. Try to match the written descriptions on the paper to one of the numbered twigs.
5. Assess your description. Did it make matching the twigs easier or more difficult? If some of the twigs were similar, how much detail is needed to make a correct match? What else could you have included that could have made matching easier? Would measurements help?

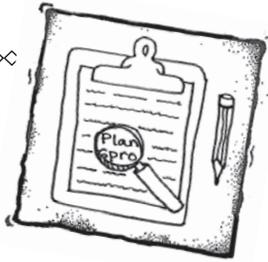




Botanical Terms Challenge

Reflection

Make a journal entry about leaf shapes or margins. Make a sketch or leaf rubbing of two leaves that have different shapes. Why do you think leaves come in so many different shapes and with so many different types of margins? Put on your analytical hat and brainstorm. How might those differences benefit the plant?



EARLY FINISHERS

- For each of the following growing conditions, make a list in your field journal of the leaf characteristics that you think would help a plant thrive in the following conditions: windy, very dry, very wet, low light (shade), and high light (full sun). Keep your list for testing in future lessons.
- As you explore different habitats, take note of the leaf characteristics. Do leaves in a sunny meadow tend to look different than the leaves that you find near the heavily shaded forest floor? How might those leaf characteristics help the plant thrive in that particular habitat?



Self Assessment

- 1 Examine a plant specimen. Write a thorough description using the vocabulary words in this lesson. Your description should include the shape and arrangement of the leaves, flowers, and fruits as well as any other key characteristics that would help someone identify the plant you are describing.
- 2 Use your Botanical Terms Self-Study sheet to quiz yourself. Keep your sheet and refer to it throughout your study.
- 3 Work with a partner. One partner will read a plant description from a field guide aloud. The other partner will sketch the plant from the written description only. The reader will need to give detailed and complete descriptions.

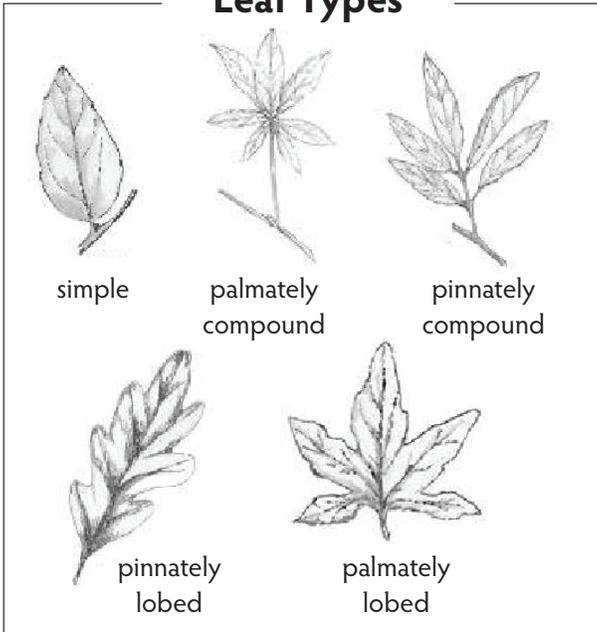
Resources

- Harris, James G. and Melinda Woolf. 2001. *Plant Identification Terminology: An Illustrated Glossary*. Spring Lake Publishing, Spring Lake Utah.
- Beentje, Henk. 2010. *The Kew Plant Glossary: An Illustrated Dictionary of Plant Terms*. x + 160 pp. ISBN-13: 978-1-84246-422-9 (pbk.). Royal Botanic Gardens Kew, U.K.
- Botanical terminology and definitions: <http://www.calflora.net/botanicalnames/botanicalterms.html>. Most field guides contain glossaries or introductory sections for plant terminology. Ivey, Robert D. 2003. *Flowering Plants of New Mexico*, RD and Ivey Publishers. An internet search on plant identification terminology could be very helpful.
- A discussion of leaf form and function; includes possible journaling topics: <http://www.learner.org/jnorth/tm/tulips/FormFunction.html>.

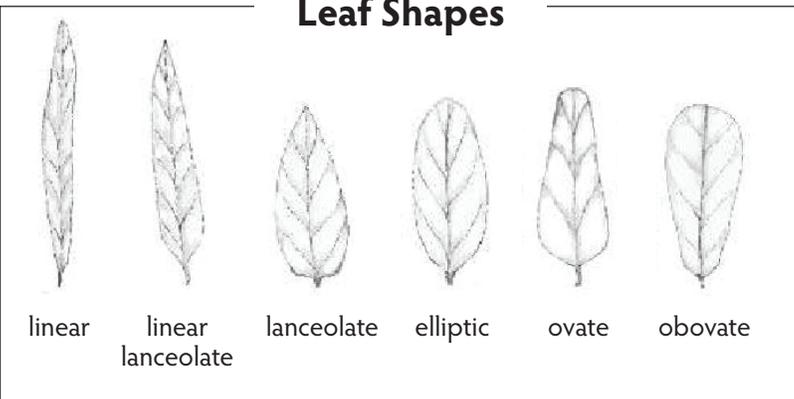


Botanical Terms Challenge

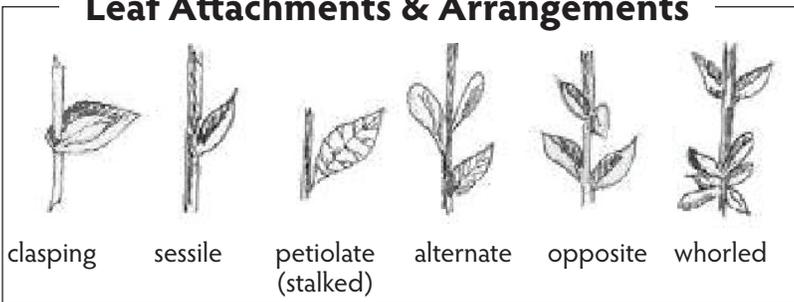
Leaf Types



Leaf Shapes

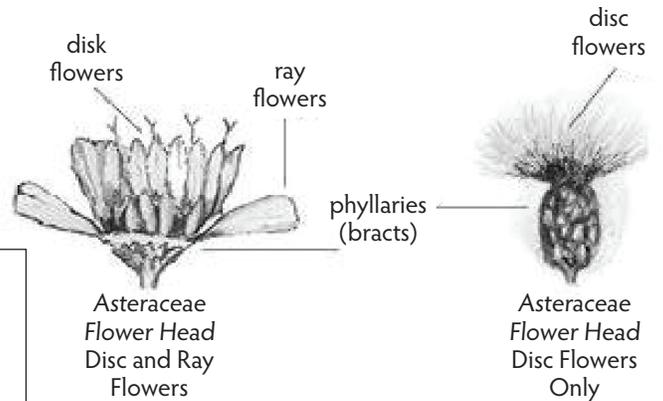
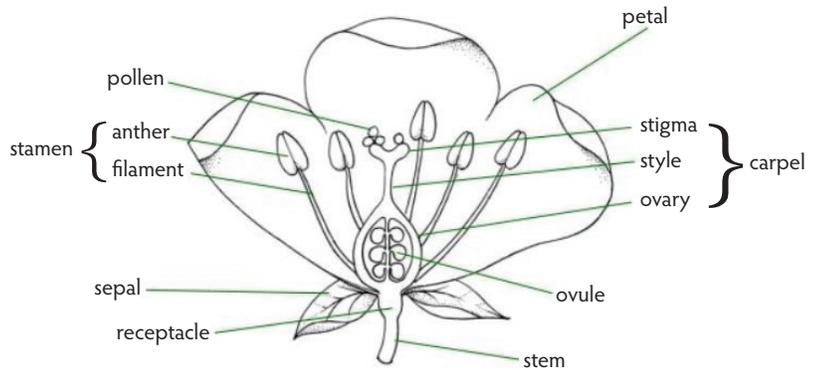


Leaf Attachments & Arrangements

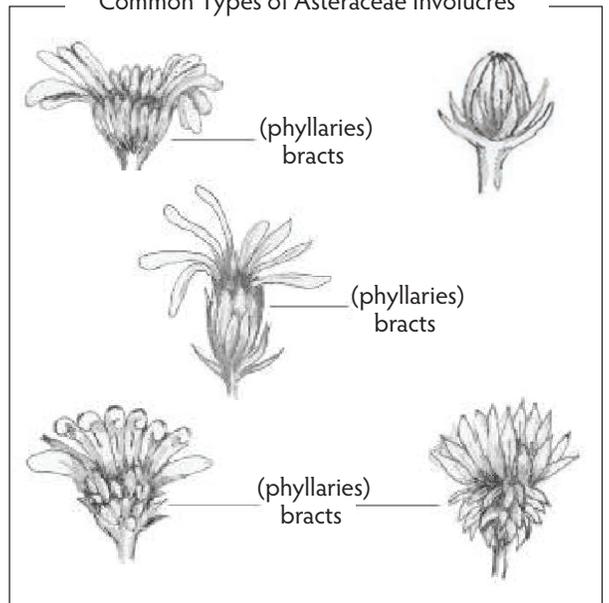


Above illustrations (not including Parts of a Perfect Flower) done by Adair Peterson taken from *Wildflowers of the Northern and Central Mountains of New Mexico* by Littleton and Burns

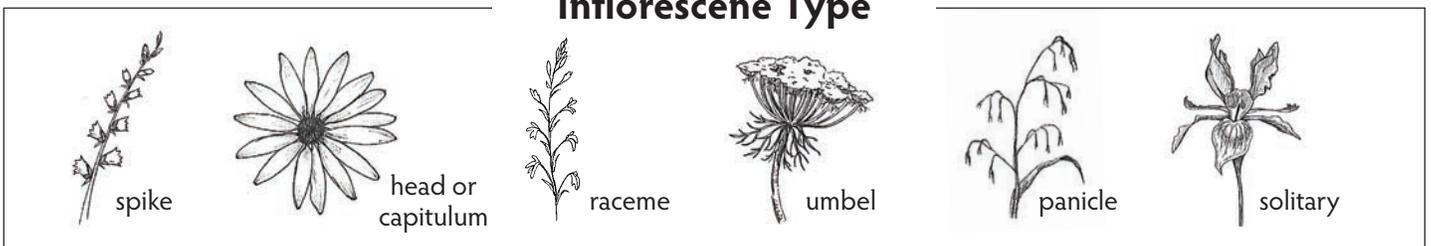
Parts of a Perfect Flower



Common Types of Asteraceae Involucres



Inflorescence Type





*Student
Project*

Botanical Terms Challenge

Picture



Botanical Terms Challenge

Across

1. Heart-shaped
3. Two leaves growing directly across from each other on a stem
5. Underground stem
6. Without stem, stalk, or petiole
7. Enlarged base of the pistil; contains developing seed
12. Leaflets or veins arranged on each side of a common stalk
13. Small swelling or knob where new growth originates
14. Thread-like stalk that supports the anther
16. A rounded, modified, underground stem for storage, not a root
17. Leaves with wavy, rounded margins
22. Portion of pistil receptive to pollen
24. Leaf that is divided from a central point into lobes
25. Structure atop the stem where flower parts attach
26. Division of a compound leaf
30. Cluster of Flowers
34. A primary, thick root
35. The whorl of a flower comprised of the petals
38. Single flower, not in a cluster
39. Umbrella-like inflorescence with multiple small flowers
41. Ripened flower part that contains the seeds
42. Branched inflorescence; central stalk with side stalks containing multiple flowers
45. Unbranched inflorescence with single, unstalked flowers

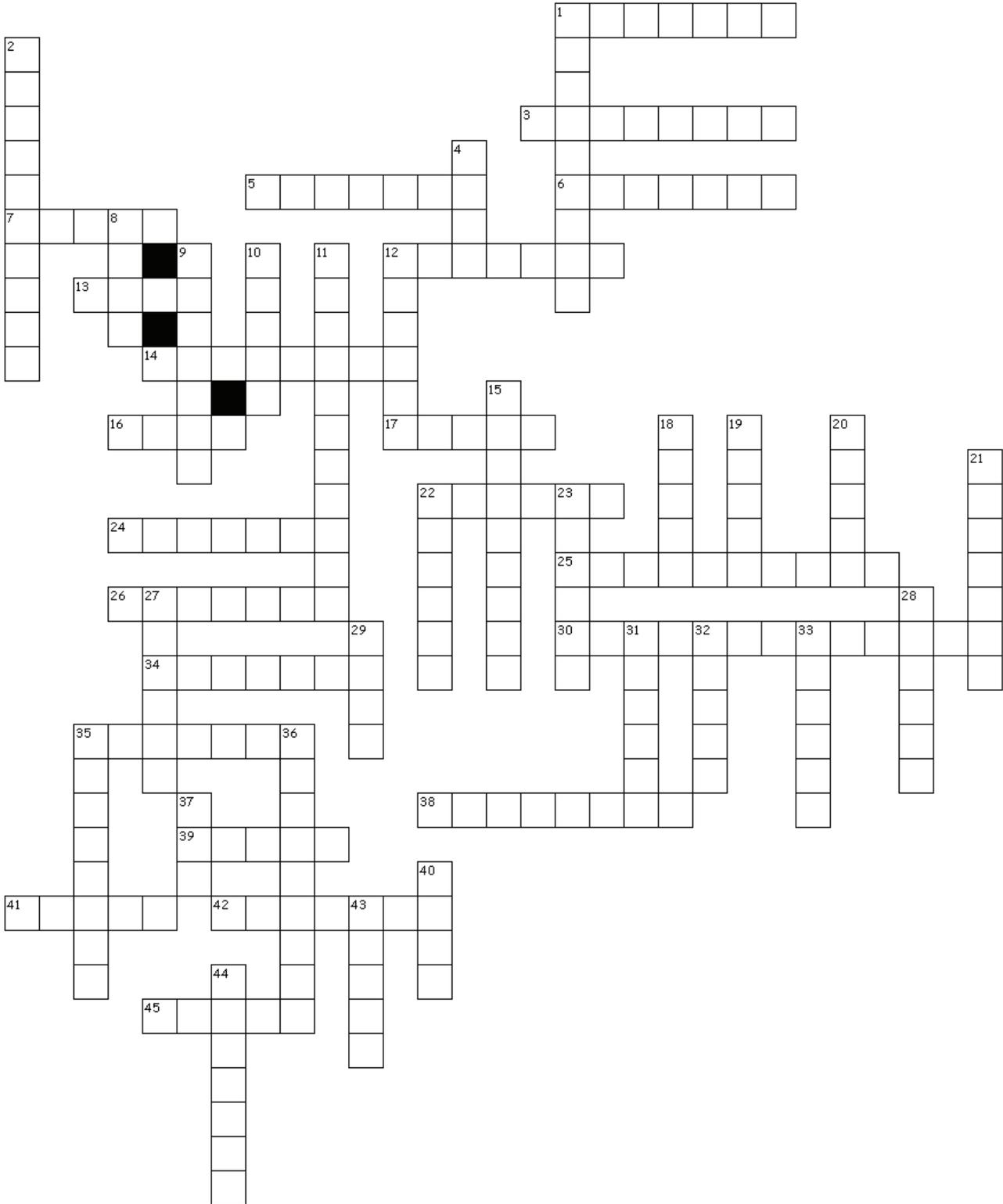


Down

1. Inflorescence with numerous small flowers on a single base
2. Lance-shaped, much longer than wide
4. Transports water, sugars, and minerals within the leaf
8. Anchors the plant and takes up nutrients and water
9. Stalk that attaches the leaf to the stem
10. A modified leaf in the whorl between the sepals and stamens, often colorful
11. Fruit not opening on maturity
12. Female reproductive structure of the flower
15. Fruit opening on maturity
18. Part that connects the stigma to the ovary
19. Small, leaf-like part at the base of a flower
20. Positioned at the base of the plant
21. Three or more leaves arising from the same node on the stem
22. Male reproductive structure of the flower
23. Edge of a leaf
27. Leaf margin that is not toothed, notched, or divided
28. Enlarged, pollen-bearing part of the stamen
29. Above-ground part of a plant that supports leaves and flowers
31. Often colorful and showy; the reproductive unit
32. Oval or egg-shaped
33. Undivided leaf
35. Leaf divided into two or more leaflets
36. Where one leaf arises from each node on alternating sides of the stem
37. Undeveloped stem or flower; covered with scales
40. Blade; primary site of the photosynthesis
43. Flower whorl beneath the petals
44. Branching root system



Botanical Terms Challenge





The Secret Life of Flowers

"Nobody sees a flower really; it is so small. We haven't time, and to see takes time - like to have a friend takes time." -*Georgia O'Keeffe*



Overview

Students will dive into the inner-workings of a flower and put their own creative spin on their findings, combining science observation with artistic appreciation and expression. In the process, they will learn flower anatomy, function, and inflorescence type.

Preparation

1. Set up a classroom display of inflorescence types for students to view. Use live flowers, if available, labeled and in water. If live flowers are not available, use photographs.
2. Visit your local farmers market or ask a florist to donate slightly wilted flowers to use in this activity. If flowers come from a florist, make sure the anthers have not been removed (do to allergies to pollen).
3. For dissecting, choose large, solitary flowers. Flowers in the lily family are especially useful for this activity because their floral anatomy is generally well developed and easily viewed.

Teacher hints

- Divide students into teams and give each team a flower in water.
- Give students time to explore their flowers. Hand out a flower anatomy diagram sheet or project on an overhead for classroom viewing. Have students use their completed Botanical Terms Self-Study Sheet and illustrations provided in the previous chapter.
- Take a minute to point out the parts of the flower. Explain that it can be called a perfect flower if it has both male and female parts, or an imperfect flower if it has only male or only female parts.

Assessments

- 1 Label the parts of a flower and name the function of each.
- 2 Define perfect and imperfect flower.
- 3 Describe inflorescence types.



The Secret Life of Flowers

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Materials Needed

large flower for dissecting (one per student pair)
Exacto knife
labeled flower diagram
11x17 white paper
hand lens
flower samples

Overview

What skills do scientists and artists share? Although artists are thought to be more intuitive and subjective, and scientists are often associated with being rational and objective, both utilize a keen sense of observation in their work. In this lesson, you will immerse yourself in the inner workings of a flower, using your creative skills to record your findings. In the process, you will learn flower anatomy, function, and inflorescence types.

Vocabulary

sepal
perfect flower
spike
bract
imperfect flower
raceme
receptacle
anther
panicle
petal
filament
solitary flower
pistil
stamen
umbel
ovary
stigma
composite head
style
inflorescence
nectar
corolla
ovule
peduncle
calyx
pedicel

Learning Objectives

1. Name and locate the parts of a flower
2. Discuss flower anatomy and function
3. Define the difference between a perfect and imperfect flower
4. Describe a flower using inflorescence type
5. Understand the role of pollinators in shaping flower anatomy
6. Understand plant reproduction and the role of pollination
7. Connect left brain and right brain processes of science and art

Background

Some flowers announce their presence with bold and vibrant hues, while others remain modest and drab. Some are simple and open in form, but others feature tricky entries or convoluted mazes. Flowers have long inspired humans with their beauty and fragrances, and we've bestowed them with symbolic meanings. Myths and symbolism aside, the real job of flowers is to ensure that plants produce offspring.

Animals can roam about and seek mates with whom to reproduce, but imagine the challenge for a plant, rooted firmly in the ground, to achieve the same end. Over millions of years, flowers have evolved a remarkable range of strategies to guarantee that male pollen is transferred to female flower parts so fertilization and seed production can occur. Together, these processes of pollination and fertilization that occur within the flower to produce seeds are a type of sexual reproduction, ensuring that genes from parent plants are recombined in novel ways. This diversifies the genetic composition of the resulting offspring (seeds). To ensure the continuation of the species, plants and animals use two methods of reproduction - sexual and asexual. Sexual reproduction is the more common form of reproduction. It involves the fusing of two genes from two partners. Asexual reproduction doesn't require a second partner.

Vegetative reproduction is a form of asexual reproduction in plants, where parts of the plant fall off and develop into new plants. Potato tubers are one example of a plant that uses this form of reproduction. Since asexual



The Secret Life of Flowers

reproduction doesn't require another partner, or pollen transfer, it doesn't require flowers and it is very quick and guaranteed. The main disadvantage of this form of reproduction is that the new plants will all grow very close to each other and to the parent and no new genes enter the gene pool. This will cause a struggle for soil, nutrients and light, and will consequently cause the plants to be less healthy.

Fragmentation is another form of asexual reproduction in plants, and is very similar to vegetative reproduction. This is when an organism is broken into two or more pieces, and each one grows into a new individual. For this type of reproduction the plant must have good powers of regeneration. This could be a disadvantage if the plant is in poor conditions, as it wouldn't have strong powers of regeneration, and so it wouldn't be able to reproduce. On the positive side, it can produce many new individuals very quickly.

Each method of reproduction has advantages and disadvantages. Overall, asexual methods are faster and easier than sexual reproduction because a partner is not necessary. Another advantage of asexual reproduction is that pollinators and pollen don't have to travel in order to propagate the species. This means the plants can conserve energy and be more discreet. The major advantage of sexual reproduction is that genetic information is shared by the two gametes, which produces variety within in the species. In the long run, this will create a species better able to survive in a changing environment. Of course, sexual reproduction has won out in this day and age of flowering plants, which is why we have such beautiful and amazing floral diversity throughout the world.

Since so many plants produce flowers, a basic understanding of floral anatomy will aid you tremendously in the proper identification of plants. In learning to identify plants, it is important to understand that flower anatomy and structure is directly linked to pollination. This plant-pollinator relationship one of the best examples of co-evolution in nature. Were it not for the process of pollination, flowers as we know them may look dramatically different, perhaps more different than we can imagine!

Reliance on the wind to move pollen from one flower to another, such as in grasses, some wildflowers, and many trees, is the oldest method of pollination. In these cases, plants produce massive quantities of pollen, with only a minuscule amount reaching its destination on another flower of the same species. These species often have small or no petals so as not to block the wind and are rarely showy since they do not need to draw in any pollinators. They commonly have feathery stigmas that comb pollen from the air. But a more efficient and fantastic means of pollination, observed widely among flowering plants, is achieved by luring unsuspecting animal partners to inadvertently transfer pollen from one flower to another as they search for food.

Insects — especially bees and wasps, beetles, ants, flies, butterflies, and moths — are the predominant animal pollinators. They have physical characteristics that make them efficient in locating flowers and transferring pollen from one flower to another. Flowers and their pollinators have evolved together throughout time, frequently engaging in relationships in which the two depend on each other for survival.

Of course, animals don't do the work of pollination for nothing (or even realize they are doing the work in the first place), so plants offer rewards to



attract pollinators. Animals use flowers as sources of food for themselves and their offspring. First of all, animal-pollinated flowers produce nectar, a sugary substance that also contains vitamins, amino acids, and other nutrients. The amount of nectar a flower typically produces relates to the needs of its pollinators. Second, pollen itself is a good source of protein for many animals. Finally, a few plants reward their pollinators with fatty oils, resins, or wax.

A typical flower contains the necessary anatomy to support transferring pollen and producing seeds. Flowers come in a broad range of sizes, shapes, and colors, from beautiful and showy to modest and plain, but most flowers are made up of the same basic parts arranged in the same order. Flower parts are commonly described as occurring in whorls, or rings, with different anatomical parts usually occurring in the same order, regardless of species.



The Secret Life of Flowers

A flower is attached to the rest of the plant by a stalk called the **peduncle**. At the end of the peduncle is the **receptacle**. The receptacle is where the reproductive parts of the flower attach. The first, outermost whorl is made up of **sepals**, which collectively are called the **calyx**. They form a protective, petal-like layer that covers an unopened bud, and are usually small and inconspicuous when a flower is open. The sepals are usually green and peel back as the flower opens; sometimes they will even fall off as the bud opens. In some species, however, the sepals may be large and showy, and may be hard to distinguish from petals. In some flowers, there is an additional whorled ring outside of the sepals. This ring is made up of **bracts**, or modified leaf-like structures. A common example of bracts in a flower is in the Indian paintbrush. One of the showier paintbrushes in New Mexico is foothills paintbrush with the bracts being rose pink, red or orange in color. The petals are found inside the bracts and are green and small.



The next whorl in from the sepals is the **petals**. The petals are typically the most noticeable parts of flowers, and are designed to attract and provide platforms for insects, bats, birds, and other roving pollinators. All of the petals of a flower are collectively referred to as the **corolla**. Think of

the petals as being billboards or flags advertising and drawing attention to the flower.

The male parts, or **stamens**, make up the third whorl. They can be quite long to maximize exposure to wind and pollinators, or hidden inside the flowers to force pollinators to touch the stigmas on their way in or out, or able to lengthen and shorten over time, as needed. The stamen is made up of the **filament**, a thread-like stalk that supports the **anther**, which produces and releases pollen. Animal-pollinated plants have large, irregular pollen grains with lots of tiny hooks, spines, and craters on the surface. A rough texture and sticky surface ensure that the pollen will stick to a visiting animal's hair, scales, feathers, or appendages and then stay there until the animal visits another flower. At the next flower, the pollen will be rubbed off onto the strategically placed stigma.

The center of a flower usually contains the female whorl, the pollen-receiving **pistil**. The **stigma** at the pistil's tip is often sticky, feathery, folded, or otherwise designed to trap pollen. When they're ready to accept pollen, stigmas prepare themselves for the transfer. They may be pushed upward by the long **style** that supports them, lean toward the male parts, or become stickier. When a pollinator carrying pollen from another plant brushes against the stigma, pollen is transferred. If the conditions are right, the pollen grain germinates and sends a tube down the style and fertilizes an **ovule**, leading to seed production. Once fertilized, the **ovary** wall takes in moisture and swells, becoming the fruit, which surrounds and protects the developing seeds. At the base of the pistil, the ovary protects ovules (eggs), which become seeds when fertilized. At the base of many flowers are

nectaries, which produce the nectar. **Nectar** is the sweet liquid produced to attract pollinators. Since this food treasure is typically tucked deeply in the flowers, pollinators are coaxed into touching the flower's reproductive organs, thus transferring pollen in their search for nourishment.

As is always the case in nature, there are exceptions to the rule. Many plants produce flowers containing both male and female parts. These are referred to as **perfect flowers**. But some plant species have some flowers that contain only male parts and some that contain only female parts, both referred to as **imperfect flowers**. In these cases, one of the whorls described above will be absent from the flower's anatomy. In some species, these two types of flowers are located on the same plant; in others they are found on separate plants.

There is a long list of vocabulary that is used to describe the way in which flowers are attached together to form a group of flowers. Sometimes plants have flowers that are found singly on the plant. These are called **solitary flowers**. More commonly, flowers are found in clusters, called an **inflorescence**. Like the anatomy of a flower itself, the arrangement of flowers in a cluster varies widely, a testament to the diversity of pollinators and plant adaptations to ensure healthy reproduction. A cluster of small flowers in a flat to rounded shape, such as those found on Mountain parsley or cow parsnip is called an **umbel** (pictured on next page).

A cluster comprised of a long central stalk with flowers attached directly to the stalk is called a **spike**. A spike with flowers attached by short stalks (**pedicels**) is called a raceme. A



The Secret Life of Flowers

raceme that is further branched is called a **panicle** (many grasses, but not nearly all!). Flowers in the Sunflower family (Asteraceae) may look like single flowers; however, if you look closely, each flower head is actually composed of numerous individual flowers, sometimes hundreds. These are called **composite heads**.



One explanation for the vast and varied differences of flower shapes, sizes, colors, and smells is that flowers have co-evolved with their pollinators. When you are observing your flower, ponder how the design might best be suited to a specific pollinator. The stigma is often sticky. Can you guess why? The ovary is often hidden. Why? The stigma generally appears sturdy compared to other parts. Why? The stamens are often frail and in great numbers. Why? Why are petals colorful? Some plants have scented flowers. Why is this? Why are some flowers showy and some very plain?

In this indispensable partnership, flowers and pollinators are utterly dependent on one another for survival. In turn, we depend on this process for much of the food we enjoy.

While exploring flower anatomy in the following activity, you will gain the skills to understand not only how to identify plants, but also to observe nature's diversity in greater detail.¹

Student Directions

1. Work with a partner on this activity. You will be sharing a flower, but each of you will turn in your own 3-panel sheet. Help each other to locate the flower parts.
2. Observe your flower closely. Can you see all of the reproductive parts or does the plant hide some its flower parts? Take note of the size, showiness, color, aroma, and anything else interesting that you observe. Use a hand lens to observe closer. Can you see nectar or pollen? Take a couple minutes to brainstorm with your partner why your flower is designed the way it is. Think of where it might grow and how it might be pollinated. Write down your ideas.
3. Fold and crease an 11x17 inch paper into three equal parts (like a brochure). Open the paper and in the first panel, draw your flower. Include the pedicel (flower stem) and how it is attached to the flower. Draw the flower as accurately as you can, showing all the different parts that are visible without touching your flower.
4. Compare your flower to the diagram of "parts of a perfect flower" from the previous chapter. Look for the reproductive parts of your flower. Most flowers have both; some have one or the other. The parts are easy to find on some flowers, such as a lily. On some flowers, such as a sunflower, the parts are very difficult to see. If the male and female parts are not visible, gently move or remove a petal or two. In the second panel of your data sheet draw the inner whorls of your flower (pistils and stamens). Is your flower perfect or imperfect?
5. Carefully use your knife to cut a cross section through the center of your flower. Try to slice through the ovary to show the inside. This will take a steady hand as the ovary is often quite small. Use your hand lens to view the inner parts of your flower closely. What does the inside of the ovary look like?
6. In the third panel of your data sheet draw an extreme close-up of the inner flower parts. Be as accurate as possible, use your hand lens and fill your drawing panel with what you see.
7. Using the flower diagram as a guide, label the parts of your flower. Use the panel(s) that best shows the parts you are referencing.
8. Label your flower with the inflorescence type. Compare to the flower diagram or classroom display and your vocabulary words.



The Secret Life of Flowers

In the Field



- Go outside to the school yard or to a natural area to draw flowers in the field. Discover the nuances of different flowers. Many of our native wildflowers are small and take close observation to note their beauty. View flowers with a hand lens to look for the fine details that they learned about.
- Visit a field of wildflowers. Look for different types of inflorescences. Is one type more common than others? See if you can find the flowers on more cryptic species such as grasses and sedges, or willows.
- Visit the same site several times over the course of the year. Does the type of dominant inflorescence change? Could inflorescence type be linked to pollination? Is one type of inflorescence more common at specific times (March compared to May)? Why? Remember that flowers must be open at the same time as their pollinators are active in order to reproduce.

Reflection

Georgia O'Keeffe had a unique way of viewing flowers and was drawn to their beautiful flowing lines. This famous artist lived part of her life in New Mexico and found great inspiration from the New Mexican landscape. Pick your favorite flower and write as if you are looking at a section of your flower through a microscope. Make the lines of your writing flow like the lines of the flower in one of O'Keeffe's paintings. Think outside of the box; what are ways you could make your writing "flow"? Use your creativity. You might also write a poem to accompany your illustration.



EARLY FINISHERS

- Turn your drawings into an art project! Color your 3 panel sheet and use shading techniques to show depth. Cut out the panels and mount them on a complementary color background.
- View your flower like a pollinator might see it and draw a part of your flower that you find most interesting. Draw the piece in great detail and large like the great American artist Georgia O'Keeffe would have. Fill the page or even larger, letting parts of the flower trail off the page. Use your hand lens to look for subtle vein patterns, hairs, color variations, nectar droplets, etc. and include these observations in your drawing. Georgia O'Keeffe painted flowers like this using plants near her New Mexico home. For inspiration, view some of her works at the Georgia O'Keeffe Museum online.
- Portray your flower in an alternate artistic medium of your choice from the perspective of a pollinator. Paint, sculpt, design a video game, film, poetry/creative writing, music, dance; the options are limitless.
- Design a flower for a specific new pollinator (you could even use a coyote!). What kind of characteristics will this flower need to attract the pollinator? What shape, size, and smell would the flower have? Include a drawing and description of your new flower.



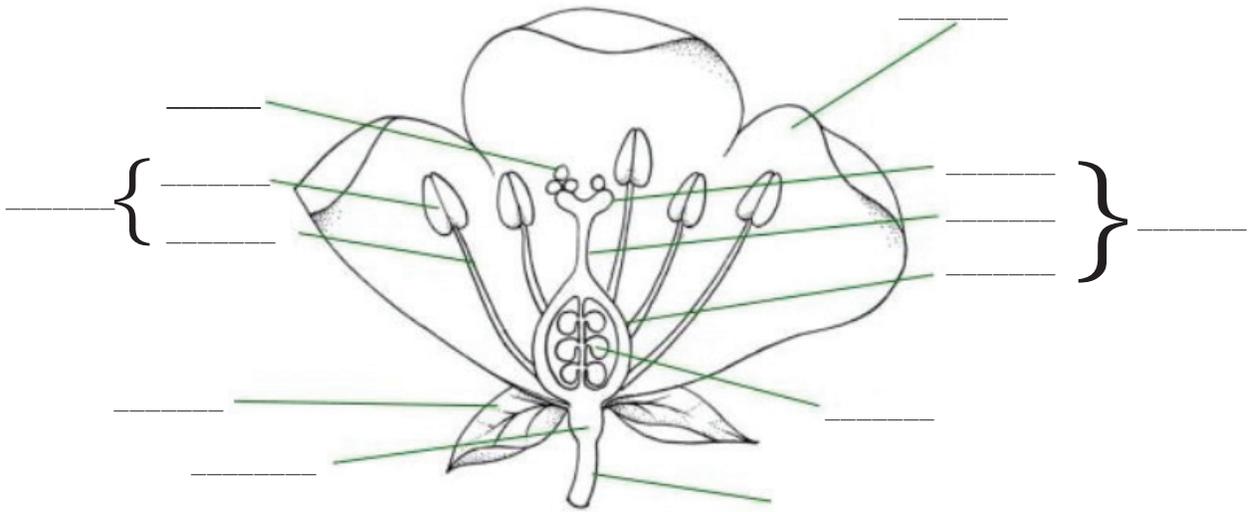
The Secret Life of Flowers



Self Assessment

- 1** Label the parts of a flower and name the function of each.
- 2** Define perfect and imperfect flower.
- 3** Describe inflorescence types.

Parts of a Perfect Flower



Resources

- Harris, James G. and Melinda Woolf. 1994. *Plant Identification Terminology: An Illustrated Glossary*. Sixth Edition. Spring Lake Publishing, Spring Lake Utah.
- Georgia O'Keeffe; source to view many of Georgia O'Keeffe 's flower paintings: <http://www.phaidon.com/agenda/art/articles/2014/february/05/what-do-you-see-in-georgia-okeeffes-flowers/>
- Search the web for diagrams of flower structure fact sheets and many great examples. Flower Structure from Merriam Webster online visual dictionary: <http://visual.merriam-webster.com/plants-gardening/plants/flower/structure-flower.php>

T

Teacher Page

Drupes, Pomes, & Loculicidal Capsules A Botanist's Lingo for Describing Fruits

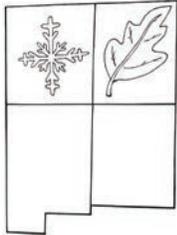
Time flies like an arrow, fruit flies like a banana. - *Groucho Marx* (1890-1977)



Time Estimate

60 minutes; additional time required for In the Field!

Best Season



Fall
Winter

Materials Needed

plates, cutting boards, and knives for slicing and displaying fruits

towels for clean-up

hand-clippers for collecting native plant materials

Teacher hints

- Let students sample store-bought fruits by having bite-sized samples at each station.
- Encourage students to use hand lenses to examine fruit carefully.
- Vocabulary words not defined in the text can be found in the glossary.

Assessments

- 1 Students use a key to classify common grocery fruits and apply to native fruits.
- 2 Through observation, students make inferences to seed dispersal methods by analyzing fruit types.
- 3 Identify and name the three parts of a fruit as applied to common fruit types.

Overview

In this hands-on lab, students learn about the basic parts and development of fruits. By classifying familiar fruits using observable characteristics and fruit type vocabulary words, students familiarize themselves with the botanical origins of fruits and the adaptations of different fruit types. Following the lab experience, students can extend their new knowledge of fruits to native plants by collecting fruits of native species in the field and comparing them to familiar fruits to understand their botanical relationships. This could be a great fall or winter activity, as many native fruits can be foraged easily in the fall and many tropical examples are available in the grocery store in the winter.

Preparation

Collect fruit from a local market and set up about ten stations chosen from the list below. Number the stations, and include at least two or more of each suggested fruit (when possible) at the station. Include one that is whole and one cross section for each different fruit used. Definitions for vocabulary words can be found in the glossary if not explained in the text.

- **pome:** apple, pear, quince
- **berry:** tomato, grape, avocado, pomegranate, banana, date
- **drupe:** peach, plum, nectarine, apricot, cherry, olive, walnut (including hull and shell), almond (including hull and shell)
- **nut:** hazelnut, acorn, chestnut
- **caryopsis:** corn, wheat, barley, oat, rice
- **legume:** bean (in pod), peanut (in shell), snow pea (in pod)
- **achene:** sunflower seed in shell
- **multiple fruit:** pineapple, mulberry
- **pepo:** cucumber, pumpkin, squash
- **aggregate fruit:** blackberry, raspberry
- **hesperidium:** orange, lemon, lime, grapefruit

For native fruit, set up the lab with wild fruit and have students repeat the activity. Field guides can help you classify wild fruit types. Some suggestions:

- **pome:** hawthorne, serviceberry, mountain ash
- **berry:** prickly pear, ground cherry, wolfberry, honeysuckle, Oregon grape, many Lily family plants
- **drupe:** choke cherry, manzanita, Russian olive (not native), sumac, kinnickinnick, snowberry
- **legume:** mesquite, New Mexico locust, lupine, vetch, astragalus (milkvetch)
- **nut:** hazelnut, acorn, chinquapin
- **nutlet:** self heal, bedstraw, four o'clock flower, field mint
- **samara:** maple, ash, Siberian elm (not native)
- **caryopsis:** any grass species
- **achene:** buckwheat, four-wing saltbush
- **capsule:** paintbrush, yucca, penstemon, iris, willow
- **aggregate fruit:** wild red raspberry, rosehips
- **multiple fruit-** osage orange
- **cypsel:** dandelion, thistle, rabbitbrush, sunflowers
- **follicle:** milkweeds



Drupes, Pomes, & Loculicidal Capsules

A Botanist's Lingo for Describing Fruits

Time flies like an arrow, fruit flies like a banana. - *Groucho Marx* (1890-1977)

Materials Needed

- magnifying or hand lens
- key to Fruit Types handout

Overview

In this lab, you will learn how to classify fruits and understand their development. You will have a chance to familiarize yourself with the botanical origins of fruits and the adaptations of different fruits types. Compare what you learn in the lab to the fruits of native plants to understand their botanical relationships.

Vocabulary

Amateur Botanist

drupe	simple fruit
pome	multiple fruit
achene	aggregate fruit
locule	pericarp
hip	seed
capsule	nut
legume	ovule
berry	ovary
indehiscent	carpel
dehiscent	

Expert Botanist

exocarp	schizocarp
mesocarp	nutlet
endocarp	samara
pepo	caryopsis
hesperidium	accessory fruit
follicle	cypsela
silique	

Learning Objectives

1. Develop and use observational skills on multiple scales
2. Understand how fruits are categorized botanically
3. Increase understanding of plant diversity
4. Increase botanical vocabulary
5. Apply knowledge of familiar fruits to local native plants

Background

If a friend asks you for a piece of fruit, they might give you a strange look if you hand them a cucumber. Perhaps you have heard people argue as to whether a tomato is a fruit or a vegetable. In the grocery store, things that are sweet and generally used in desserts are generally labeled as fruits. In the world of botany, the term "**fruit**" means something else, and encompasses many things that are commonly referred to as vegetables, nuts, and even grains. From a botanist's perspective, a fruit is the ripened (mature) ovary of the flower containing one or more seeds. Sometimes a fruit contains other parts of the flower as well. Fruits develop after a flower is pollinated and the ovules inside the flower's ovaries are fertilized. Every fruit contains at least one or more

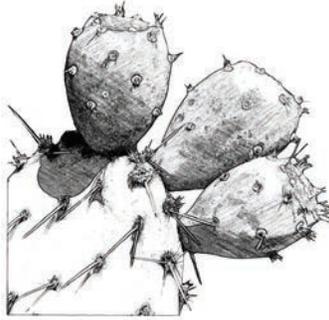
seeds inside (with the exception of some commercial fruits that are intentionally bred to be seedless). Fruits come in many shapes and sizes and are divided into different fruit types with fancy botanical names to describe their form and function. As the seed develops or matures, the ovary tissue undergoes changes that result in fruit. This **ovary** turned fruit is made up of three layers, together called the **pericarp**. These three layers are easy to see in some fruit, such as the apple, which has skin, flesh, and a core. In other plants, the pericarp layers are very hard to see, such as in the grasses. Fruits with similar forms are often evolutionarily related, such as a cucumber and zucchini. However, other fruits that may appear to look nothing alike, such as a strawberry, raspberry, apple, and cherry, may



Drupes, Pomes, & Loculicidal Capsules

A Botanist's Lingo for Describing Fruits

be lumped into one plant family, in this case the Rosaceae, or Rose family. Why is it important to be familiar with the different types of fruit? Field guides often use fruits as an important feature for identifying plants. Being able to distinguish fruit type will get you one step closer to proper identification. Also, plants from the same family will frequently have the same type of fruit, another hint to their identification. Fruit type can also give you a hint as to how the seeds are dispersed, an important window into the ecology of the plant and the animals that may depend on it. The method by which a fruit is dispersed can generally be determined by examining the structure of the fruit itself. Fleshy, sweet fruit is likely to be eaten, with the seeds transported inside of an animal to be deposited somewhere else with a ready-made packet of fertilizer to get it started. Hard nuts are cached (buried) by squirrels and jays to eat later in the winter, but many are never found and from them sprout new trees. Light seeds may be dispersed by wind or water, and often have special appendages on them such as wings, parachutes, or corky floats to aid in the process. Some fruits also have hooked barbs on them that adhere to animal



fur for dispersal. During this exploration, you will have an opportunity to think critically about the mechanisms of dispersal of native fruits. What do the fruits you find in the grocery store have in common with our native plants?

Many of our native plants have domesticated relatives that have delicious edible fruit. For example, the delectable cherry you find in the produce section is related to the native sand cherry (*Prunus angustifolia*) and chokecherry (*Prunus -virginiana*), which have fruit so bitter (which explains its other common name, bitter-berry) that they are inedible for humans when unprocessed. If you look at native plants, you will find that many of them have fruits that are similar to ones you are familiar with from the grocery store. However, many fruits that are popular to eat are shipped from subtropical, and tropical areas, such as bananas, pineapples, and citrus, and have no local relatives. In this lab you will be looking at fruit from the grocery store as well as fruits from local native ecosystems. Use your observation skills to examine the structure and characteristics that are used to classify fruit into categories or types.

Student Directions

1. Divide evenly across the stations. Begin by visiting only the stations with commercial, grocery store fruits. Native, wild fruits will be examined later.
2. Spend 3-5 minutes at each station. Note the number of the station on your paper (use a half sheet of paper for each station), sketch a cross section of the fruit, and write a description in words. Observe closely all the small details you find in each group of fruits. Is the fruit soft, fleshy, dry, hard? How many seeds are there? What is the arrangement and texture of the pericarp? Are there any chambers within the fruit? Note anything else that may be an important identifying feature. Use the magnifying lens to look closely.
3. Rotate to the next fruit station; write the station number and continue to sketch and gather observations. Be sure to visit all the stations (or the number specified by your teacher).
4. Use the Key to Fruit Types to determine what type of fruit is at each station. Fill in the fruit type in the top right corner of your data sheet.
5. After you have visited all of the stations with commercial grocery store fruits, visit the native, wild fruits stations. Follow the same directions for the native fruits stations as you did for the grocery fruit. Use a hand lens to examine the fruits carefully, as wild fruits are often much smaller than their grocery store cousins.
6. Apply what you have learned. Can you match the wild version with fruit types you eat? In all likelihood you will discover some new fruits that do not fall into the categories that you have worked with so far, as they do not have a domestic equivalent that we eat (e.g. samara).



Drupes, Pomes, & Loculicidal Capsules A Botanist's Lingo for Describing Fruits

In the Field



- Take a field trip in the fall to see how many different wild fruit types you can collect. When collecting, if you know the name of the plant, write it down. Take your collection back to the classroom. Dissect your wildfruits and use your observation skills to classify them by fruit type. How many different types of fruit did you find? If you were able to identify any of the plants when collecting, look in the field guide to see what type of fruit it has. Does your plant name and fruit type match what is found in the field guide?
- When you are finished with this activity, dispose of the seeds in the trash can. Invasive plants are common and it is likely that you have them in your collection. Don't take a chance of spreading them; act responsibly and dispose of the seeds properly.

Reflection

Use your imagination. Invent a new fruit and draw it inside and out. Hypothesize about why this fruit looks, tastes, smells, and lives as it does. Describe in detail how each characteristic of your fruit helps your plant survive and disperse in its habitat. Write a story or poem about your fruit, or from a fruit's perspective.



EARLY FINISHERS

Some fruits are designed to literally hurl the ripe seeds at you when you touch them, while others hold their seeds deep within fleshy layers. Take this lab one step further by making observations and inferences as to what method of seed dispersal this plant uses (mechanical, wind, water, animal carried). Examine the structures of the fruit and make your best guess as to how the fruit may be dispersed to new sites. Refer to the paragraph in the background information for clues. What structures on the fruit lead you to think that it is dispersed in that way?

Self Assessment



- 1 Use observational skills to identify fruit types using a dichotomous key. Apply the knowledge to native fruits.
- 2 Through observation, make inferences about seed dispersal methods by analyzing fruit types.
- 3 Identify the three parts of a fruit as applied to common fruit types.

Resource

Plant Identification Terminology, An Illustrated Glossary 2nd Edition, Harris, James & Melinda, 2001, Spring Lake Publishing, Utah.

Dichotomous Key for Common Fruit Types

- 1a. Fruit from more than one ovary but from a single flower **Aggregate fruit**
- 1b. Fruit from one ovary from one flower (simple fruit).....2
 - 2a. Fruit fleshy at maturity.....3
 - 3a. Fruit with single large, hard pit containing the seed (stone fruit).....**Drupe**
 - 3b. Fruit without a large, hard pit.....4
 - 4a. Fruit with a papery endocarp (inner layer of ovary) forming a core.....**Pome**
 - 4b. Fruit without a papery endocarp, fleshy throughout.....5
 - 5a. Exocarp (or skin) thin, not leathery or hard.....**Berry**
 - 5b. Exocarp thickened, leathery or hard (modified berries).....6
 - 6a. Exocarp leathery with aromatic oil glands, citrus.....**Hesperidium**
 - 6b. Exocarp hard or variously thickened, oil glands absent, gourds, melons, and squash.....**Pepo**
 - 2b. Fruit dry at maturity.....7
 - 7a. Dehiscent (splits open at maturity).....8
 - 8a. Fruit from a single ovary with only one locule (chamber or cell)....9
 - 9a. Fruit splitting along two lines (sutures) producing two halves like a pea pod.....**Legume**
 - 9b. Fruit splitting along one line only not producing two parts or halves.....**Follicle**
 - 8b. Fruit from several fused ovaries, usually with two or more locules.....**Capsule**
 - 7b. Indehiscent, does not split open at maturity.....10
 - 10a. Fruit wall forming a wing.....**Samara**
 - 10b. Fruit wall not forming a wing.....11
 - 11a. Pericarp not thick or hardened; fruit small.....**Achene**
 - 11b. Pericarp hard; fruit usually rather large but if small then called nutlets.....**Nut**



What's In a Name?

"What's in a name? That which we call a rose by any other name would smell as sweet."

- William Shakespeare (*Romeo and Juliet*)

Time Estimate

- 60 minutes in the classroom
- An additional session is required for In the Field!

Best Season

		Winter
		Fall
		Spring

Overview

This lesson uses a technology-based practical application to explore scientific names. Students will access the United States Department of Agriculture (USDA) website to explore some of the challenges with using common names. They will learn a brief history of scientific names, general rules on how to write scientific names, and hints for pronouncing botanical Latin.

Teacher hints

- Plants commonly referred to as "thistles" provide an excellent opportunity to explore the utility of scientific names and the challenges with common names. For example, the plants in the genus **Cirsium** are referred to as thistles, while the genus **Centaurea** represents star thistles, plants in the genus **Sonchus** are sowthistles, and plants called Russian thistles are in the genus **Salsola**. Each of these genera, however, are distinctly different. Make a set of thistle identification cards for your region. Find photos and a species list on the USDA PLANTS database site. Use these cards when you go out in the field to help students identify the "thistles" found in your area. When using photos from this site, set a good example for your students and include the credits on your cards. This may also be set up as a student project.
- If your students need extra practice to remember the proper techniques for writing scientific names, make up a worksheet writing scientific names incorrectly and have students rewrite them in the correct form.

Preparation

Student pairs will need access to a computer with Internet capability.



Assessments

- 1 Students can recognize and use proper formatting for written scientific names. (capitalization - Genus, species; *italics* if typed, underlined if handwritten)
- 2 Students can describe at least one situation where it is important to use scientific names and why.
- 3 Students can name at least one situation where using a common name is preferable.



What's In a Name?

"What's in a name? That which we call a rose by any other name would smell as sweet."

- William Shakespeare (*Romeo and Juliet*)

Materials Needed

- computer with Internet access
- digital camera for use outdoors (optional)

Overview

This lesson uses a computer-based application to explore the importance of scientific names. Using the USDA PLANTS database website, you will explore the importance of using scientific names to describe plants and the challenges that arise from the use of common names. You will do this by researching a group of familiar and common plants, the thistles. Learn the history of scientific and common names, formatting guidelines for writing names, and hints for pronouncing botanical Latin that will make you sound like a pro.

Vocabulary

genus/genera

species

binomial nomenclature

scientific name

common name

taxonomy

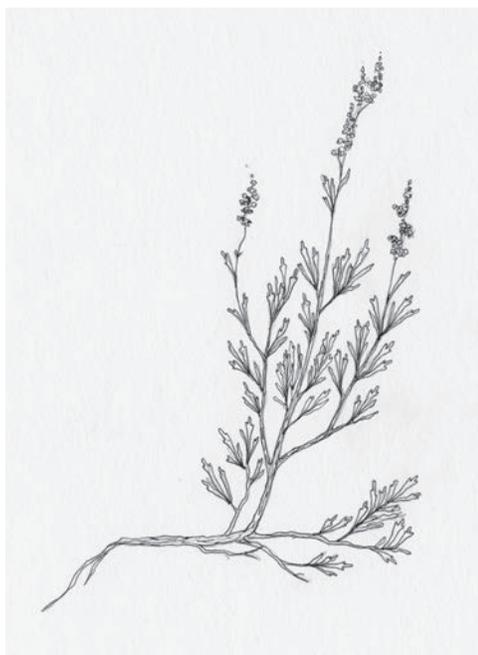
Learning Objectives

1. Become familiar with a technical website resource to gather scientific information
2. Understand the history and function of scientific names
3. Understand the importance of using scientific names
4. Understand the uses for common names of plants
5. Write scientific names in the proper format

Background

Chances are you are familiar with a plant called a thistle. The name "thistle" is a common name used to describe many different plants that are spiny or prickly. However, some plants that are called thistles have no spines. If someone says they saw a thistle, how do we know which one they are describing?

Common names can function appropriately when everyone uses the same name for the same plant. However, this is a rare occurrence in the botanical world. Most plants are known by more than one common name, if not several. Sometimes these names differ from one region to another. Common names also do not cross over language barriers. Imagine a plant found in both Arizona and northern Mexico, where the common name for a plant found in both of these neighboring places would be different in Spanish and English. This variation can make plant names very confusing! In spite of this variation and the challenges that arise from it, common names are used frequently. They are easy to pronounce, can be easier to remember than scientific names, and are often descriptive of the plant (i.e. blackberry). All of these factors contribute to the utility of common names in communicating with your friends and acquaintances in your community. However, there is often a need for a greater level of accuracy than common names allow. For this use, we have a standardized system of scientific names that do not change by language, region, or local usage. As you learn some of the Latin roots used to make scientific names, also called Latin names, they become easier to understand and remember, and can help you learn more about the cool plants where you live.





What's In a Name?

Scientists have experimented with many systems for classifying living things. Prior to the invention of our current system, scientific names were long descriptive phrases that were hard to remember. An example of a plant name under one such system was *Physalis annua ramosissima, ramis angulosis glabris, foliis dentato-serratis*. Now that is hard to remember! The system in use today was created by Carolus Linnaeus (1707-1778), a Swedish botanist and physician. Linnaeus's system, referred to as binomial nomenclature (*bi* = two, *nomen* = name, *calo* = call), involves a standardized two part name. In **binomial nomenclature**, the name for the species above was shortened to *Physalis annua*. Although other earlier scientists had worked on such a system, Linnaeus formalized the system and in 1753 published names for all known plant species in his book *Species Plantarum*. Linnaeus is credited with implementing the hierarchal classification system and is often referred to as the father of **taxonomy** (the science of classification).

This hierarchal classification system uses the **genus** name and a **species** name to make up the **scientific name** of an organism. Scientific names use Latin and sometimes ancient Greek as the root sources. Latin was chosen for several reasons; it is not used as a modern spoken language and therefore does not change with slang and the introduction of new words, it was historically used for scientific names prior to our current system of classification, and it allows for the standardization of scientific names regardless of the native spoken language. This naming system gives each species a surname and a personal name, much like many people. If you are named Pat Jones, then Jones is your surname, and Pat is your personal name. Scientists call the equivalent of a person's last name the genus and the equivalent of a person's first name the specific species. Unlike most people's names, the genus name (surname) comes first and the specific species (personal name) is second in the binomial system. For example, the Latin name for maple trees is *Acer*. This is the genus name, which is shared by the "sibling" species of maple, just as you and your siblings would share a last name. Each "sibling" maple has a unique species name, similar to how your first name and your siblings' first names are unique in your family. For example, in the eastern United States, you are likely to come across *Acer rubrum* (*rubr* = red), and as you travel west into the Rocky Mountains you may encounter *Acer grandidentatum* (*grand*=big, *dent*=tooth) in the interior, and *Acer macrophyllum* (*macro*=large, *phyll*=leaf) on the west coast. However, just like you may know other students

who have the same first name as you, sometimes the specific epithet for two different plants are the same, but only if those plants are in different genera.

Scientific names often reference a physical characteristic of the plant, a famous person or scientist, or the geography of a plant's range. They can come from a person (*Lewisia* for Capt. Meriwether Lewis), ancient Greek (*Daphne* from Greek mythology), a local language (*Camassia* for a Native American word Camas), a false resemblance (*Pseudotsuga* = a false *Tsuga*), a place (*columbiana* = Columbia River), a color (*alba* = white), a landscape where the species might be found (*montanum*=mountain) or a description (*contorta* = twisted).

To maintain this standardized naming system, there are some basic rules.

- The genus is listed first and is always capitalized.
- The specific epithet is listed second, is never capitalized, and is unique among members of the same genus.
- The entire two-part name should be underlined if hand written or in *italics* if typed.

When writing a name multiple times, use the entire name the first time. In successive uses of the scientific name in the same work, abbreviate the genus by using only its first letter, i.e. *Acer rubrum* becomes *A. rubrum*.

Botanical Latin Tips

from *The Jepson Manual: Higher Plants of California* (pg. 11,12)

Many people avoid using scientific names because they don't feel comfortable pronouncing them. For each new Latin name you encounter, remember that there is commonly more than one way to say it. Botanist William Stearn said, "Botanical Latin is essentially a written language, but the scientific names of plants often occur in speech. How they are pronounced really matters little provided they sound pleasant and are understood by all concerned..." Even professional botanists can be strikingly different in the way they pronounce names. If you feel unsure of yourself, remember a bit of wisdom from a wise botanist: "When someone presumes to correct your pronunciation, a knowing smile is an appropriate response." So be brave, go ahead and say those scientific names!



What's In a Name?

Quick tips for pronouncing Latin

1. Divide words into syllables (it is safe to assume every vowel belongs to a different syllable)
2. Pronounce every syllable
3. General practice is
 - **a:** "ah" not "ay"
 - **e:** "eh" not "ee"
 - **i:** "ee" not "eye"
 - **y:** "cynic" not "eye"
 - **ae:** "eye" not "ee"
 - **ii:** held longer "eeee"
 - **ti, ci:** "tee" or "cee" not "she"
 - **ch:** generally "k," not as in "ouch"
 - **g:** as in "go" not "gem"

Student Directions

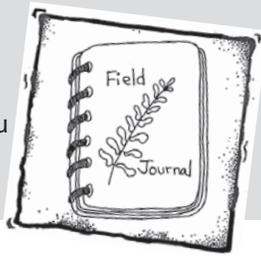
1. Each person or pair needs to work at a computer with Internet access. Use the handout at the end of this lesson as a guide.
2. Go to the website <http://plants.usda.gov/>. This website is designed for use with scientific or common names.
3. Search on the USDA Plants Database website for the common name "thistle." Search options are located on the upper left of the homepage. Type in the word "thistle" and chose the option "common name."
4. How many records are returned (noted at the top of the results page)?
5. How many different genera come up for the name thistle?
6. Scan down the right hand column of common names. Locate "common sowthistle" and write down the scientific name for this plant using proper form.
7. Click on the "common sowthistle" entry to learn more. Would you find this plant in your state? Is this plant native or introduced? If introduced, where did it come from (hint: you will need to search further on related links to answer this question)?
8. Look at the pictures on the website. Have you seen this plant before? Examine the pictures and look for it on your walks around open spaces, around town, or on trips to the country.
9. Now look specifically at the genus *Cirsium*. How many *Cirsium* species are there in your state? Find one species of *Cirsium* that is invasive and one that is native to your state and write their common and scientific names on your worksheet.
10. Now click on the map of your state on the website and see if you can find a species of thistle that is found specifically in the county where you live.
11. Investigate the Latin word definitions of the scientific names you found. Look up both the genus and specific epithet. You can use a website such as: <http://www.winternet.com/~chuckg/dictionary.html>. Why do you think it was given the scientific name that it has?



What's In a Name?

In the Field

Find all the plants in your area that people call "thistles." A good place to start is by searching the common name "thistle" on the PLANTS Database site. Record your findings. While in the field, take a photo, make a sketch, or make an herbarium specimen in a plant press. In the classroom, identify and label each photo, sketch, or pressing with the scientific name, and write a description of each plant. How many different "thistles" did you find?



Reflection

Now you are familiar with a great botanical web resource. Brainstorm and describe how databases such as the USDA Plants Database might be used for conservation or scientific projects.



EARLY FINISHERS

Look at two plants that people call "thistles" but are different species, and if possible, are from different genera. Use a dissecting scope or a hand lens to carefully look at your specimens. Make sketches and notes about your observations. What makes these species different? Be sure to look at all of the plant parts and note the differences. Now make notes about the similarities. What features do you think led people to call both of these plants "thistles?" Can you think of a better common name that reflects what is unique about these species?

Self Assessment

- 1 Can you write scientific names in the proper format?
- 2 Name a situation where it is important to use scientific names and explain why.
- 3 Name a situation where using common name is preferable.



Resources

- *New Mexico Thistle Identification Booklet*. Bob Sivinski (pdf available on the Native Plant Society of New Mexico website: <http://www.npsnm.org/education/thistle-identification-booklet/>)
- USDA/NRCS PLANTS Database home page: <http://plants.usda.gov/>
- Concise information on scientific names: <http://oregonstate.edu/dept/ldplants/sci-names.htm>
- Dictionary of botanical epithets: <http://www.winternet.com/~chuckkg/dictionary.html>
- Botanical Latin hints: <http://www.calflora.net/botanicalnames/pronunciation.html>
- *The Jepson Manual: Higher Plants of California*. Hickman, James C (ed.). University of California Press, Berkeley, 1996.
- International Association for Plant Taxonomy website with the official regulations on botanical nomenclature: <http://ibot.sav.sk/icbn/main.htm>



What's In a Name?

Names: _____ Date: _____

Log into the website < <http://plants.usda.gov/> to start your search.

1. Search for the common name "thistle." How many records are returned? _____
2. Count the number of different genera with the common name "thistle." How many do you find? _____
3. Find "common sowthistle." What is the scientific name for this plant? _____
4. Click on common sowthistle to learn more about this plant. Is this plant found in your state? _____
5. Is it a native plant or introduced species? _____
6. If introduced, where did it originally come from? _____
7. Download a picture of the sowthistle with proper photo credits. Have you seen this species? _____

If so where did you see it? _____

8. What is the meaning of the scientific name for the common sowthistle? Use this website (<http://www.winternet.com/~chuckg/dictionary.html>).

9. Why do you think it was given its scientific name?

10. Now do the same as steps 1-9 for the genus *Cirsium*. Write what you find here. Can you find any native species in that genus?



Plants Have Families Too

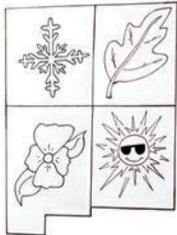
"I have seen trees as my friends. When they grow along my path, I reach out to them, draw their needles through my hands, and smile. I say their names, an acknowledgment of kinship." - *David Sobel* (Contemporary)

Adapted from: Earth Partnership For Schools K-12 Curriculum Guide,
University of Wisconsin-Madison Arboretum

Time Estimate

20 minutes for each plant family (includes time to investigate and discuss findings); an additional session is required for *In the Field!*

Best Season



Winter
(using photos)
Fall
Spring
Summer

Overview

Students learn about the science of taxonomy while studying plant families living in their ecoregion.

Preparation

1. The day before or the day of the activity, obtain several specimens of multiple species for each family to learn. A list of potential species follows each family description. Plants appropriate for dissection are weedy or common, found along roadsides or in gardens. (Be aware that garden plants are often hybrids and may have more flower parts than plants growing in the wild). Flowers may also be available from florists (same hybrid warning applies, and florist sometimes remove stamen).
2. Keep specimens cool and moist. Lay short-stalked flowers between moist sheets of paper towel in a sealed plastic bag; put long-stemmed plants in a vase.
3. If plants are no longer blooming, students can investigate fruits, seeds, and seed dispersal mechanisms. As an alternative, collect photos of plants, flowers and fruits to do this activity in winter.
4. Set up numbered stations with several representative species of each plant family. Have enough stations so there are 3-4 students at a station at a time.
5. Divide students evenly among the stations. Act as timekeeper, have groups move at 10-15 minute intervals to next station.

Teacher hints

- Supplement the student's field journals with vocabulary words from this lesson for a handy reference on field trips and during outdoor activities.
- If completed, students can use the Self-Study Sheet from the "Botanical Terms Challenge" chapter.



Assessments

- 1 Recall the common name and the Latin name for each plant family learned.
- 2 List at least two characteristics from each family learned that make that family unique.
- 3 Identify one representative of each plant family learned.



Plants Have Families Too

"I have seen trees as my friends. When they grow along my path, I reach out to them, draw their needles through my hands, and smile. I say their names, an acknowledgment of kinship." - *David Sobel* (Contemporary)

Materials Needed

- plant specimens in flower or seed
- hand lens
- Self-Study sheet (if completed) from the "Botanical Terms Challenge" chapter.
- Plant Families chart
- field journals

Overview

Learn about the science of taxonomy by observing patterns of plant characteristics of related species in common families.

Learning Objectives

1. Observe and identify flower, fruit, and leaf structures of plants
2. Identify and recognize patterns and characteristics that group plants into families
3. Understand the science of taxonomy in classifying and naming organisms

Vocabulary

plant families



Background

In this lesson, you will learn to identify the most common plant families from your region of your state. Why study plant families as part of plant identification? It would be close to impossible to blindly thumb through a field guide to find the plant you are looking for. It would take a tremendous amount of time to read each description and compare each photo in the field guide to your plant. Understanding **plant families** is a very helpful tool to make plant identification easier and to understand the relationships between species. When you see a plant whose identity you don't know, if you can figure out its family just by looking at it and making a few observations, you will have narrowed your list of possible candidates to a much smaller group, making the challenge of identification easier. Also, some families have a tendency to share functional, edible, medicinal, or poisonous properties. Knowing the plant families is a fun way to become more familiar with the wild places around you. Walking down a trail in your local forest, it is always a treat to see plants from common families that you recognize. Even if you don't know the name of the plant itself, just by recognizing the plant as being from a particular family, you will feel more at home in amazing wild places.



Plants Have Families Too

When you have finished this activity in your classroom, take it out into nature. It will help you understand the composition of plant communities in your ecoregion.

Ten common or significant plant families in New Mexico for you to learn are:

1. **Agavaceae**—Century plant family (century plant, agave, yucca)
2. **Asteraceae**—Daisy family (goldeneye, mules-ears, hawkweed, rabbitbrush, brickelbush, fleabane, gumweed, daisy, cosmos, aster, coneflower, marigold, snakeweed, sunflower, groundsel, goldenrod, sagebrush)
3. **Brassicaceae**—Mustard family (arabis, mustard, hoary cress, draba, wallflower, bladderpod)
4. **Cactaceae**—Cactus family (cholla, prickly pear, hedgehog, fishhook, barrel cactus)
5. **Fabaceae**—Pea family (vetch, pea, leadplant, milkvetch, astragalus, prairie clover, lupine)
6. **Pinaceae**—Pine family (pine, spruce, fir, piñon pine)
7. **Poaceae**—Grass family (side-oats grama, dropseed, barley, squirreltail, ryegrass, three-awn, sacaton, muhly, rice grass, brome, bluestem)
8. **Polygonaceae**—Smartweed family (buckwheat, dock, knotweed, sorrel, smartweed)
9. **Rosaceae**—Rose family (rose, hawthorn, plum, cherry, raspberry, cinquefoil, cliffrose, mountain mahogany, Apache plume)
10. **Scrophulariaceae**—Figwort family (toadflax, monkeyflower, lousewort, figwort)

Student Directions

1. Divide the class into groups with students evenly distributed among the stations.
2. Closely examine the specimens at your first station. Look for characteristics that are similar that would help you group all of these plants into one family. Draw or write descriptions of what you see and feel. Get up close and personal with your specimens. Use a hand lens to look for things like hairs on leaves, numbers of petals, stamens. Look for fruits and flowers and describe them in detail. Look for other distinctive things that may be common to all the species you see such as bracts or other distinctive looking parts. Spend 10 minutes studying your family and then, when instructed, discuss your findings within your group until you change stations.
3. Rotate through each of the stations.
4. After rotating through all the stations, gather to share as a class. What characteristics identify each family you observed? Were there any families in which you found species that didn't seem to quite fit the general family characteristics?
5. Match the shared characteristics that you find on the Plant Families handout to your observed plants. Label your sheet with the family name and add any key traits from the cards that you don't have.
6. Write each family name and important traits into your field journal for reference in the field.
7. Practice Latin by learning to say and spell the names of the plant families you have just learned.



Plants Have Families Too

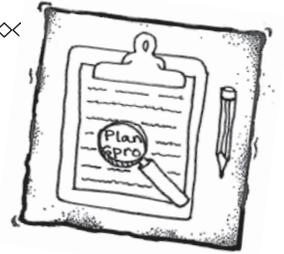
In the Field

Practice your new taxonomy skills on a plant walk in a natural area. Look for plants that have traits that match the family characteristics that you learned in this lesson. Notice if a particular plant family tends to be one habitat over another (such as cactus, which are mostly found in dry places). If you don't find a match for your families, pick a new plant to look at and record the characteristics you observe. Once you have made your observations, look in field guide and try to discover which family it belongs to based on the characteristics that you observed. Teach a friend or family members the plant families you just learned.

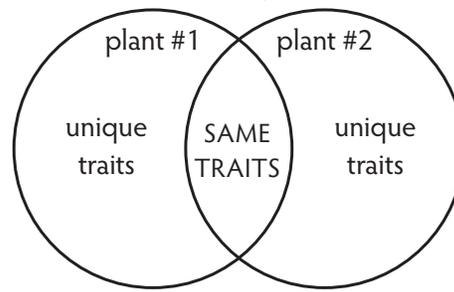


Reflection

Do you think it will be useful to be able to recognize plant families? Create a poem, riddle, or prose piece about one of the plant families, including the key traits that you learned about this plant family and how you would recognize it in a natural area.



Venn Diagram

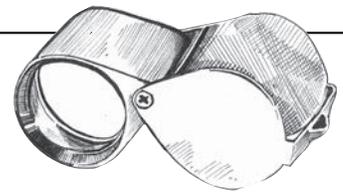


EARLY FINISHERS

Use your observation skills to gather data about plant families. Look at 2-4 plant specimens from one family. Use a Venn diagram to display the information that you collect. Each circle will represent one of the plant specimens; write down observable traits in that circle. In the overlapping area write any traits that are shared by all the plant specimens.

Self Assessment

- 1 Give the common and Latin name of each plant family learned.
- 2 List two characteristics of each family that make that particular family unique.
- 3 Identify one feature per family that potentially may improve their ability to survive and reproduce successfully and discuss why.





Plants Have Families Too

Resources

- Elpel, Thomas J. *Shanleya's Quest: A Botany Adventure for Kids Ages 9-99*. 2005. HOPS Press, LLC, 12 Quartz Street, Pony, Montana 59747. www.hopspress.com
- Elpel, Thomas J. *Botany in a Day: The Patterns Method of Plant Identification*, 5th Edition. 2004. HOPS Press, LLC, 12 Quartz Street, Pony, Montana 59747; www.hopspress.com
- NLE Encyclopedia under Botany for information on Agavaceae: http://www.balsas-nahuatl.org/ency/botzoo/bot/fampage/agavaceae/agavaceae_fampage.htm
- Encyclopedia Britannica for information on Brassicaceae: <http://www.britannica.com/plant/Brassicaceae>
- The Cactus Page: <http://www.succulent-plant.com/families/cactaceae.html>
- Botanical-online information on cactus family: <http://www.botanical-online.com/familiacactaceasangles.htm>
- Reed College for information on Scrophulariaceae: http://www.reed.edu/biology/Courses/BIO332/plantfamily/family_info/Scrophulariaceae.html





Plants Have Families Too

Characteristics							
Family Name	General	Leaf	Flower	Fruit	Ex. of Natives	Common Weeds	
				Garden or Landscape Plants			
Agavaceae (ah-gah-VAH-see-ee) century plant family	Succulents with a network of shallow rhizomes; each rosette grows slowly and flowers only once; adapted to very dry conditions	Basal rosettes of fibrous sword-shaped leaves with sharp, spiked edges; persistent, remaining on the plant for many years; leaves coated to prevent evaporation	Short, tubular flowers in tall spikes [some species pollinated by bats]; perfect flowers forming terminal or clustered panicles; 3-fused carpel ovary; a single and slender style; 6 stamen at base of perianth (collectively, the sepals and petals) tube	Indehiscent pods	soapweed yucca (<i>Yucca glauca</i>), banana yucca (<i>Yucca baccata</i>), Parry agave (<i>Agave parryi</i>)		century plant, tequila, mescal
Asteraceae (as-ter-AY-see-ee) daisy or sunflower family	Some heads have only disk flowers (thistles and snakeroots), others have only ray flowers (dandelions, chicory); many species have both ray and disk flowers (sunflowers, asters); bracts: flower head is subtended by involucre bracts; modified leaves that protect the growing bud	Alternate or occasionally opposite; usually toothed, lobed or divided	Small flowers in center called disk flowers attach to fleshy area (receptacle) and make up a single inflorescence Inflorescence: although may look like single flower, is actually cluster of flowers called a head, which may contain a few hundred individual flowers	cypsel	wood sunflower (<i>Helianthella quinquenervis</i>), Mexican hat (<i>Ratibida columnifera</i>), Bailey's rabbit-brush (<i>Chrysothamnus pulchellus</i>)	ox-eye daisy (<i>Leucanthemum vulgare</i>), dandelion (<i>Taxacurum officinale</i>), bull thistle (<i>Cirsium vulgare</i>)	artichoke, lettuce, sunflower, asters, hysanthemums, chamomile, cosmos, echinacea
Brassicaceae (bras-i-KAY-see-ee) mustard family	Usually annual, biennial, or perennial herbs	Simple, alternate leaves	Always 4 petals in a cross, usually 6 stamen, 4 long, 2 short; usually 4 upright sepals; 2-chambered ovary positioned above the other flower parts.	A distinctive pod of 2 carpels; long, thin fruits (siliques) and short, rounded fruits (silicles)	Fendler's arabis (<i>Arabis fendleri</i>), western wallflower (<i>Erysimum capitatum</i>), spectacle pod (<i>Dimorphocarpa wislizeni</i>)	broadleaved pepperweed (<i>Lepidium latifolium</i>), tumble mustard (<i>Sisymbrium altissimum</i>) shepherd's purse (<i>Capsella bursa-pastoris</i>)	cabbage, broccoli, kale, turnip, brussel sprouts



Plants Have Families Too

Characteristics						
Family Name	General	Leaf	Flower	Fruit	Ex. of Natives	Common Weeds
Cactaceae (kak-TAY-see-ee) cactus family	Vary greatly in size and general appearance. Most are spiny stem succulents, although there are a few woody shrubs (Pereskia) and succulent epiphytes; many cacti have ribbed bodies that allows easy expansion in response to water uptake during rain and contraction in times of extended drought. Water loss is reduced by a waxy epidermis	Cacti have modified buds or areoles from which grow multiple spines and glochids; leaves where present are alternate but usually reduced or absent	Many tepals; many stamens; inferior ovary; 3 or more carpels	Berries with multiple seeds, which may be surrounded by juicy flesh or a membrane and may have areoles with spines or glochids	tree cholla (Cylindropuntia imbricate), plains prickly pear (Opuntia polyacantha), claret cup cactus (Echinocereus triglochidiatus)	plains prickly pear (Opuntia phaeacantha)
Fabaceae (fa-BAY-see-ee) bean, pea, or legume family	Nodules on roots of plants in this family have a special symbiotic relationship with bacteria in the genera Rhizobium and Bradyrhizobium, which acquire food and a protected home in root nodules; in exchange, the bacteria provide the plant with nitrogen	Alternate, compound with three to numerous leaflets, two stipules located at the base of leaf stalk	5 petals, each with a specific name- one banner on top, one wing on each side, and 2 largely fused lower petals called the keel; the keel surrounds 10 stamens fused into a tube or 9 fused and one solitary stamen; flowers are structurally adapted for pollination by bees (the bee lands on the keel, triggering the stamen cluster to be exposed and showering the bee with pollen); Inflorescence: flowers are usually borne on a stalk of many flowers called a raceme	A pod that when dried, often splits along the two lengthwise edges or at the joints between each seed (legume)	stinking milkvetch (Astragalus praelongus), American vetch (Vicia americana), low lupine (Lupinus pusillus)	common sweet clover (Melilotus officinalis), Scotch broom (Cytisus scoparius), black locust (Robinia pseudoacacia), silk tree (Albizia julibrissin)
						Garden or Landscape Plants prickly pear peas, beans, peanuts, lentils, alfalfa, clover, honey locust (tree), wisteria



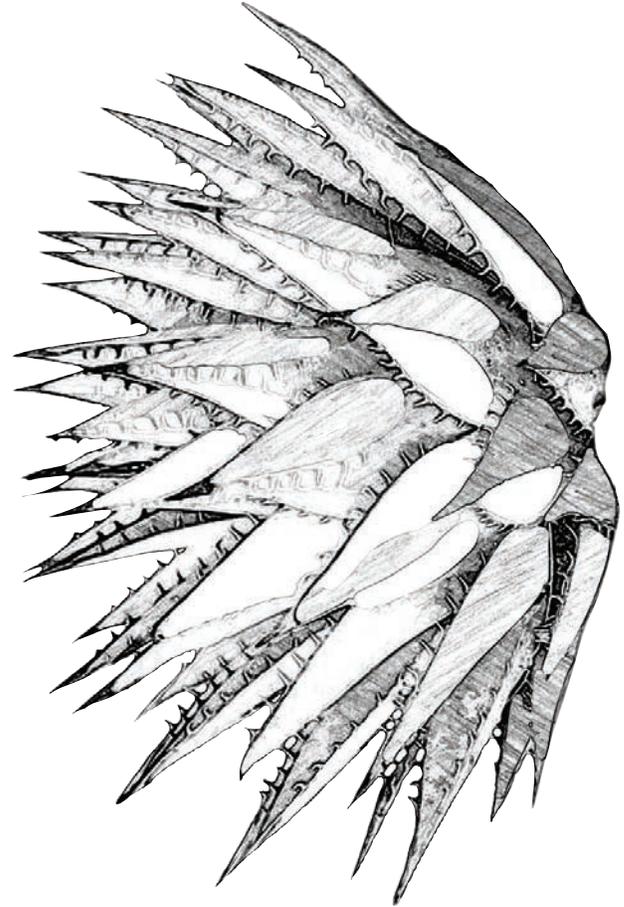
Plants Have Families Too

		Characteristics						
Family Name	General	Leaf	Flower	Fruit	Ex. of Natives	Common Weeds	Garden or Landscape Plants	
Pinaceae (pine-AY-see-ee) pine family	Mostly evergreen trees; pollen dispersed by wind	Needle-like, borne in whorls on branches	Separate male and female flowers borne on the same plant; pollen-bearing male cones are solitary or clustered and have many spirally arranged scales, each bearing 2 pollen sacs; female cones have 2 winged seeds on each scale	Seeds borne on a woody cone (no fruits)	ponderosa pine (<i>Pinus ponderosa</i>), piñon (<i>Pinus edulis</i>), Douglas fir (<i>Pseudotsuga menziesii</i>)		blue spruce, stone pine, (pine nuts)	
Poaceae (po-AY-see-ee) grass family	Wind pollinated; hollow stem between nodes; monocots	Usually long and narrow, with the base of the leaf, the sheath wrapped around the stem. Leaf attaches to the stem at the ligule, a small membranous part (often important for identification)	Small florets on dense spikes or open clusters, 3 stamens, one pistil, bracts instead of sepals or petals, the grass floret is surrounded by a second pair of bracts called the lemma (on the outside) and the palea (tucked inside); Inflorescence: upright or drooping spike, raceme, or panicle	A single grain (caryopsis)	alkali sacaton (<i>Sporobolus airoides</i>), side-oats grama (<i>Bouteloua curtipendula</i>), mutton grass (<i>Poa fendleriana</i>)	reed canary grass (<i>Phalaris arundaceae</i>), cheat grass (<i>Bromus tectorum</i>), Bermuda grass (<i>Cynodon dactylon</i>)	wheat, oats, rice, barley, corn, rye, sugar cane, bamboo	
Polygonaceae (pol-ee-gon-AY-see-ee) buckwheat or smartweed family	Most are perennial herbaceous plants, but trees, shrubs, and vines are present; notable swollen nodes on the stems of some species	Simple, alternate leaves; leaves have a peculiar pair of fused, sheathing stipules at the base of the leaf	Inflorescences are generally cymes or racemes; perianth of 3 to 6 sepals; individual flowers are bisexual with a superior ovary consisting of 3 united carpels at the base of a single ovule; 3-9 stamen; single locule that produces one ovule	Small dry fruit almost entirely one seed	antelope sage (<i>Eriogonum jamesii</i>), pale dock (<i>Rumex latissimus</i>), smartweed (<i>Polygonum lapathifolium</i>)	prostrate knotweed (<i>Polygonum aviculare</i>)	buckwheat, rhubarb, sorrel	



Plants Have Families Too

Characteristics						
Family Name	General	Leaf	Flower	Fruit	Ex. of Natives	Common Weeds
Rosaceae (rose-AY-see-ee) rose family	Usually 2 stipules are at base of leaf stalk	Alternate, simple, divided or lobed, often toothed	5 sepals, 5 petals, one or many pistils, many have stamen in a rings of 5; Floral cup: most have a floral cup beneath the flower which may be a shallow saucer, deep bowl, or tube shape	Aggregate, pomes, drupes, capsules, and follicles; determined by floral cup and fertilization process	silverweed (Potentilla anserine), mountain mahogany (Cercocarpus montanus), Apache plume (Fallugia paradoxa)	sulphur cinquefoil (Potentilla recta), multiflora rose (Rosa multiflora), Himalayan blackberry (Rosa armeniacus)
Scrophulariaceae figwort or snapdragon	Herbs, some shrubs, rarely trees; annual to perennial	Leaves opposite, alternate, entire or pinnatifid	Inflorescence a raceme or cyme; mostly irregular flowers with 5 united petals; flowers in racemes or spikes; superior ovary	Usually 2-celled fruit; capsule or berry	spotted monkeflower (Mimulus guttatus)	foxglove, snapdragon, butterfly bush
						Garden or Landscape Plants apple, pear, cherry, peach, plum, strawberry, raspberry, apricot, almond, rose





Mechanics of a Key

"Obstacles don't have to stop you. If you run into a wall, don't turn around and give up. Figure out how to climb it, go through it, or work around it." -*Michael Jordan*

Time Estimate
60 minutes in the classroom
An additional session is required for In the Field!

Best Season

		Fall
		Spring
		Summer
		Winter

Overview

Students will learn how to use a dichotomous key to identify plants by constructing a key to their shoes! Once students are comfortable with how a key works, they transfer their knowledge to keying out a tree using a dichotomous tree key and local field guides.

Preparation

1. Part 1 requires little preparation, but students may appreciate notice in advance that their shoes will be used as an example.
2. Part 2 introduces students to using a dichotomous tree key. If you do not have a good local field guide with a simple dichotomous key available, Oregon State University offers an excellent user friendly, on-line dichotomous tree key example <http://oregonstate.edu/trees/index.html>). The following trees are found in New Mexico and can be identified to genus using the Oregon key: Pine (*Pinus*), Juniper (*Juniperus*), Ash (*Fraxinus*), Oak (*Quercus*), Russian-olive (*Elaeagnus*)(not native), Sycamore (*Platanus*), Walnut (*Juglans*), and Willow (*Salix*).
3. Collect as many branches from trees as possible (get fruits or cones too if you can) to provide enough material for students (or student groups) and a variety of tree species to compare. If there are no trees around your school, you can use photos. You can search for images on the internet or you can use Oregon website by simply clicking on "Trees By Common Name". Make sure you can provide the images needed to work through the key. For example, photos may need to include fruits or cones and capture certain characteristics such as the shape of the leaf, number of needles, and arrangement on stem. Once the students determine the genus of tree they are working with using the key, they can then more easily narrow it down to species by looking in a local field guide.

Teacher hints

- Read background information and become familiar with the how a dichotomous key works. Many field guides have descriptions of how a key works and specifically how the key in that book works. If you are using a specific field guide with your students, it may be helpful to read this section. It is usually found at the beginning of the guide.
- When trying out a dichotomous key on a tree, try starting with a native evergreen, which often are simpler to key out and can be used in any season.

Assessments

- 1 Students can explain how to use a dichotomous key.
- 2 Students can work in a cooperative group to construct a simple key.
- 3 Students are able to key out a tree using a dichotomous key.



Mechanics of a Key

"Obstacles don't have to stop you. If you run into a wall, don't turn around and give up. Figure out how to climb it, go through it, or work around it." -*Michael Jordan*

Materials Needed

Part 1: Key to shoes

- blank dichotomous key handout
- flexible measuring tapes
- your own shoes!

Part 2: Tree key

- Internet access for working with the dichotomous tree key (for groups of students or project website on screen)
- branches and fruits or cones of tree species for keying-out (use pictures if not available)
- local field guides and *Trees and Shrubs of New Mexico* by Jack L. Carter

Overview

Learn how a dichotomous key works by walking through the steps of creating a key to the shoes in your classroom. Apply your newly learned keying skills to use a dichotomous key and you will be well on your way to identifying native plants.

Learning Objectives

1. Learn to use a dichotomous key
2. Develop the ability to phrase key questions to construct a key
3. Create a key for others to use

Background

A **dichotomous** key is a useful way to identify plants, animals, or anything for which a field guide is available. The word dichotomous comes from the Greek dichotomia, meaning divided (from dica, meaning "in two"). A dichotomous key works by dividing one group of objects (in our case plants) into two smaller groups by using characteristics that do not overlap to place the items into their respective groups. The wording is written as such that none of the objects in the original group can belong to both divisions. The key is assembled in steps that you go through in order, one at a time. Each step will divide the group of objects into smaller and smaller groups until you have just one option and an exact identification. A great way to learn how to use a key successfully is to construct one of your own. The best test of your key is to give it to others and see if they can successfully identify something with it. A key can be made in many ways and still get to the same end. The nature of the questions and the order that you ask them can vary; it is only critical that the key works to get you to the correct answer.

The way it works is that a key provides a series of paired statements. Each statement will have only two possible options. Each of the two answers will guide you along a path to another set of statements. Continuing in this manner, you will answer a series of questions about your object and eventually discover its identity.

Vocabulary

dichotomous



Mechanics of a Key

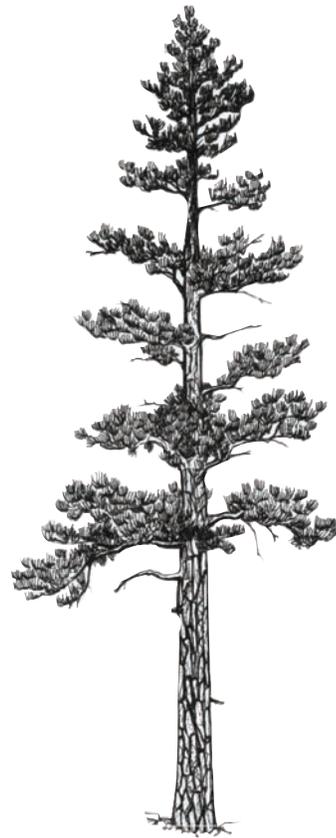
Here is an example of a simple dichotomous key step. These paired statements split evergreen trees into one group, while deciduous, broadleaf trees comprise a second group:

1a. Trees with leaves that are needle-like or scale-like and evergreen.....Group 1

1b. Trees with leaves that are broad and deciduous.....Group 2



deciduous...Group 2



evergreen...Group 1

In activity, you will learn how to create your own dichotomous key using shoes in your classroom. In the second part of the activity, you will have a chance to practice with a key to trees.

Preparation for Part 1 of the Activity:

- Your first grouping of statements should divide the shoes in your class into two categories based on some fairly obvious trait, such as closed-toe shoes vs. sandals, or boots vs. shoes. The two groups do not need to be equal in size. Try to focus on traits that are commonly shared between several individuals, though it is okay to divide out one or a couple of individuals earlier in the key if they are very obviously different.
- Continue to build your key by asking creating more statements that identify a clear trait that divides the remaining individuals into only two groups. Remember, it is vital that each statement must be worded so as to have only two possible pathways.
- The statement should refer to a trait that is obvious, unambiguous, and observable. Do not use traits that are opinions such as "fancy" or "plain", or "clean" or "dirty."
- Continue to offer statements in your key until all shoes have been identified.
- Once it is complete, give your key to a classmate and see if they can follow it.



Mechanics of a Key

Student Directions

Part 1: Key to shoes

1. Carefully read over the background information before starting and refer to it as needed.
2. Either a teacher or a designated recorder should write down each key step that the class chooses as you make your dichotomous key. Use the Construct a Key Handout for this exercise.
3. This activity will walk you through constructing a dichotomous key that will lead to the identification of each shoe in the classroom.
4. Begin by having everyone in the class place one of their shoes in a pile or stacked along a desk. This will help you visualize how the key works.
5. The first step of the key will divide the class into two parts by making a statement with only two possible categories. Remember, as you frame these statements, you will want to use traits that are obvious (easily seen) and measurable, not subjective (such as "cool"). Record the first statement on your empty key sheet at the top. Now physically move the shoes into the two new groupings.
6. Work within your smaller group. The next step is to divide your group of shoes again. Here's a hint: notice that each grouping has only two answers. For example: "Divide into those that have blue laces and those that do not have blue laces." Notice that the question didn't ask you to divide into those with blue laces and those with green laces, since it is possible that other shoe lace colors, such as black, brown, orange, gray, multi-colored, or pink may be present. Record your division on your key sheet and physically separate your shoes into those groups.
7. Continue to work through the groups until each shoe has been individually identified. Be sure that you have recorded each step on the dichotomous handout that accompanies this lesson.
8. Once you have a completed key to the entire class, choose a classmate of yours and try to identify their shoe by working through the key. Were you able to properly identify them?
9. Discussion questions: Would the cue "shoes with mud on the bottom" work in your key? What if you used this key in the classroom tomorrow? Would the muddy shoe statement still lead to the same set of shoes? For the same

reason, the easiest and best plant keys do not depend on having a flower or fruit visible; you might have one to look at today, but next week is a different story. It is, however, quite common for keys to focus on flower and fruit characteristics, as they are quite often necessary for proper identification.

Part Two: Tree key

Key out a tree species to genus in your schoolyard using the dichotomous tree key at <http://oregonstate.edu/trees/index.html>. Your teacher will provide photographs if your school has no trees or the plant materials are not available due to the season.

1. The first step in this key will ask you if you have a conifer or broadleaf. The webpage provides a definition of the terms. Subsequent steps will help you to narrow down to the genus of your tree.
2. Walk through the steps of the key by following the numbers until you reach the genus name for your plant. From there you may be able to identify your plant species by looking at field guides from your region.
3. Confirm that you have arrived at the right species by finding a description for the appearance and habitat of your species and make sure that they match with the individual you chose. For example, if you chose a tree from a low wetland and then the species you arrive at lives in the mountains, you know you have made a mistake somewhere in the key. This happens to professional botanists all the time. When this happens, go back to any couplets (pairs of statements) where you were unsure about which statement to choose and choose the one you had not chosen the first time. Keying out a difficult species can be an adventure so have fun with it!

(Hint: It helps to write down which choices you make as you key out a species.)
4. Even if you think you know the name of the tree, work through all of the steps in the key for practice. When you finish, try another species. The more you do this, the easier it gets!



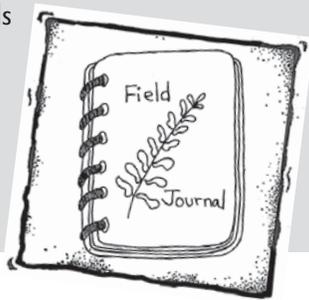
Mechanics of a Key

In the Field

Learning to identify plants has been the backbone of this section of this curriculum. You have learned about plant terms, plant families, scientific names, plant keys, and you now have the skills and tools to identify plants. So, get out there!

Take a local field guide out into nature and identify the plants you see! You can even “branch-out” from the trees learned in this lesson. Look for helpful clues, such as the ecology of your plant. Are you looking at a plant in a wetland, grassland, desert, on a mountain or in a forest?

You now have the basic tools to identify plants; it is now your challenge to increase your skills with practice, practice, practice!



EARLY FINISHERS

Continue to key out other tree species. The more practice you get, the more proficient and confident you will become with identifying plants using dichotomous keys.

Self Assessment



- 1** Explain how to use a dichotomous key.
- 2** Cooperate as a group to construct a simple key.
- 3** Key out a tree using a dichotomous key.

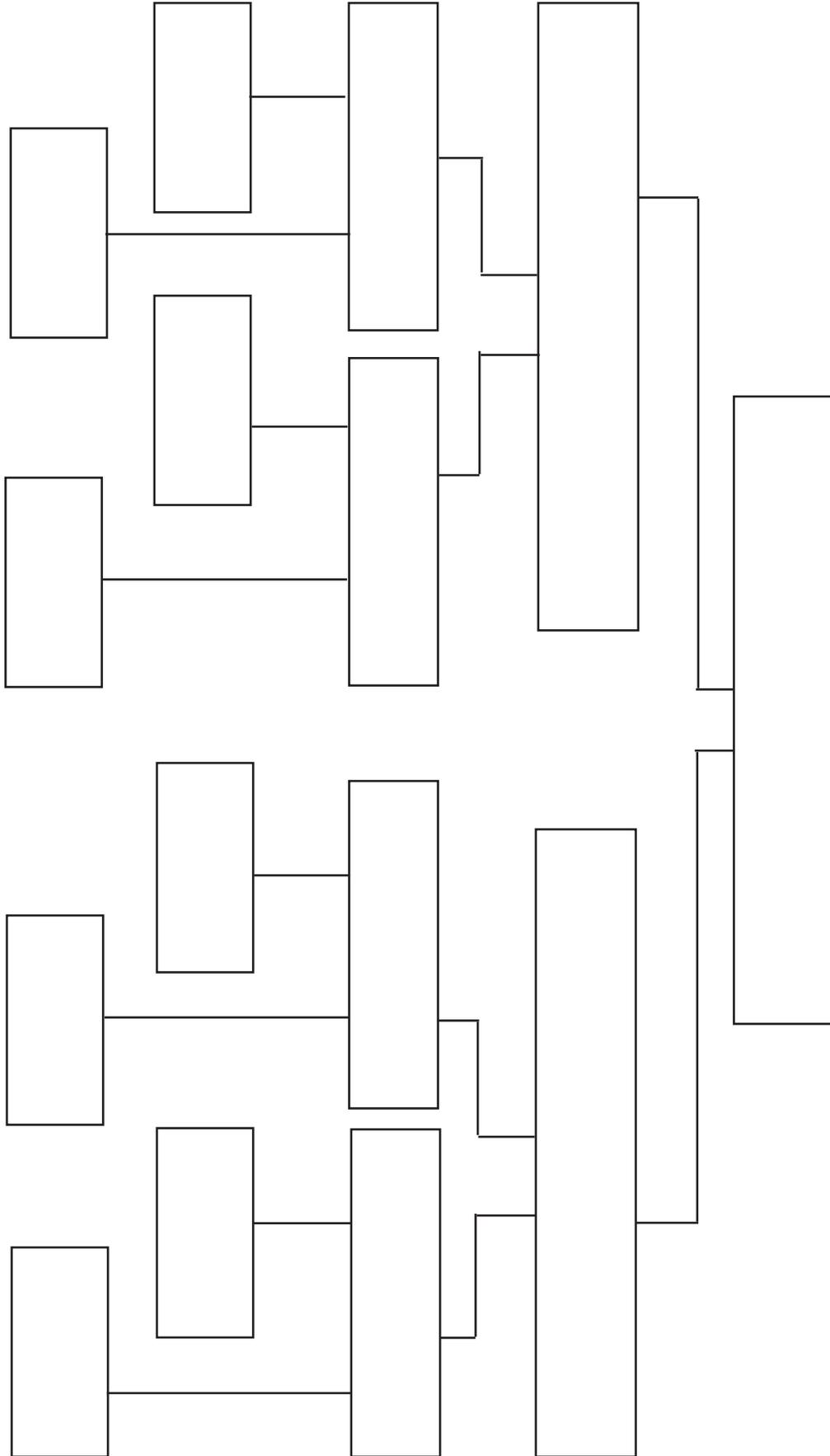
Resources

- *Trees and Shrubs of New Mexico*. 2012. Jack L. Carter. Revised and Expanded.
- Field guides for your ecoregion (see Appendix 1 for listings)
- New Mexico Envirothon Tree Identification: Tree Identification, Forestry Key #1 Tree: <http://nmenvirothon.org/categories/forestry>
- Identification Study Guide: https://swamericana.files.wordpress.com/2011/02/ch-1_nm-trees.pdf
- Virginia Tech Dendrology Tools; Dichotomous Keys: <http://dendro.cnre.vt.edu/dendrology/ident.htm>
- Detka, Jon. *Designing & Using a Dichotomous Key. Return of the Natives: A Cycle of Restoration Curriculum.*
- Watershed Institute California State University Monterey Bay; <http://ccows.csUMB.edu/pubs/>



*Student
Project*

Mechanics of a Key



Construct Your Own Key

Add more branches and boxes as necessary.



Make A Field Guide

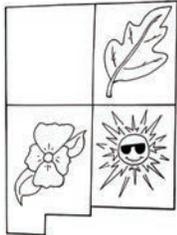
"The voyage of discovery is not in seeking new landscapes but in having new eyes." -*Marcel Proust*



Time Estimate

Class and field time varies depending on the scope of the field guide

Best Season



Fall
Spring
Summer

Overview

Students culminate the exploration of botanical skills learned in the plant identification section of this curriculum by constructing a field guide to the plants (and more, if desired) of a natural area on or near the school grounds.

Preparation

1. Before taking students outdoors, scope out a suitable location for this activity, preferably on the school grounds or close by. If possible, use a natural area with a diversity of plant species. If this is unavailable, students may use ornamental landscape plants.
2. Divide the students into teams of four or fewer.

Teacher hints

- You and your students will need to understand dichotomous keys and how they are constructed (from the previous chapter) as well as the components of a field guide before beginning this activity. The Plant Creation Checklist from the "Create-A-Plant" chapter will be helpful for this activity as well.
- Consider the scope of your guide. For example, you could have students produce a guide to just the trees in your school yard, or broaden the scope slightly to include both trees and shrubs.
- One possibility is to build your guide year by year, so that the first class produces a guide to trees, the next year produces a section on shrubs, and the following year adds a section for wildflowers.
- To make this lesson more challenging, instruct your students to choose plants for their key that have a lot of physical similarities (i.e. several grass species). To make this lesson easier, have your students choose plants that are obviously very physically different.

Assessments

Exchange keys among student groups and have each group test other groups' keys for effectiveness. Write a peer review of the key or guide that others have constructed. The review should be balanced, noting both positive attributes of the guide and giving constructive suggestions for improvement.

- 1 What works well about the key?
- 2 Did they include terminology that you could understand?
- 3 Were the steps of the key easy to follow?
- 4 What constructive suggestions can you give for improving the ease of use?



Make A Field Guide

"The voyage of discovery is not in seeking new landscapes but in having new eyes." -*Marcel Proust*

Materials Needed

Part 1

- flagging tape
- Construct Your Own Key handout from "Mechanics of a Key" lesson
- clipboard
- pencils
- waterproof marker
-

Part 2

- Plant Creation Checklist from "Create-a-Plant" lesson
- colored pencils
- digital camera (optional)
- computer (optional)

Overview

Put your new plant identification skills to work. Use your knowledge of dichotomous keys, plant terminology, families, and scientific names to construct a key to a natural area on or near the school grounds.

Learning Objectives

1. Learn to use a dichotomous key
2. Develop the ability to phrase key questions to construct a key
3. Create a key for others to use

Background

In this activity, you will design a field guide to the plants (and more if you like!) on your school grounds or a natural area in your community. A field guide will be an excellent asset to your community and will provide other visitors to the area with important natural history and botanical information. Your teacher may ask that you engage in additional community service opportunities, such as using your field guide as a tool to lead groups on tours, or giving presentations to groups to promote use of the area. The previous activity, "Mechanics of a Key," gives you the groundwork for constructing a **dichotomous** key, which will be necessary to include for people to be able to use your field guide.

To ensure the success of your dichotomous key, each question can only have two possible answers. Your key will not function properly if there are more than two answers per question. Read the following pair of statements and find the problem: "Plant is less than 30 cm tall." OR "Plant is more than 30 cm tall." In which category would a plant that is exactly 30 cm tall be placed? This statement needs to be reworded to read: "Plant is less than or equal to 30 cm tall OR plant is more than 30 cm tall." Now there are only two possible options.

The Plant Creation Checklist from the Create-A-Plant chapter will give you an idea of the type of information that should be included in a field guide. Review the background information for this activity. Use the other skills from the plant identification section (such as terminology). Each page in your field guide should include a photo or drawing (or both) that shows the general look of the plant with close-ups for distinguishing features. The following is an example of what a page for quaking aspen (*Populus deltoides*), the most

Vocabulary

dichotomous





Make A Field Guide

common tree in the world, might look like. Key features to be sure to include for each plant are in parentheses:

Common Name: Quaking Aspen (a.k.a. trembling aspen, aspen, popple, mountain aspen, white poplar)

Scientific Name: *Populus tremuloides*

Family: Salicaceae (willow family)

General description: The bark is usually smooth and very pale green to pale white with a dusty look, or cream, or pale to dark yellow green, or a whitish green. Near the base of the trunk, in the lower few feet, aspen trees may have gray to very dark gray slashed or fissured bark, usually caused by winter feeding of animals especially elk.

Leaves: Aspen leaves are nearly round, a broad oval, or heart shaped; 1 1/2 to 3 1/2 inches (3.8 to 9 cm) long and wide; sometimes larger especially on young shoots. Pale green to pale yellow green in color; bright yellow in autumn and sometimes yellow-orange or red-orange. 20 to 40 small teeth per side of the leaf blade. Leaf stalk is 1 to 3 inches (2.5 to 7.5 cm) long and flattened. The flat leaf stalks allows the leaves to flutter back and forth in the slightest breeze. (Include: arrangement; simple vs. compound; color; size; basic shape; margin description)

Flowers: The small light green male (staminate) and female (pistillate) flowers are on separate trees (dioecious), each type of flower borne in pendent catkins. Flowering occurs March–April (East) or May–June (West), before the leaves appear and fruiting in May–July, often before the leaves are fully expanded. Temperatures above 12 ° C for about 6 days apparently trigger flowering. Female trees generally flower and leaf out before male trees. (Include: where applicable: odor; color; number of petals; symmetry; size; arrangement; time of emergence)

Fruits: The fruits are narrowly ovoid to flask-shaped capsules 5-7 mm long, splitting to release about 10 seeds; seeds 2 mm long, each with a tuft of long, white, silky hairs, easily blown by the wind. The common name is in reference to the shaking of the leaves in light wind. (Include: type, color, size, description, mode of dispersal)

Ecology: Quaking aspen is the most widely distributed tree species in North America. Generally found in well drained but seasonally moist soils. Generally lives in large vegetative clumps of genetically identical clones.

(Include: where it lives; with what other species; specific soil types or habitats if relevant)

Enthonobotany: Aspen bark contains salicin, a chemical closely related to aspirin, and the bark was used by Native Americans and pioneers to treat fevers. Native Americans used *Populus* buds (including aspen) for food and chewing gum. In times of famine, they also scraped off and baked cakes from the inner bark or ate the inner bark raw.

(Include: how did Native American tribes or other people use this species?)

Wildlife habitat, uses, and other cool facts: Young quaking aspen provides food and habitat for a variety of wildlife: black bear, deer, beaver, porcupine, elk, grouse and many smaller birds and animals, including small mammals such as mice, voles, shrews, chipmunks, and rabbits. Bark, buds, new sprouts, twigs from the tops of fallen or logged trees, and fallen leaves all are wildlife foods. Beavers love to eat the bark, and use stems and trunks for lodges and dams. The seeds are eaten by grouse. The twigs, bark, and buds are eaten by pika, beaver, deer, elk, mountain sheep, moose, bear, squirrel, rabbits, and porcupine. Mountain men, early fur trappers and explorers who preceded the miners and settlers by decades fed aspen leaves and bark to their horses when other forage was lacking. Bark damage by browsing animals, especially elk, makes an entry point for disease.

Aspen stands are good firebreaks, often dropping crown fires in conifer stands to the ground when they reach aspens and even sometimes extinguishing the fire because of the small amount of flammable accumulation. They allow more ground water recharge than do conifer forests and they also play a significant role in protecting against soil erosion. They have been used in restoration of riparian habitats. Individual trees of quaking aspen are short-lived (maximum age is up to 150 years in the West). The clones are much older: many in the Rocky Mountain and Great Basin regions are at least 8000 years old, persisting since the last glacial retreat. (Do some research to learn more about your plant's wildlife uses and other cool facts. Consider including observations about your species in the area you are working—for example, perhaps there is a large stand of your plant on the south edge of the property, or you notice that the plant seems to prefer the shade of certain trees, type of soil, etc).



Make A Field Guide

Student Directions

Part 1: Construct a key

1. Divide into teams of 4 or fewer.
2. Each team should first select individuals of different plant species from a small area. To make this project more challenging, choose plant species that share more obvious similarities. Place a flag next to each one and number consecutively with a permanent marker. Choose plants with flowers or fruit if they are available. Try to choose plants that are fairly close together for ease of comparison. Carefully examine each of your plants.
3. Devise the first pair of statements for your key. Remember: Begin with statements that are broad and general and apply to all of your individuals. For example: "Plants have woody stems" OR "Plants are herbaceous (non-woody)." All paired statements should have only two possibilities. Be sure that none of your options are subjective or relative. For example, you cannot ask if a plant is tall or short. You must give specific measurements.

Be careful with statements that can vary greatly from one individual plant to the next (such as colors or measurements). Be sure to observe several individual plants of the same species before deciding to include these in your key.

Consider the time of year. If you are doing this activity in the spring, the same species might be much taller later in the summer. You can cross-check your information with a field guide for your region or an on-line source.

4. Continue working through your key in this manner until your key directs the user to each individual plant through the series of statements.
5. Fill in your blank key handout when you are confident that the questions you have chosen will lead the reader to the individual plants.
6. When finished, exchange the test keys with another group and try to work through their key filling in the number of the plants for the answer. When you are done, look at the answer key. How did you do? What parts of their key work well and are clear? What parts are confusing? How would you improve their key?

Part 2: Make a field guide for a natural area in or near your schoolyard

1. Do a complete survey of the plant species in the area you will be describing. Note the habitat and specific locations where each is growing. Record vital information for each of the plants that are in your key on the identification handout. Describe the plants as completely as possible, using correct plant terminology. Include a sketch or photograph the species.
2. Use a published plant field guide to identify your species. If you are unable to make a positive identification, collect a specimen to press (ONLY collect if you have permission) and check with local experts who can help you identify them (check the appendix of this guide for a list).
3. In the classroom, use the internet and other field guides to collect research about your species. Collect additional information on bloom times, flowers, fruits, and the scientific name. Be sure to find out to which plant family your species belongs.
4. Assemble your information together in the form of a field guide page for your species. The first pages of your guide should be a dichotomous key to all of the species. Devote a half or whole page of your field guide to each plant. Include a description, drawing or photograph, the common and scientific names, and anything else interesting that you discovered in your research. Use published plant field guides as examples for the type of information that is important to include.

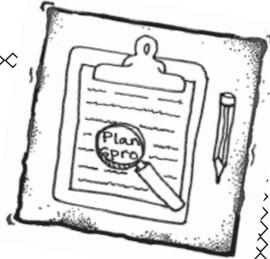




Make A Field Guide

Reflection

Like most skills, plant identification improves with practice. Do you feel that you have the tools you need to identify plants? Write the steps that you would use to identify a plant with which you are unfamiliar. Make a list of skills you need to practice or improve on to make plant identification easier for you. This can be called your plan of study for plant identification. Could this planning process help you learn another skill or help with a different subject at school?



EARLY FINISHERS

Use your inquiring mind. Design a different way of sorting or classifying plants to identify them. Some field guides divide plants by growth form or flower color or plant family. What other ways can you come up with? No classification system is perfect. What are the advantages and disadvantages of the system you chose?



Self Assessment

- 1 Does your key use proper botanical terminology?
- 2 Is your field guide usable by someone who has never been to the area you are describing?
- 3 Is your field guide usable by someone who is unfamiliar with how to identify plants or the other species you may have included?
- 4 Check your paired statements to make sure that they have only two possibilities.
- 5 Test your key to see if you can easily follow it to the proper plant.

Resources

- Field guide examples (see Appendix I for recommendations)
- USDA/NRCS PLANTS Database home page for additional plant research: <http://plants.usda.gov/>



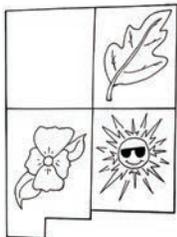
Make Your Own Plant Collection

"Are we happy to suppose that our grandchildren may never be able to see an elephant except in a picture book?" - *Sir David Attenborough*

Time Estimate

60 minutes in the classroom;
An additional session is
required for In the Field!
Can be structured as an
ongoing project

Best Season



Fall
Spring
Summer

Overview

Make a plant press, collect native plants, and create a herbarium for your school. Students learn the skills needed for the project by assembling a plant press and making their own personal herbarium of local species. They will learn proper techniques for collecting, pressing, labeling, mounting, and storing plant materials. Students will practice their botanical terminology and plant identification skills.

Preparation

Introduce this lesson by starting a classroom discussion on what botanists and students can learn from a collection of pressed plant specimens.

1. Allows for the observation of plants at different stages in their life cycle (i.e. vegetative, flowering, fruiting)
2. Can be used as a reference to help identify plants
3. Provides a sample of the variability within a species
4. Provides an official record of what plant species are found in a particular area

Teacher hints

- Have students practice plant collection techniques using weedy species. Then move on to creating a native plant herbarium collection once proficient at collecting and mounting.
- Alternatives to making the cardboard presses described in this lesson include: purchase a plant press, make your own from plywood boards, or use old telephone books for additional weight to press the plants flat.
- For the class herbarium, use archival quality paper and glue for mounting the specimens. Store specimens lying flat in large boxes or metal cabinets for long life. Keep them out of sunlight. Monitor periodically for insect damage.

Assessments

- 1 Produce four herbarium specimens using correct procedures for collecting, pressing, mounting, and labeling each specimen.
- 2 Record complete field notes when collecting: include date and location of collection, plant description, and habitat notes.
- 3 Label the specimen with common and scientific names using the proper form and demonstrate correct use of botanical terminology.



Student Project

Make Your Own Plant Collection

Materials Needed

- newspaper
- mounting paper – heavy cardstock for individual specimens; archival paper for class herbarium
- herbarium glue
- small paint brushes
- 5-6 cardboard pieces per student (8 1/2 x 11 inches)
- acid-free resume paper (for labels)
- large rubber bands or webbing straps
- plant pruner for collecting
- shovel or trowel

Vocabulary

herbarium

herbaria

“Are we happy to suppose that our grandchildren may never be able to see an elephant except in a picture book?” – *Sir David Attenborough*

Overview

Through this activity, you will learn the botanical skills needed to record and preserve plant specimens by creating an herbarium. You will assemble a plant press and make a personal herbarium of local weed species. In doing so, you will learn the proper technique for collecting, pressing, labeling, mounting, and storage of your collection. This will also give you an opportunity to practice using your plant identification skills. You will also participate in making a classroom herbarium by creating or adding to a collection of native plant specimens for your school.

Learning Objectives

1. Learn and demonstrate proper techniques for collection, drying, preserving, and cataloging plant specimens
2. Contribute to a classroom herbarium with a usable system of organization
3. Use botanical terminology as well as common and Latin names to correctly describe a plant specimen (review)
4. Practice plant identification skills (review)

Background

An **herbarium** is a library of dried, pressed plant specimens that are identified, labeled, and catalogued for posterity. Herbarium specimens can be used for many purposes. Accurate identification of a freshly collected plant can be made by comparison with an herbarium specimen. **Herbaria** are used by scientists in their studies of plant form, to compare range and measurements, and to help in the construction of guidebooks. More recently, specimens are used in DNA analysis to study plant relationships.

Each specimen in the herbarium is labeled with the name of the plant, the person collecting, date collected, and location of collection. Often the label will include additional helpful information like the plant community the specimen was found in, soil type, pollinators or known uses. Herbarium specimens are treated with the utmost care so that they will survive and be available for study for hundreds of years. These specimens are the historic record of plants, where and when they have grown. Additional applications for the study of herbaria specimens include how climate change has affected plants. For example, specimens can document the range of species, demonstrate change in characteristics over time and across habitats, track the





Student Project

Make Your Own Plant Collection

spread of non-native weeds, and confirm the former ranges of now rare plant species.

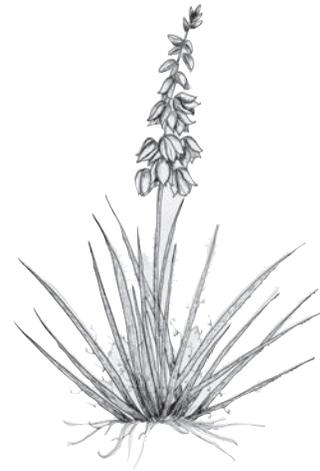


Herbaria are located around the world and are often housed at museums, botanical gardens, or universities. Many modern day herbaria are available online for access worldwide. The largest herbarium collection in the world is found at the Museum National d'Histoire Naturelle in Paris France with over 8 million specimens.¹ In the United States, The Academy of Natural Sciences in Philadelphia, Pennsylvania houses a very famous herbarium collection from the Lewis and Clark Expedition 1804-1806. This collection is documented so that it can be cross referenced to the dates and locations found in the diary entries of the Lewis and Clark. The Museum houses 226 specimens from the expedition which are still in amazing condition more than 200 years later.²

The Museum of Southwestern Biology at the University of New Mexico in Albuquerque houses New Mexico's largest herbarium. The focus of the museum is to document and preserve a record of the flora of the state. The herbarium houses more than 130,000 specimens; most are from New Mexico and the southwestern U.S. These specimens represent over 7700 species and serve as a reference for what's been documented within the southwest region. Our collections are used by scientists, plant enthusiasts, artists, archaeologists, anthropologists, geologists, and, occasionally for unanticipated uses. It is interesting that, after over 100 years, the potential uses of this collection are still unfolding and answering new questions.³

Herbaria are made up of plant specimens that are dried and pressed so as to highlight features that enhance identification. A specimen should include all parts of a plant, including roots, flowers, and fruit, if possible. The collected plant is carefully positioned on blotter paper, labeled, sandwiched between layers of cardboard, and tightly squeezed within the plant press until dried. Plant collectors will document the location, date, and all other pertinent information in a field book. Once the plant is completely dry, it is mounted on archival quality paper with a detailed label. Herbaria sheets are collected into folders by species and folders are filed alphabetically by family, genus, and specific epithet. The folders are stored lying flat, usually in metal cases or cabinets in climate controlled rooms to help preserve them.⁴

Herbaria can also be very useful for figuring out where extinct or very rare species previously existed. Written records on specimen labels indicate location and habitat information that can be used by conservation biologists to decide where to relocate species that they are reintroducing.



One more important aspect for consideration in the development of an herbarium is your plant collection ethic. Below is a list of ethics that can guide you. Look them over and discuss them as a class. Should they be expanded? Why or why not?



Make Your Own Plant Collection

Ethics of Collecting Guidelines:

- Tread lightly – what does that mean to you?
- Don't take any plants that you will not be pressing
- Take care not to spread seeds of invasive plants
- Know your region's rare and endangered plants. If you are lucky enough to find them, take only pictures of these.
- Do not collect a plant if you do not see at least 10 others of that kind in your location. Why is this important?
- Be aware that you may be harmed by your interaction with some plants. Take necessary precautions and watch for plants that can sting, have thorns, or give you rashes.
- Learn the process of collecting, pressing and mounting a plant collection by using readily available local weeds to start. Although pressing plants sounds fairly straight forward it takes attention to detail and careful handling to do it well. Practice the techniques first and then move on to developing a school herbarium project.



Student Directions

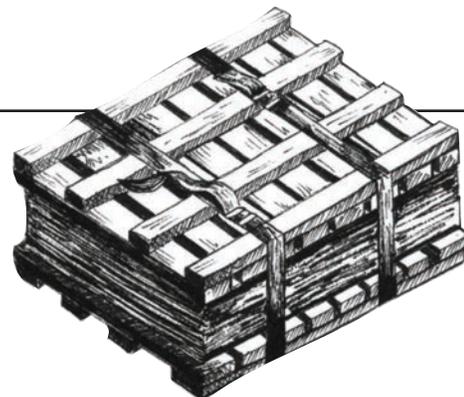
1. Assemble a personal plant press. (The traditional press is 12 x 18 inches, but a smaller press can be used for convenience.) You will need 5-6 pieces of heavy cardboard, several sections of newspaper, and 4 long, heavy rubber bands. Cut the cardboard pieces to the size of a folded newspaper. Use newspaper as your blotter paper to position your plant specimen, plus use additional layers of newspaper between each specimen to help absorb moisture. Use an 8 1/2 x 11 sheet of paper as a size guide; your finished specimen will be mounted on this size paper.
2. Make a weed collection from your home, roadside or vacant lot (follow the steps below). Collect 4-5 different weed specimens. Do not collect from parks, natural areas, or personal property without the owner's consent. **BE RESPONSIBLE**; do not spread weeds. Be sure to contain any seeds that may fall off your collections and dispose of extra weedy materials that you bring back to the classroom in the trash.
3. To collect your first plant; carefully dig up a weed. Try to collect a plant that is average size and vigor of nearby plants. This will make a better example of the species than a plant that is the smallest that you can find. Gently clean the dirt from the roots of the plant.
4. Arrange the plant on the inside of a folded newspaper. Once the plant is dried, you will not be able to move parts around without breaking it. You must be careful to arrange the plant to properly show its leaves, roots, flowers and/or fruits. Lay a leaf out flat so that you can see the shape and show the arrangement along the stem. Include flowers, if possible, (arrange some flat open and some in profile) and fruits. Include the roots if you can; brush the excess dirt off before putting in the press. If your plant is too tall to fit on the newspaper, you will need to bend the stem to make it fit. Another mounting method if your plant is too large for one sheet of paper is to cut the plant and position it on more than one sheet. Number the sheets so that they can be



Make Your Own Plant Collection

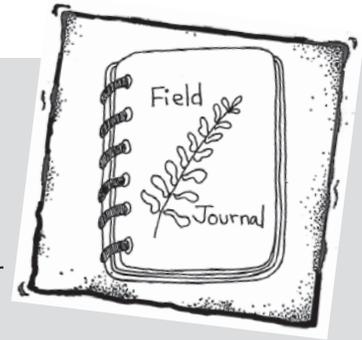
reassembled in the proper order. Try to minimize overlapping plant parts; it can lead to moldy plant parts and makes them hard to see once they are dry.

5. Label each specimen with a number directly on the newspaper and a corresponding numbered entry into your field journal. Include the name of the plant if you know it, the location, date, your name, and any additional information that you can. Additional information may include the names of other plants growing nearby, the type of ecosystem (forest, field, wetland), whether it was growing in the sun or shade, pollinators observed, or notes about the soil.
6. If for some reason you cannot put your plant in the press right away, seal it in a plastic bag and keep it out of direct sunlight until you can place it in the press. Try not to squish it or break any of the branches.
7. Assemble specimens in your press like layers of a sandwich. The cardboard is the bread; add a few layers of newspaper, then your specimen, another couple layers of newspaper, a piece of cardboard for strength, and repeat until the press is full. Finish with a final cardboard piece and bind with 4 large rubber bands.
8. Take your press home. Lay it on a flat, dry surface in a warm location to dry (a sunny window, the top of the refrigerator, a furnace room, or a car with the windows rolled up will suffice). Add additional weights (books) to help squeeze the moisture out of the plants. If you have a very succulent plant, change the newspapers every day for the first couple of days.
9. Leave the plants in the press until completely dry. This can range from a couple of days to a couple of weeks, depending on the thickness of the plant material and the air temperature and humidity.
10. Mount the specimen once it is completely dry. Use heavy cardstock paper for display. Carefully remove the specimen from the newspaper by the stem. It might be helpful to use tweezers when working with delicate plant material. Arrange the dried plant on the paper and adhere with drops of glue at multiple points along the stem and the outer leaves. For heavy plants, you can glue strips of paper over them to hold at key points. Set aside and let the glue dry before handling.
11. Design a label to go on your specimens. Be sure it includes the plant name, date, your name, where it was collected, and any special notes. Glue a label to the bottom right corner of the paper on which you mounted your specimen.
12. Write a habitat description that goes with your pressed plant. Include a general description of the form and identifying features of your species. Specimens will fade with age so be sure to include notes in the description on the flower and leaf color.
13. Contact a plant expert (examples: a local nursery, local Forest Service or BLM botanist, Native Plant Society member) if you are having difficulty identifying your specimen.
14. Visit one of the online herbaria listed in the resource section to see an example of a mounted plant specimen and label.





Make Your Own Plant Collection



In the Field

Create an herbarium for your school. Give the herbarium a theme that can be expanded or added to from year to year (examples: plants on the school grounds, or from a natural area that students visit regularly, or a broad ecoregion collection). Offer tours of your herbarium to other science classes or to younger grades in your school.

- Be careful not collect too many samples of a single species. Work to fill gaps in the herbarium collection if it is already an ongoing project.
- Reread the Ethics of Collecting Guidelines in the background section before going out to collect.
- Learn which rare and endangered plants exist in the area from which you will be collecting so that you can avoid collecting them. Over collection is one of the causes of decline for several rare plant species. Instead, take a digital camera and make a visual record of the plant if you are lucky enough to see one. Get an overall photo of the plant, a wider photo showing the habitat, and multiple close-ups of leaves, stems, flowers, and fruit. Take notes as you would if you were collecting a specimen. Mount the photos and include the page in your herbarium.

Reflection

How can you be sure that you are not damaging a rare plant population? Is there a time that taking a rare plant specimen would be acceptable? Justify your reasoning. Can you add at least one additional rule to the Ethics of Collecting plants? What would it be?



EARLY FINISHERS

Develop a filing system for the class herbarium. Specimens are commonly organized alphabetically first by family, then genus, and finally the specific epithet. Write an explanation of how your system works so that others can follow it. Organize a way to track additional records, such as a notebook with a page devoted to each species and a way to enter information about occurrences including the name of the observer, the date, and location. Be sure to make it easy for visitors to access the needed records.

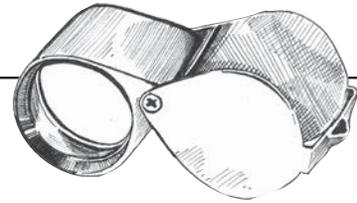


*Student
Project*

Make Your Own Plant Collection

Self Assessment

- 1** Evaluate your pressed plant specimen. Are you happy with the way the pressing turned out? If not, review the procedures. Did you accurately follow them? If you are unhappy with your pressing, try it again, making sure that the plant has as little moisture in it as possible and that you have positioned it carefully.
- 2** Design a label to go on your mounted pressing. Did you record complete field notes including date and location of collection, plant description, and habitat notes to make a good label?
- 3** Evaluate your written description. Did you use proper botanical terminology? This may be important if you need help from a botanist to identify your plant.



Resources

- The New York Botanical Garden herbarium is the largest in the western hemisphere, with over a million and a half digital specimens available online. This diverse herbarium has specimens from around the world, and includes vascular plants, fungi, and lichens: <http://www.nybg.org/science/>
- The Ohio State University Museum of Biological Diversity Herbarium can also be accessed online. This herbarium has worldwide coverage, with a focus on the flora of the Northeastern U.S. View the specimens at: <http://herbarium.osu.edu/>
- The Wikipedia website has a list of herbaria located in the United States organized by state: https://en.wikipedia.org/wiki/List_of_herbaria_in_North_America
- New Mexico's Herbarium is located at the University of New Mexico in Albuquerque; the Museum of Southwestern Biology: <http://msb.unm.edu/divisions/herbarium/>

Create-A-Plant

"Creativity is intelligence having fun." -*Albert Einstein*



Overview

In this lesson, students will explore plant adaptations and demonstrate their accumulated plant identification knowledge and understanding by designing their own fictional plant species. Working from a checklist of possible traits, students will determine the physical characteristics, ecology, habitat, history, and uses of their newly invented species. Students will show their understanding of the connections between anatomy and habitat by creating a field guide page with a sketch of their plant, a written description, and will give their plant both a common and scientific name.

Teacher hints

- Be sure that students have a basic foundation in plant terminology before using this lesson. The "Botanical Terminology Challenge" lesson provides a review or a means of learning this new vocabulary.

Preparation

1. Make copies of the Plant Adaptations Chart for students to use in designing their plants.
2. Have field guides for your region (see Appendix I for suggestions) available for students to view. Point out features on the pages such as the physical description of the plant, habitat, confusing species, and special characteristics and uses or whatever your particular field guide offers. Show the students photos, drawings, or diagrams of unique aspects of the species, measurements, plant descriptions, and habitat details.
3. Information about scientific names can be found in the "What's In a Name?" lesson of this curriculum.
4. Students apply their knowledge of botanical terms, scientific names, habitat, and life history characteristics. Students will make creative connections between the traits of their plant and how the traits help the plant adapt to the habitat they create for it.

Assessments

Students will submit their checklist and field guide page for grading. Check for the following:

- 1 Does their plant sketch and description match the checklist options?
- 2 Is the written description complete, using proper botanical terms, and including metric measurements?
- 3 Did the student use proper format for writing scientific names?
- 4 Did the student put thought into relating plant anatomy/adaptations to their habitat choice, dispersal mechanism and pollinator?
- 5 Was the student creative in crafting a unique species?



Create-A-Plant

"Creativity is intelligence having fun." -*Albert Einstein*

Materials Needed

- Plant Creation Checklist
- Plant Adaptation Chart
- Field Guide Page
- drawing materials
- metric ruler
- various field guides to use as examples

Learning Objectives

1. Demonstrate knowledge of botanical terminology
2. Correlate plant characteristics (form) with adaptation to habitat and life history (function)
3. Apply knowledge of scientific and common names
4. Engage imagination to advance scientific and critical thinking processes
5. Associate visual images with new vocabulary by labeling drawings to accentuate important plant identification characteristics

Vocabulary

adaptation
habitat

Overview

Demonstrate your understanding of botanical vocabulary and natural history by inventing a new plant species. You will explore the diverse adaptive strategies plants use to survive in various habitats. You will choose the physical and ecological characteristics of your species from a checklist of traits and give it a common and scientific name. In the end, you will create a page with a detailed sketch of your new species and a written description.

Background

Plants can be found growing nearly from pole to pole on our planet, thriving under a vast diversity of conditions. From dry deserts to frigid tundras to rainforests, every environment provides a unique suite of challenges to the plants that live there. In order to survive, plants have adapted to the environments in which they live through generations and generations of natural selection. This is called **adaptation**.

Because plants are immobile, they cannot move around to find resources and more favorable conditions. This puts them under extraordinary pressure to come up with adaptive strategies to survive and reproduce in the face of whatever challenges their environment delivers. In this way, plants become a reflection of their environment, both past and present. When you look at a plant, the characteristics you observe can give you clues about its **habitat** and the challenges that it faces in order to survive and reproduce. Consider a Rocky Mountain Juniper. A Rocky Mountain juniper five feet high may be over 100 years old. In northern New Mexico, Rocky Mountain junipers are some of the oldest trees in New Mexico. Some of these trees have lived in the exact same place for over 1,500 years, through all the conditions and changes and climates and are still alive!

Every physical feature that you observe plays some functional role for the plant. Not all adaptations are visible to the human eye. Physiological adaptations allow plants to survive in all kinds of environments, too. For example, in order to cope with hot and dry conditions, some plants open their stomata only in the cool of the night, and then metabolically fix and store the carbon dioxide they capture until daylight, when they can photosynthesize without losing precious moisture from open pores. In frigid temperatures, some plants can produce antifreeze proteins that slow ice formation.

Spend some time looking at the Plant Adaptations Chart provided here. This chart lists examples of adaptations that allow plants to survive under different conditions. As you look over the chart, you will notice that there



Create-A-Plant

are many strategies for surviving in a particular type of environment. Some of these strategies are almost complete opposites—for example, some desert plants have very short life cycles that can be carried out entirely during a short period of precipitation, avoiding drought altogether. Other plants living right next to these fast-paced annuals instead have very long life cycles, growing extremely slowly to cope with limited resources. The prevalence of desert plants using both of these very different approaches illustrates that there is no one best strategy for survival in a given environment.

Think about the unique conditions where you live. Is the climate mild or extreme? Does moisture fall predominantly as snow or rain in the winter? Are summers windy and dry or cool and moist? How are the plants that you see around you adapted to these conditions?

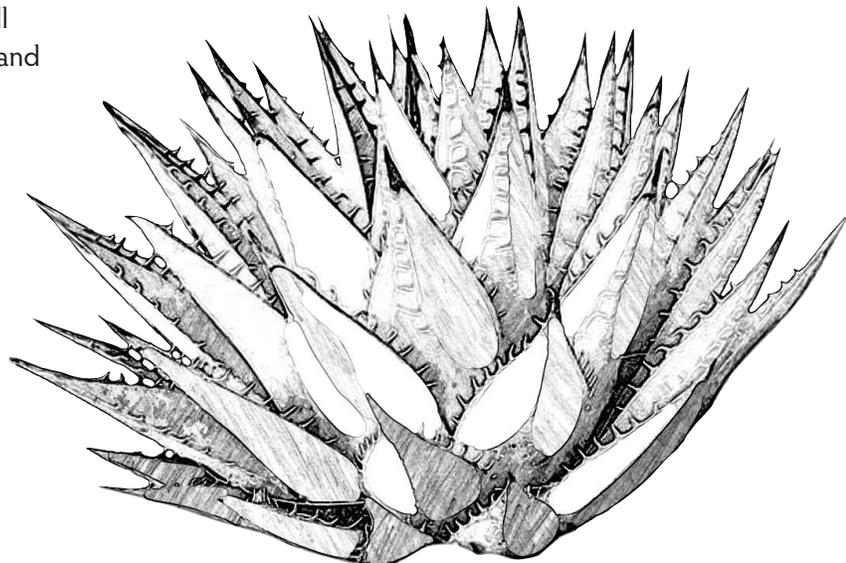
This activity will give you a chance to showcase what you already know about plant anatomy and terminology and expand your knowledge about adaptations. You will use your creative side to design a fictional plant. Remember that plants can appear as simple as a single tiny leaf, such as the pond-dwelling duckweed, or as complex as an elaborate orchid that grows in the canopy of a tree. Your plant can be large or small, woody or herbaceous. Does it have thorns or chemical defenses to keep it safe from predators? What makes your plant well suited to grow in the habitat you will choose for it? Be sure to give it the adaptations it will need to survive there. Remember, a plant's appearance and

traits are a product of the place where it lives and where its ancestors lived and evolved.

When you open a field guide, you may see that each species entry is frequently divided into sections. Each section contains information intended to help you identify your species and understand its natural history. Each field guide is different, but most contain sections with general information, as well as specific information about the leaves, flowers, fruits, ecology, and any special notes that will aid in identification. Plants are an extremely diverse group of organisms; the information presented in field guides organizes this diversity and helps to distinguish one species from another.

When you make your field guide page, be sure to include all the details that someone will need to identify your plant. Many field guides also contain ethnobotanical information regarding historical human uses of plants. Be sure to add this type of information for your created plant. For example, is your plant used for food, as a tool, or for medicinal purposes? In what other ways could plants be used?

Field guides include not only a written description, but also a photo or drawing. Draw your plant, illustrating the traits that you have chosen, being careful to show and label the features that make your plant unique.





Student Directions

1. Begin by choosing a habitat for your plant. Would you find it in the desert, forest, prairie, wetland, or elsewhere? Make your choice as general or specific as you like—perhaps your plant is a generalist that lives in grasslands around North America, or maybe it is endemic to a natural area near your hometown. Take a minute to think about what life is like in your chosen habitat; is it dry, wet, shady, sunny, hot, cold, or somewhere in between? Think about your habitat as you work through the checklist; what plant traits do you think would be most successful in your chosen habitat? For example, large flat leaves may lose excess moisture to evaporation and are not well suited to an arid habitat such as a desert but would work well in a shady forest understory. Use the “Plant Adaption Chart” adaptations for guidance.
2. Work through your “Plant Creation Checklist”. Choose one option from each section to define the characteristics of your plant. The list will guide the design of your fictional plant. If you come across an option that you do not understand, consult your terminology glossary, check a field guide or dictionary, or review earlier activities.
3. Create adaptations in your plant that relate to the habitat type that you picked on your checklist. Use the plant adaptations chart to come up with ideas, but don't be limited by the examples on the chart—this is by no means a complete list. Brainstorm other adaptations you have seen or heard of, or come up with some that are completely new. Be sure to explain each adaptation and how it benefits your plant.
4. When you have completed your checklist, design your field guide page. Use a piece of scrap paper to experiment with design options. When you are comfortable that your drawing shows your checked options, draw it in the box provided. Fill in the smaller boxes with close-up detail of your leaf, flower, and fruit. If you feel that it is important, you can draw your plants roots as well. Be sure your drawings clearly match your choices on the checklist.
5. Looking at your plant sketch, follow prompts on the field guide template checklist and write a description for your field guide page. Start with a general description of the plant and progress to the details such as leaf shape, leaf margin, and so forth through the page. Use botanically correct terminology for your descriptions.
6. A field guide will always include measurements to help in identification. Metric measurements are generally preferred in science. Measurements of greater than 1 meter (m) should be expressed as meters, while those less than 1 meter should be expressed as centimeters (cm), and you might even want to use millimeters (mm) for very small details. Include measurements for your overall plant size, and for individual details. You may show measurements by including a scale bar in your sketch or by including the information in your written descriptions.
7. Write a description of your fictional plant's habitat. Consider light, moisture, elevation, and associated vegetation. Describe the adaptations that help your plant survive in this habitat.
8. Give your plant a scientific and common name. As the first person to discover and document your plant, you have the honor of naming it. Consider using a descriptive name (after a plant trait), place name (a specific region found in) or even name it after a friend or local public figure. However, it is against the rules of Botanical Nomenclature (naming plants) to name a species after yourself. Show correct form for writing names. If you need a review, look at the “What's In a Name?” activity.
9. Show off your new species and completed guidebook page!



Create-A-Plant

In the Field

Visit a local natural area and observe the plants that you find there. What features do you notice that might help each plant survive in its habitat? How do these adaptations benefit the plants? Do you notice certain characteristics that are shared amongst many species in the same area? Record your ideas in your field journal.

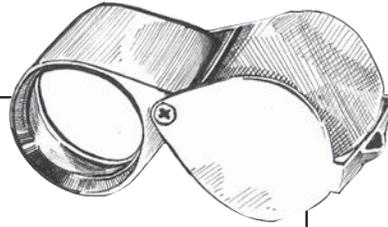


Reflection

Tell the story of the evolution of your plant. What did its ancestors look like? Where did they live? How have conditions changed since it germinated? What environmental conditions and challenges (also called "selection pressures") induced the changes and adaptations that are now evident in your plant? How might it continue to evolve in the future in a changing environment?



Self Assessment



- 1 Submit checklist and field guide page for assessment.
- 2 Does the checklist, sketches and description show that you have an understanding of the plant terms used?
- 3 Is the written description complete, using proper botanical terms, metric measurements, and a scientific name written in the correct format?
- 4 Did you relate your plant's anatomy to adaptations to its habitat?

Resources

Harris and Harris. 2001. *Plant Identification Terminology: An Illustrated Glossary*. Spring Lake Publishing, Spring Lake, UT. 206 pages.



Create-A-Plant

Plant Creation Checklist

Habitat Type (where does your plant live?)	
WETLAND	ALPINE PEAK
GRASSLAND	DESERT/ARID LANDS
FOREST	OTHER _____
Habitat Clues - Adaptations your plant exhibits that make it suited to live here:	
_____	_____
_____	_____
Stem	
SINGLE	MULTIPLE
Leaf attachment to stem	
PETIOLE 	SESSILE 
Leaf arrangement	
ALTERNATE 	OPPOSITE 
WHORLED 	BASAL 
Leaf margin	
ENTIRE	SERRATE
LOBED	OTHER _____
Leaf shape	
CORDATE	PALMATE
LANCEOLATE	OTHER _____
OVATE	
Leaf Division	
SIMPLE	COMPOUND

How does your plant protect itself from predation?	

Pollinator (refer to Secret Life of Plants lesson or learn more in the Native Plant Ecology section)	
BEE	BUTTERFLY
BEETLE	WIND
BIRD	MOTH
BAT	OTHER _____
Inflorescence Type	
COMPOSITE	SPIKE
RACEME	PANICLE
UMBEL	SOLITARY
Flower	
PERFECT	IMPERFECT
# OF PETALS: _____	# OF STAMEN: _____
Seed Dispersal Method (refer to Drupes lesson)	
MECHANICAL/THROW	ANIMAL/EDIBLE
WIND/BLOW OR SHAKE	ANIMAL/CACHE
ANIMAL/HITCHHIKE	OTHER _____
Fruit Type	
DRUPE	NUT
SAMARA	BERRY
LEGUME	OTHER _____
POME	
Ethnobotanical Use (historic human use)	
FOOD	TOOL
FIBER	OTHER _____
MEDICINAL	



Create-A-Plant

Plant Adaptation Chart

CHALLENGE	ADAPTATION	HOW IT WORKS	EXAMPLES
Limited Water			
	Hairs	Hairs slow down the movement of air over the surface of leaves and stems to minimize water loss by evaporation. Light-colored hairs can also reflect solar radiation.	Sagebrush, desert ironwood
	Water Storage	Some plants store large amounts of water within their stems and leaves for use during dry periods. Waxy coatings and thorns help protect these water stores.	Cacti, aloe
	Reduced leaves	Decreasing or eliminating leaf surface area minimizes water loss by evaporation.	Conifers, cacti
	Specialized root systems	Deep root systems allow plants to reach low water tables. Alternatively, extensive, shallow root systems maximize absorption of light precipitation by capturing water that doesn't infiltrate deeply into soil layers.	Mesquite, saguaro cacti
	Specialized Life Cycle	Rapidly developing annuals can carry out their entire life cycle during short periods of rain, avoiding drought periods. Other plants develop very slowly to minimize their requirements of limited resources, but live for many years.	Ghostflower, Bigelow's monkeyflower
	Dormancy	Both mature plants and seeds can remain inactive for long periods of drought. Growth can then be triggered very rapidly by precipitation.	Ocotillo
	CAM Photosynthesis (Crassulacean Acid Metabolism)	Some plants can conserve water by opening their stomata only in the cool of the night, and then storing the carbon dioxide they capture until daylight, when they can photosynthesize without losing precious moisture from open pores.	Cacti, purslane
High Moisture or Aquatic Conditions			
	Hollow or spongy stems	Air spaces in stems transport oxygen to waterlogged plant roots.	Cattail
	Flexible stems	Plants growing in the water column can bend in currents without breaking.	Water lily
	Prolonged seed viability	Seeds can wait to germinate for many years until they come in contact with soil and air.	Bulrush, cattail
	Floating leaves	Buoyant leaves allow plants rooted in standing water to reach sunlight and air. Stomata are located on the upper surface of the leaf for gas exchange.	Water lily
	Lenticels	Specialized pores allow plants to absorb nutrients, water, and necessary gasses from the water.	Willows
	Modified root systems	Modified and adventitious roots can extend above the waterlogged soil or water line to allow contact with oxygen. This also provides support in soft soil.	Mangroves
	Rot Prevention	Anti-fungal or anti-bacterial chemicals can help prevent rotting.	Cedar, larch



Create-A-Plant

Plant Adaptation Chart

CHALLENGE	ADAPTATION	HOW IT WORKS	EXAMPLES
Hot Conditions			
	Hairs	Hairs can insulate a plant against heat. Light-colored hairs can also reflect solar radiation.	Brittlebush
	Leaves used as shade	The arrangement of leaves, spines and persistent dead leaves on the plant can provide umbrella-like shade.	Joshua tree
	Altered daily rhythms	Flowers may open only at night to attract nocturnal pollinators that avoid daytime heat.	Evening primroses
Cold Conditions			
	Evergreen needles	Evergreen needles allow plants to photosynthesize all year, lengthening the short growing seasons in cold regions of the world. The narrow, waxy needles decrease water loss in areas where moisture is locked up as ice. They also help shed heavy snow to prevent broken branches.	Pines, spruces, hemlocks
	Deciduous leaves	Shedding broad leaves during cold months prevents damage from the cold and lack of water. Deciduous plants can be found where moisture is plentiful in some seasons, but unavailable in cold seasons because it is frozen.	Oaks, willows, maples
	Small size	Small, low-growing plants, sometimes called "dwarf," are more protected from cold air, and require less water and nutrients.	Arctic willow
	Hairs	Thick, woolly hairs help insulate plants against cold air and wind.	Lousewort
	Seasonal dormancy	Dormancy during the cold months prevents damage from the cold and lack of water. Soil moisture is often unavailable in cold conditions because it is frozen.	Broadleaf trees, larch
	Antifreeze proteins	Damage from freezing can be prevented with specialized proteins that slow ice formation.	Antarctic hairgrass
	Tussocks	A clumped or bunched growth form, sometimes called a tussock, helps trap warmth and insulate plants from cold conditions.	Arctic cottongrass
	Underground structures	Energy-storing structures like rhizomes and corms help plants get a head start in areas with a short growing season.	Arctic lupine
Limited Nutrients			
	Symbiotic relationships	Soil bacteria including Rhizobia and Frankia form nodules on the roots of certain plants and fix nitrogen into a usable form. Some fungi can help plants increase their absorption of water and nutrients. Under some soil conditions, certain nutrients can only be taken up by plants with the help of these fungi.	Legumes, alders
	Carnivory	In nutrient-poor soils, some plants obtain nutrients by trapping and digesting insects and other arthropods.	Pitcher plant
Limited Light			
	Vines	Vining plants use larger plants as ladders to reach light without putting energy into producing large supporting trunks and branches.	Grapes
	Broad leaves	Increased leaf area maximizes the photosynthetic capacity in light-limited conditions, but result in increased water loss as well.	Oaks, maples



Create-A-Plant

Plant Adaptation Chart

CHALLENGE	ADAPTATION	HOW IT WORKS	EXAMPLES
Limited Light (continued)			
	Specialized life cycle	Some understory plants in deciduous forests develop and mature early in spring in order to utilize light before they are shaded out by the growth of leaves on larger trees.	Spring beauty, trillium
	Height	Trees can grow very slowly under low-light conditions, eventually reaching incredible heights in order to reach sunlight at the canopy of a forest. A very strong trunk and root system are required to support such height, which can only be obtained through plentiful water and nutrients.	Oaks, cedars, maples, hemlocks
Fire			
	Serotinous cones	Cones can be sealed tightly by resin, open only after the intense heat of fire, which allows seeds to germinate under optimal conditions and repopulate burned areas.	Lodgepole pine
	Resprouting	Substantial underground structures like rhizomes, root crowns, and branches are protected by the insulating soil and can allow plants to survive and continue to grow after the aboveground portions have been burned.	Many grasses, Rabbitbrush
	Thick bark	Thick plates of armor-like bark can allow trees to survive some fires with little damage.	Ponderosa pine
Herbivory			
	Armaments	Different types of armaments work against different types of herbivores. Large thorns and spines deter larger animals like deer, while hairs can be effective at deterring insects.	Cacti, roses
	Toxins	A wide variety of toxins, both mild and potent, keep herbivores from eating certain plants. Effects can range from bitter tastes to skin irritation to fatal poisonings.	Poison ivy, water hemlock
	Protected crown	Buds and stored carbohydrates located in the crown at the base of a plant are protected and allow for quick and low-cost recovery if the top of the plant is grazed.	Grasses
	Mast-fruiting	This is a phenomenon where individuals of a certain species will produce very few seeds for several years, followed by a year of high seed production. It is thought that this helps keep the population of seed predators low so they don't devastate the seed bank each year.	White oak



Create-A-Plant

Field Guide Page

Plant Name

Habitat:

Description:

Leaves:

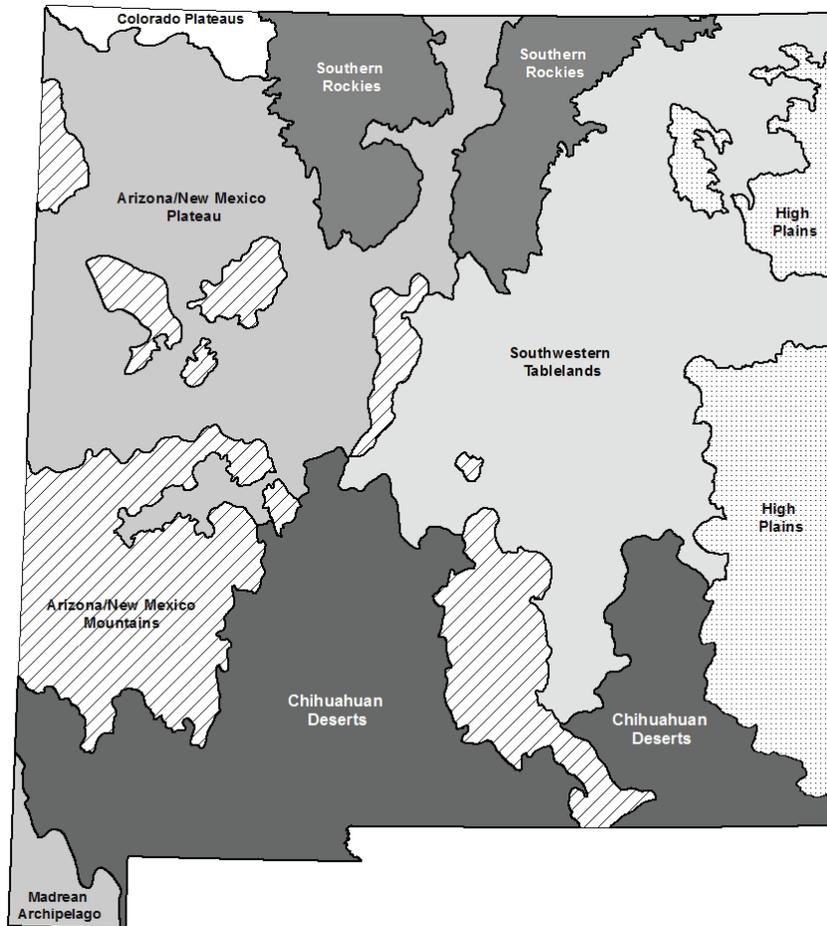
Inflorescence/Flower:

Fruit:

Ethnobotanical use:

Field Notes (include adaptations and defense):

Section 2: Ecoregions of New Mexico





Exploring New Mexico's Ecoregions

"There is an eternal landscape, a geography of the soul; we search for its outlines all our lives." –*Josephine Hart* (Contemporary)

Time Estimate

Part 1: 30 minutes
Part 2 and 3 combined:
60 minutes

Best Season



Winter
Fall
Spring
Summer

Overview

Students gain an understanding of the concept of ecoregions – geographic areas with distinctive climatic, geographic, and ecological features. Students will learn about the drivers of diversity in our landscape and explore the interactions between various biotic and abiotic features of the natural world. Students investigate New Mexico's eight ecoregions by gathering climate data, relating it to geography, and using inquiry skills to identify differences in vegetation from one ecoregion to another.

Preparation

1. Review the Student Resources section to become familiar with interpreting maps.
2. For Part 3 of the activity, have students work individually or divide the class into eight groups; each group can gather data for one ecoregion to share with the entire class.

Teacher hints

A great source to use for the ecoregion section is "Characteristics of the ecoregions of New Mexico"; this handout for New Mexico's ecoregions is available online or a hard copy can be ordered by contacting EPA staff on the ecoregions home page (<https://www.epa.gov/eco-research/ecoregion-download-files-state-region-6#pane-29>).

- This is a multi-part activity and each section has associated discussion questions provided. These questions are designed to stimulate thought for the subsequent ecoregion lessons.
- Combine this activity with a study of geology of New Mexico to help students connect New Mexico's landforms with the geological activity that produces them.
- Definitions for vocabulary words can be found in the glossary if not explained in the text.

Assessments

- 1 Discuss factors that define an ecoregion.
- 2 Name and locate the eight ecoregions of New Mexico.
- 3 Explain the connection between geography and climate.





Exploring New Mexico's Ecoregions

"There is an eternal landscape, a geography of the soul; we search for its outlines all our lives." –*Josephine Hart* (Contemporary)

Materials Needed

- computer with Internet access
- New Mexico topographic map
- New Mexico outline map
- New Mexico ecoregion map

Overview

An ecoregion is a geographic area characterized by a distinct climate, soil, geology, topography, and vegetation. You will learn about the drivers of diversity in our landscape and explore the interactions between various biotic and abiotic features of the natural world. In this lesson, you will compare and contrast New Mexico's eight ecoregions by gathering historical climate data, relating it to geography, and using inquiry skills to identify differences in vegetation of different ecoregions. Through this process you will discover the vast diversity of plant life in your botanically rich state.

Vocabulary

biome
abiotic
biotic
ecoregion
plant diversity
climate
weather
precipitation
topography
watershed
latitude

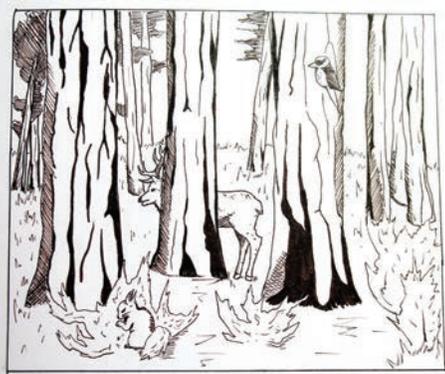
Learning Objectives

1. Locate and name New Mexico's eight ecoregions
2. Use the library and internet for resources and research
3. Describe and gain understanding about the connections between the geology, climate, and vegetation of the ecoregions of New Mexico
4. Appreciate the variety of New Mexico's diverse landscapes and the biodiversity it supports
5. Use maps as a tool to gather and correlate information relating topography to climate

Background

New Mexico is enormously rich in biodiversity. If you were to walk starting at the Continental Divide on the Colorado border and traverse south through New Mexico to Texas, along the way you would encounter a myriad of vegetation communities such as high elevation alpine systems, different kinds of forests, shrublands, riparian valleys, grass-covered plains, lava fields and volcanic plateaus, and arid deserts. As you look around New Mexico, you will notice the vegetation can change drastically depending on where you are. You may run into a lush wetland with scores of migrating birds or a barren lava flow or gypsum dune with very little vegetation at all.

At a broad level, the different types of ecosystems are organized into **biomes**.¹ Types of biomes include forest, desert, grassland, tundra, marine, and freshwater. However, not all forests are the same; nor are any two desert, grassland, marine, or freshwater systems the same, so biomes are further divided into **ecoregions**. The concept of dividing areas into ecoregions originated from the scientific view that similar geographic areas





Exploring New Mexico's Ecoregions

and their interacting functions and species create a whole that is greater than the sum of its parts. This has led to a fundamental change in natural resource management, moving away from managing individual species and towards managing larger landscape-level units, such as ecoregions, or finer ecoregional subdivisions such as vegetation communities or **watersheds**.

The US Environmental Protection Agency uses three different scales for dividing up ecoregions. Most natural resource agencies consider Level III ecoregions to be the



most practical scale for resource planning. New Mexico has eight Level III ecoregions: Arizona/NM Plateau, Arizona/NM Mountains, Chihuahuan Deserts, Colorado Plateaus, Southern Rockies, Southwestern Tablelands, Western High Plains, and Madrean Archipelago. These ecoregions can be further divided into distinct vegetation communities. For instance, the Arizona/NM Plateau includes five different communities: black greasewood, juniper-piñon, mountain brush, shadscale saltbush, and Wyoming big sagebrush.

There are many **abiotic** (non-living elements) and **biotic** (living) factors that contribute to the diversity of ecoregions that occur in New Mexico. **Precipitation**, elevation, temperature, **topography**, soil, and living organisms all work together to create unique character of each ecoregion. Across the world's landscapes, the amount of sunlight and rainfall greatly affects the types of plants and animals that

can live there. New Mexico has a mild (arid or semiarid) **climate** characterized by light precipitation, abundant sunshine, low relative humidity, and a relatively large annual and day/night temperature range. The monsoon season typically begins in early July delivering dramatic **weather** such as intense rain, large hail, powerful winds, whirling dust, and a startlingly high number of lightning strikes. Hot summer temperatures are suppressed and vegetation is resuscitated.² Average annual precipitation ranges from less than 10 inches (over much of the southern desert and the Rio Grande and San Juan Valleys) to more than 20 inches at higher elevations. Why is this so?

Let's now consider factors that can affect climate so that you can more easily see the relationship between climate, ecoregions, and their inhabitants. Where a region is located on the planet (its latitudinal position) is a key factor that influences a region's climate. Areas that are located at high **latitudes** (far from the Equator) receive less sunlight and are drastically cooler than places at low latitudes (near the Equator). For example warm rainforests and deserts are found near the Equator, chaparral, grasslands, and temperate forests are at mid-latitudes, and tundra is at the highest latitudes. New Mexico's latitude (between the 32nd and 37th parallel North) is closer to the Equator than it is to the North Pole, but is still fairly close to midway (45th parallel North). Elevation also plays a major role in climate. Because air thins and cools as it rises, mountains tend to be cooler than one would expect based on latitude alone.

Besides climate, what other abiotic factors shape ecoregions and affect the types of plants and animals you will find there? **Topography** influences hydrology, sunlight, and soils, all of which are very important indicators of where plants live. Because of the erosive force of water runoff, steeper slopes tend to have shallow and poorly developed soils, on which only certain plants can grow. Soil is then deposited in the valley bottoms below, resulting in deeper, richer soils where other species thrive. Water running off of slopes and collecting in gullies and drainages promotes the growth of water-loving species. The exposure or direction a slope faces also affects moisture levels. South-facing slopes benefit from more direct sunlight and have



*Student
Project*

Exploring New Mexico's Ecoregions

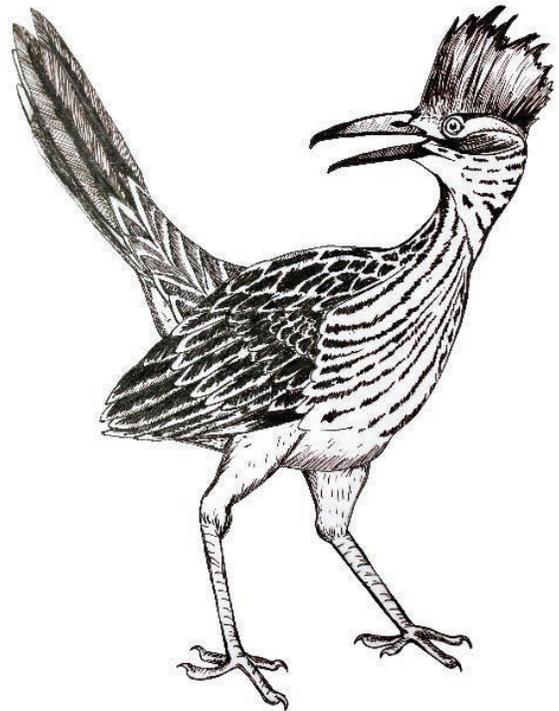
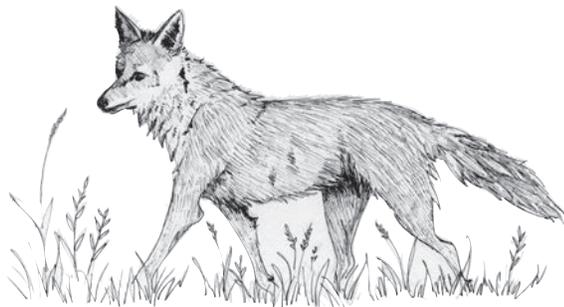
higher temperatures throughout the year, whereas the cooler, north-facing slopes are shaded from sunlight and retain moisture for longer periods. The next time you are outside, see if you notice a certain species (or plant community) whose location on the landscape corresponds with a particular elevation or topography. Soil type is also an important player in this story as different plants have different soils needs.

Soils are influenced by many variables including the type of rock from which they are formed (parent material), chemical composition, pH, texture, topography, climate, vegetation, and age creating a diversity of soil types for plants to choose from. Several of New Mexico's rare plants are specialized to a particular soil type and are never found on other soil types. For example, Gypsum Townsend's aster is only found on weathered gypsum outcrops in Sandoval County, New Mexico.

Ecoregions do not exist in isolation, but interact and often blend into one another. The transition zone between two ecoregions often exhibits characteristics and species from both ecoregions and provides important and unique intermediate habitats. For example, the Arizona/New Mexico Mountains and the Arizona/New Mexico Plateau are adjacent and share many lower elevation species in common such as piñon and juniper trees and habitat for the piñon jay. However, sometimes, the transition between one ecoregion and another is more abrupt and obvious. For example, in southern New Mexico, you can see a distinct difference as you go from the sparse arid grassland and shrubland vegetation of the Chihuahuan Deserts ecoregion and climb into increasingly diverse and lush vegetation communities

of the Sacramento Mountains of the Arizona/New Mexico Mountains ecoregion.

Because New Mexico's climate, geology and geography are so diverse, the state has many ecoregions for its size and, as a result, a great **diversity of plants**, animals, and other living things. Nevada, in comparison, has only three ecoregions compared to New Mexico's eight. New Mexico ranks fourth of all 50 states in the diversity of plant life, with 3,614 known plant species.³ Can you guess which other states have more plant species? (Look up the answer on the internet). In this activity you will take a visual journey through New Mexico's diverse ecoregions from high mountain tops to low canyons and use your knowledge to imagine what it might be like to live in these ecoregions.





Exploring New Mexico's Ecoregions

Student Directions

Part 1: Drawing Exercise to Predict Ecoregions

1. Natural boundaries such as mountain ranges or changes in elevation can affect climate and often divide ecoregions. Look at the New Mexico topographical map to predict where ecoregion boundaries fall. Use a pencil to lightly transfer ecoregion boundary predictions onto your topographic map.
2. Now compare your predictions to the map of New Mexico's ecoregions. Were you successful in predicting the locations of some of the boundaries? Add the correct ecoregion boundaries to your outline map over the top of your prediction lines and label the ecoregions.
3. Discuss the following:
 - Can you correlate geography with ecoregion boundaries?
 - How might geographic factors such as landforms and elevation affect ecoregions?
 - How might features such as mountain ranges and different elevations affect the climate?
 - Why are ecoregions important to distinguish?
 - What implications could ecoregions have for ecological restoration?

Part 2: Predict Climate

This activity challenges you to predict how topography might affect the climate of each ecoregion. Start with describing the climate of your own ecoregion. Personal observations can be considered in your predictions such as, "What is the weather like where I live?" and "What are

the significant topographic features here?" Now, estimate what the climate will be like for the other ecoregions (e.g. its temperatures, and type and amount of precipitation). Hint: Ask yourself, "Based on the landforms in this ecoregion, and its position in the state, what climate might I expect for this area?"

Part 3: Assess Ecoregion Characteristics – Was your climate prediction correct?

1. Find the following information about each ecoregion: 1) climate (average high/low temperatures in January and July, annual precipitation amounts, amount of precipitation that falls as snow, and number of sunshine days), 2) elevation, and 3) topography (include a general description of how the topography of the area you are studying was formed such as by volcanic deposits or flood sediments). It may be easiest to simply pick a city within each ecoregion and find data for that city. Collect data using library sources, atlases, and websites such as US Climate data: <http://www.usclimatedata.com>, which is a great source for temperatures and elevation.
2. Discuss the following:
 - Did this data support your climate prediction for your ecoregion? If not, what did you learn?
 - Talk about what you might see if you were dropped in the middle of each ecoregion? How do topography and climate influence the plant and animal life of an ecoregion?



*Student
Project*

Exploring New Mexico's Ecoregions



Self Assessment

- 1** Define an ecoregion and discuss some of the factors that distinguish one from another
- 2** Name and locate the eight ecoregions of New Mexico on an outline map
- 3** Explain the connection between geography and climate

Resources

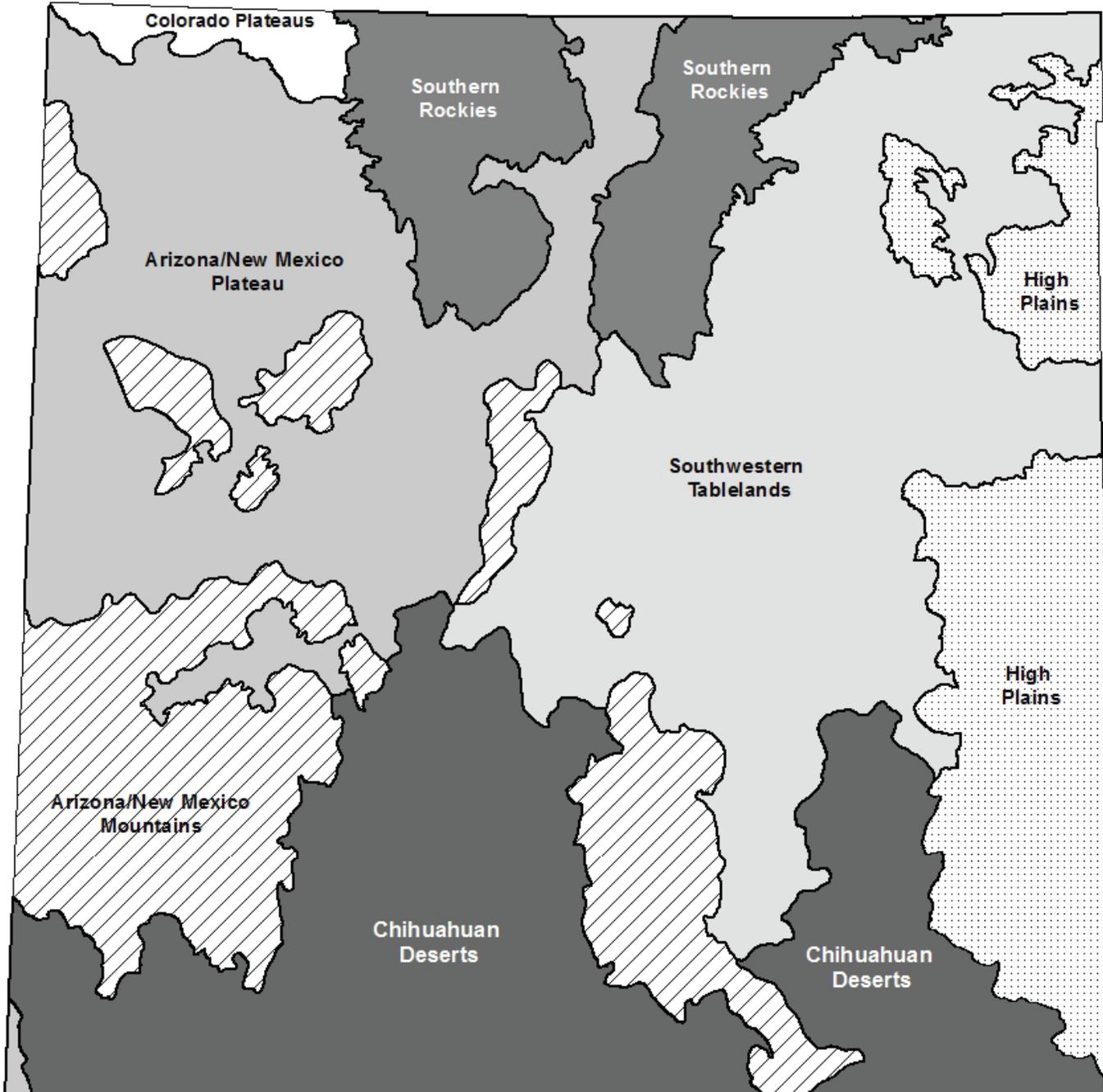
- "Characteristics of the ecoregions of New Mexico"; this electronic handout for New Mexico's ecoregions can be ordered by contacting staff on the EPA Ecoregions homepage (search EPA ecoregions by state if the link is broken): <https://www.epa.gov/eco-research/ecoregion-download-files-state-region-6#pane-29>
- Native Seed Network New Mexico ecoregion map and descriptions of vegetation communities: <http://www.nativeseednetwork.org/index>
- The Encyclopedia of Earth; Ecoregions of New Mexico: <http://www.eoearth.org/view/article/152138/>
- US Climate data: <http://www.usclimatedata.com/>
- Yellow Maps World Atlas; Elevation contour map of New Mexico: <http://www.yellowmaps.com/map/new-mexico-elevation-map-300.htm>
- Stein, B. A. (2002). States of the Union: Ranking America's Biodiversity. Arlington, Virginia: NatureServe. Retrieved from <http://www.natureserve.org/library/stateofunions.pdf>



*Student
Project*

Exploring New Mexico's Ecoregions

New Mexico Ecoregions

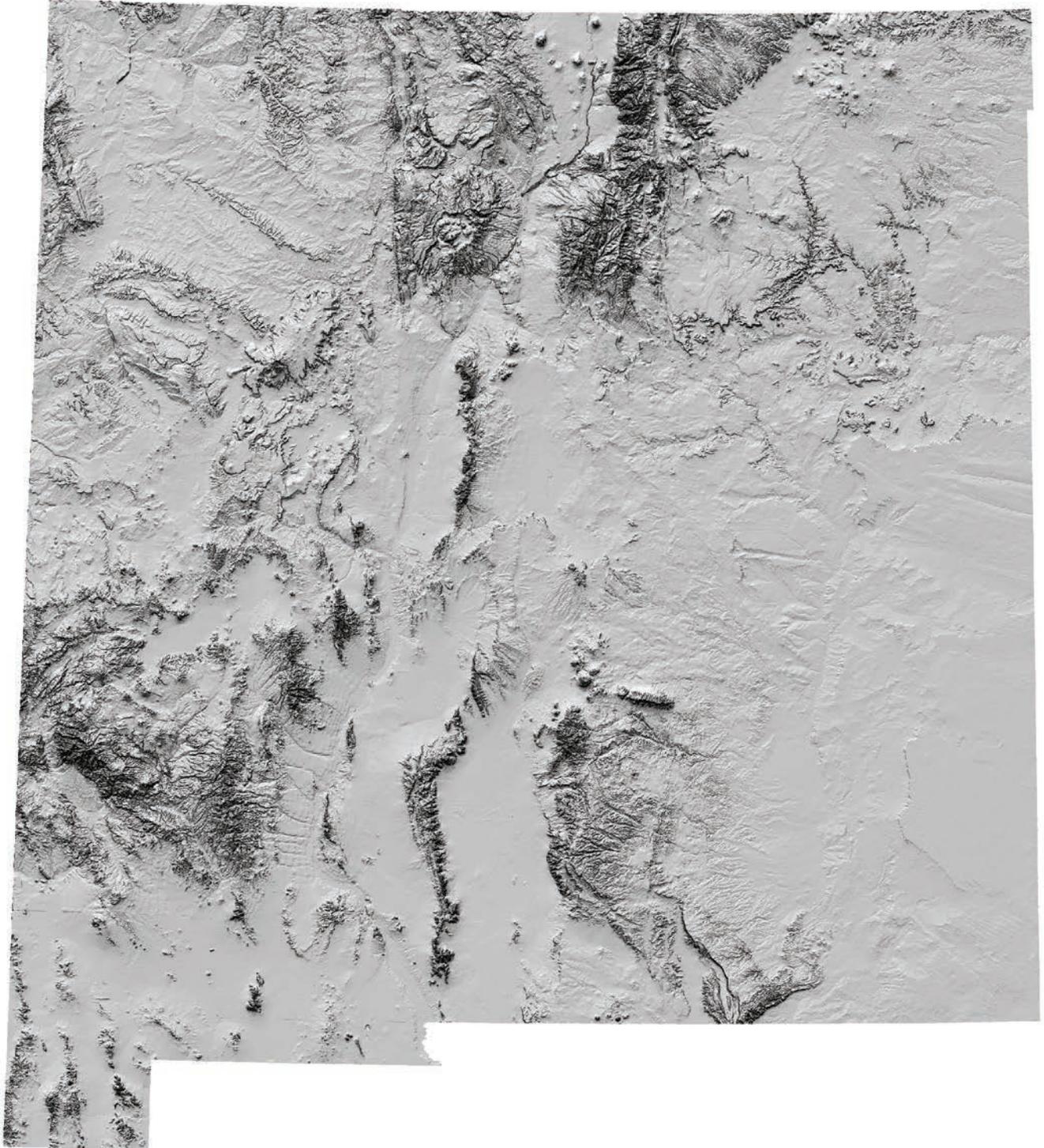




*Student
Project*

Exploring New Mexico's Ecoregions

New Mexico Topography





Exploring New Mexico's Ecoregions

	Arizona/NM Plateau	Arizona/NM Mountains	Chihuahuan Deserts	Colorado Plateaus	Southern Rockies	South-western Tablelands	Western High Plains	Madrean Archipelago
Average temp. in January								
Average temp. in July								
Average annual precipitation								
Amount of precipitation that falls as snow								
Elevation range								
Number of sunshine days								
Describe major geographic features								



The Place I Call Home

"Life is like a landscape. You live in the midst of it but can describe it only from the vantage point of distance." -Charles Lindbergh (1902-1974)

Time Estimate
1-2 hours; an additional session is needed for In the Field! (optional)

Best Season

		Winter
		Fall
		Spring
		Summer

Overview

In this lesson, students will take an in-depth look at their home ecoregion. Students will explore what makes their ecoregion different than the rest of New Mexico. Students research climate, geology, native vegetation communities, human influences, land uses, and a few of the rare and invasive species that reside in their ecoregion.

Teacher hints

- Consider setting a minimum number of resources students must use to research their ecoregion.
- This lesson works well when preceded by the *Exploring New Mexico's Ecoregions* lesson, where students are introduced to the concept of ecoregions and the ways in which abiotic factors influence the biotic elements of a region.

Preparation

1. You will need to look at a map of the level III ecoregions to determine which ecoregion you call home.
2. Gather a list of web sites and materials to help the students glean information about their home ecoregion. An electronic handout provides information on land cover and use for level III ecoregions for New Mexico can be found <https://www.epa.gov/eco-research/ecoregion-download-files-state-region-6#pane-29>. It needs to be enlarged to 100% be able to read the details of land cover and use. This handout for New Mexico's ecoregions can be ordered by contacting staff on the EPA Ecoregions homepage (search EPA ecoregions by state if the link is broken).

Assessments

- 1 Name and describe one native and one invasive plant species found in your ecoregion.
- 2 Name and locate one (or more) natural areas or natural landscapes in your ecoregion.
- 3 Describe at least two primary land-uses in your ecoregion.





The Place I Call Home

"Life is like a landscape. You live in the midst of it but can describe it only from the vantage point of distance." —*Charles Lindbergh* (1902-1974)

Materials Needed

- poster board or Powerpoint
- computer and Internet access

Overview

What makes your ecoregion special? Whether you have lived in your ecoregion for a long or short time, it holds many surprises of which you might not be aware. In this lesson, you will take an in-depth look at your home ecoregion. Explore what makes your ecoregion different than the rest of New Mexico. Find out about the climate, geology, native vegetation communities, human influences, land uses, and a few of the rare and invasive plant species that reside in your ecoregion.

Learning Objectives

1. Gain knowledge of the components of the ecoregions of New Mexico
2. Gain awareness of nature-based recreation areas in the ecoregions

Background

In the last lesson, we learned about ecoregions and how distinctive climatic, geographic, and ecological features help define each ecoregion. In this lesson, we focus on the ecoregion in which we live. As you become more familiar with your own ecoregion, think about what you already know based on your observations of your surroundings. Ask yourself the following questions about the place you call home:

Where do I live?

What is the nature of this place?

Why do you live there?

What sustains this community?

What is the nature of this place?

Picture where your hometown is located on a map of the world. Are you near or far from the equator? One of the primary factors that influences the "personality" of your ecoregion is the latitude. This affects the overall climate of your region, and the pervasiveness of seasons. As you move from south to north, the climate generally becomes much cooler, due to the sun angle and duration of sun exposure. The earth's tilted axis means that ecoregions located far to the south or north of the equator spend part of the year pointed away from the sun, which causes winter. The farther from the equator an ecoregion is located, the more pronounced the seasonal changes are. Think about the seasonal changes that you observe around you every year. Are they subtle or dramatic? You might detect changes in temperature, precipitation, weather patterns, migrating animals, and vegetation.

Now think about where you are located on the continent. If you live near the Great Lakes or near the ocean, you might experience the moderating effects of water on climate. Water responds very slowly to changing air





The Place I Call Home

temperatures, so regions adjacent to large bodies of water often have relatively warmer winters and cooler summers than inland locales of similar latitude. If you live in the interior of the country, far from large bodies of water, you likely experience seasonal changes that are much more extreme.

Next, consider the elevation/altitude where you live. How far above sea level is your hometown? How might elevation affect the climate? Elevation can make a big difference on both large scales and small scales. For example, snow might be a rare occurrence in one location, while another location just a mile away and a few hundred feet higher in elevation might experience snow regularly in the winter.

How much moisture or precipitation a region receives is a key part of every ecoregion's character. The amount and the time of year precipitation is received impact the native vegetation. Aspect, or the direction a slope faces, is important to the local climate, too—a town located on a north facing slope might still be facing winter-like conditions when the warm weather of spring has arrived on south-facing slopes.

How do these abiotic factors such as geology, topography, latitude, climate, and soils affect the native vegetation in your area? Think back to what you know about plant adaptations. What kinds of adaptations do plants need to survive where you live? Consider the local native plants that you know. How do they exhibit some of these adaptations?

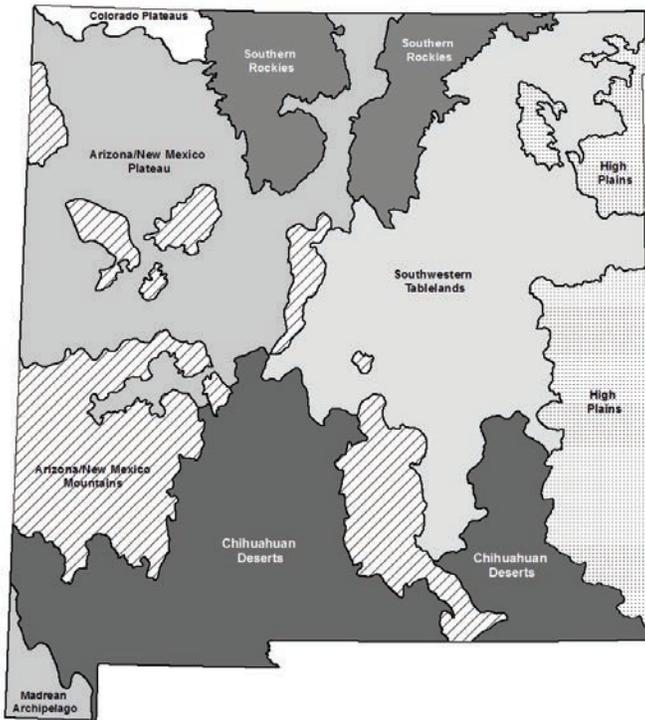
Why do you live there? Our cities and towns are located where they are for a reason. New York City, for example, grew out of a flourishing beaver trade. The winding waterways and wetlands were lush with a diversity of native forests and marsh vegetation that supported a wide variety of life forms, including a robust beaver population. It was the lucrative beaver trade that led to European settlement of the area and eventually dramatic growth into the city it is today. On the other side of the continent, the heavy rainfall captured by the Cascade Range in the Pacific Northwest

produces rainforests of immense trees. The timber industry that sprung up to harvest these trees led to the growth of cities and towns throughout the northwest, such as Seattle, Washington. Then, there are small towns in the Midwestern corn belt, where much of our country's food supply is grown. The extensive fibrous root systems and nitrogen-fixing associations of native prairie vegetation helped to form the deep, fertile soils in this region, making it an ideal place to grow food crops. Where is your hometown? What was it about the natural landscape or natural areas that led to the settlement of that location? In the ethnobotany section, you will study why the native Puebloan communities settled in particular areas.



What sustains this community? The economy and culture of the place you live reflect its natural history. In North Dakota, for example, Mandan tribes grew squash, beans, and corn in the fertile soils deposited by floods along the banks of the Missouri and its tributaries. If you look at satellite imagery of the Missouri today, you can see farm fields lining the rivers where farmers still benefit from the fertile soil deposits and accessible water. Farther from the rivers, cattle now graze the same bunch grasses that once sustained a different ungulate, the American bison. While our country has changed considerably over the years, our various communities continue to be sustained by many of the same ecosystem processes. What are the major land uses in your region? Do you live among forests, where the timber industry is still a major industry, or in an agricultural area? From which rivers does your community draw its drinking water? What are the historic and prehistoric legacies of that land-use in your area? You will find that native Puebloan communities developed along the Rio Grande River corridor where resources were abundant.

Many of us now live in urban areas, where our communities may not be obviously centered on agriculture or forestry. But though they may be inconspicuous, natural processes are still present and going on all around us. Whether you live in the city or on a farm, our lives are intertwined with the natural features and processes of the places where we live.



Ecoregions of New Mexico



Student Directions

1. Access a description of your level III ecoregion on the Native Seed Network (<http://www.nativeseednetwork.org/>). This will provide a good background, but you will need to do additional research elsewhere. Good sources of additional information include: publications and websites from the Bureau of Land Management, the EPA, the United States Forest Service, or the United States Fish and Wildlife Service; brochures, websites, or travel information for natural areas or parks within the ecoregion.
2. You will likely encounter terminology that you will be unfamiliar with. Part of your task will be to look up unknown words and use your new vocabulary to help your class understand your ecoregion.
3. Use the information that you gather to prepare a presentation that you will give to the rest of the class. Use posters or power point to include visual aids that will help your classmates picture your ecoregion. Be sure to include a map that indicates the location of your ecoregion.
4. Much of the material that you will be asked to discuss during your presentation will not come directly from research, but from brainstorming your own hypotheses based on your understanding of the interplay between physical, climatic, and biological features. Be sure to refer to the background information in this chapter and the previous ecoregion chapter for help with this, and share ideas within your group to come up with creative and informed hypotheses.
5. Break into groups to research different aspects of your ecoregions. A great source for ecoregion specific information is the electronic handout created by the EPA in collaboration with several other resource agencies: Characteristics of the ecoregions of New Mexico (Be patient to zoom in on the data needed): <https://www.epa.gov/eco-research/ecoregion-download-files-state-region-6#pane-29>
(continued on next page)



6. Your presentation could include discussions on the following subjects:
- **Location:** Where is your ecoregion located? Use a map to show the general location of your ecoregion, and relate it to the location of major features such as mountain ranges and rivers.
 - **Physical Characteristics:** Describe the general topography of your ecoregion. Are there any wetlands, rivers, or lakes in your ecoregion?
 - **Climate:** What is the average annual temperature? What is the annual average precipitation? At what time of year does this precipitation usually fall, and in what form (e.g. rain or snow)? How do the physical characteristics of your ecoregion affect the climate? How might they affect climates of neighboring ecoregions? How might neighboring ecoregions affect the climate of your ecoregion? US Climate data: <http://www.usclimatedata.com> is a great source.
 - **Biological Characteristics:** What are some of the most common groups of native plant species in your ecoregion. For example, is your ecoregion dominated by desert, grassland, small shrubs, coniferous trees, or deciduous trees? Why might this group of species thrive here? Hint: Think about the physical characteristics and the climate in your ecoregion, and what adaptations plants need to survive in such a setting.
 - **Human Activities:** What are some of the primary land-uses in your ecoregion? What features of your ecoregion make this a profitable use of the land? What are some of the notable impacts on the landscape caused by these land-uses? Can you think of any ways to minimize or reduce these impacts?
 - **Diversity within Ecoregions:** Even level III ecoregions are very large, and the landscapes they encompass are very diverse. Your level III ecoregion has many different plant communities within it. Use a combination of research and your own observations to describe the variety of plant communities encompassed by your ecoregion. What abiotic factors might affect and help form these communities? A botanist is a good person to contact for more information; try reaching out to botanists from the Bureau of Land Management (BLM), US Forest Service, US Fish and Wildlife Service, or other agencies, non-profits, or watershed councils.
 - **Local Plants:** Include a profile of one native plant and one invasive plant that occurs in your ecoregion. Include a description of the plant's appearance, adaptations, and habitat. How is it adapted to live in your ecoregion? Appendix II provides examples of native plants and Appendix III provides examples of invasive plants for each ecoregion.
 - **Rare Plants:** Does your ecoregion have any rare plant species? What are some activities or land uses that may be a threat to the survival and health of populations of rare plants? Visit the New Mexico Rare Plants Website for information: <http://nmrareplants.unm.edu/>
7. Be sure to cite the sources you used for research.
8. Present your information to the class. Be sure that everyone in your group plays a part. Use your creativity to display images and information that help your classmates to picture your ecoregion.



The Place I Call Home

CLASS DISCUSSION

1. How does human activity impact your ecoregion now? How do you expect it to change in the next 10 years? The next 50 years? Include both negative impacts and positive impacts.
2. What actions could be taken to minimize harmful impacts and enhance positive impacts to your local area?

Reflection

What sets your ecoregion apart from the others around it? What makes it a special place?

Think about what you like about the different seasons: winter, spring, summer and fall. Are there things that you enjoy doing outdoors that are enhanced by or only possible in your ecoregion? Do you have a special place that you like to visit? Describe it. If you don't have a particular special place, think about characteristics that would make an outdoor place special to you—describe it. What are some things that you can do to help the conservation efforts in your community, ecoregion, and state?



In the Field

Go on a field trip or go on your own time to a natural area in your own level III ecoregion. Bring a hand lens and your field journal. Find and observe several samples of different native plant species and take careful notes about each in your field journal. Use your knowledge of plant adaptations to explain how each species is adapted to your ecoregion. Where else might these species thrive? What factors do you think limit the range of each species?



EARLY FINISHERS

Design an experiment that will test control methods for an invasive plant species that is a problem in your area. Start by brainstorming possible ways to limit the further spread of the plant. Think outside the box to create new, more effective, environmentally friendly methods that could be used for control. Narrow your ideas to ones that you can test. Write a proposal and submit it to your teacher. The proposal should outline what you are controlling, what is the method that you will be testing, and how you will set up the experiment.

Self Assessment

- 1 Name and describe one native and one invasive plant species found in your ecoregion.
- 2 Name and locate one (or more) natural areas in your ecoregion.
- 3 Describe at least two primary land-uses in your ecoregion.





Resources

- New Mexico Environment Department: <https://www.env.nm.gov>
- Characteristics of the ecoregions of New Mexico; this electronic handout provides information on land cover and use for level III ecoregions; this handout for New Mexico's ecoregions can be ordered by contacting staff on the EPA Ecoregions homepage (search EPA ecoregions by state if the link is broken). The chart needs to be enlarged to 100% to be able to read the details of land cover and use: <https://www.epa.gov/eco-research/ecoregion-download-files-state-region-6#pane-29>
- *Troublesome Weeds of New Mexico* by Jamshid Ashigh, James Wanstall and Frank Sholedic, New Mexico State University College of Agricultural, Consumer and Environmental Sciences Cooperative Extension Service, Las Cruces, New Mexico, 2010: http://www.nmda.nmsu.edu/wp-content/uploads/2012/04/troublesome_weeds_nm.pdf
- New Mexico Agriculture In the Classroom poster sponsored by New Mexico Agriculture Education (identifies what crops are grown in each county of New Mexico: http://newmexico.agclassroom.org/resources/doc/literacy/essential_poster.pdf
- Native Seed Network: <http://www.nativeseednetwork.org/index>
- New Mexico Rare Plants Website: <http://nmrareplants.unm.edu/>
- The Nature Conservancy; New Mexico Conservation Science; NM Statewide Natural Resources Assessment, Strategy and Response Plans: http://nmconservation.org/projects/nm_natural_resources_assessment/





Ecosystem Comparisons

"Between every two pines is a doorway to a new world." -John Muir



Overview

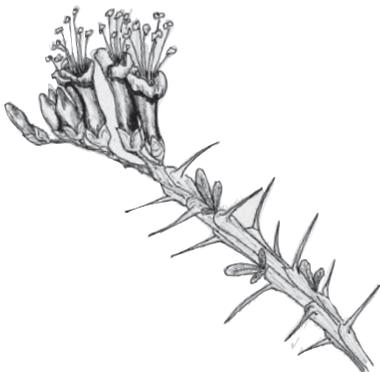
In this lesson students will collect vegetative, soil, wildlife, and other abiotic and biotic data in the field to compare and contrast two ecosystems in your ecoregion. Using this data, students will identify key adaptations that plants have evolved to survive the conditions in different ecosystems.

Preparation

1. Make or obtain meter square frames or four stakes and a meter tape you can use as a frame.
2. Identify field sites for exploration. Students will need two different ecosystem types to study. It is helpful if the two systems are near or adjacent to one another, but this is not necessary. Try to find two areas that are distinctly different. Examples include a grassland vs. a deciduous forest or a desert vs. a riparian area. In New Mexico, comparing ecosystems at different elevations can be a confounding variable so try to compare ecosystems at relatively similar elevations (within 1000 feet). In an urban environment this could be as simple as different sections of a park or open lot, as long as different biotic and abiotic features can be observed.
3. Use the glossary to define vocabulary words not defined within the text.

Teacher hints

- Students will choose two distinctly different ecosystem and compare biotic and abiotic factors in those areas.
- Since students will be learning about biotic and abiotic factors and their influence on ecosystems, consider supplementing this lesson with other lessons on soils and natural ecosystems cycles, such as carbon, water, or nutrients.



Assessments

- 1 Create visual displays of data (e.g. graphs, tables) comparing observations.
- 2 Explain similarities and differences between ecosystems.
- 3 Demonstrate an understanding of the connection between the biotic and abiotic factors of an ecosystem.
- 4 Name a characteristic that would allow a plant to survive in each of the following situations: low light, high light, wind, low moisture, and high moisture.



Ecosystem Comparisons

"Between every two pines is a doorway to a new world." –John Muir

Materials Needed

Each team needs:

- clipboard, pencil, and data sheet
- thermometer suitable for air and soil temperature readings
- jar of bubbles
- meter square frame or hula hoop (Appendix V)
- trowel
- small metric ruler
- compass

Overview

In this lesson you will collect data to compare and contrast two or more ecosystems in your ecoregion. Using your data, you will identify key characteristics that plants have adapted to survive the conditions in different ecosystems.

Learning Objectives

1. Collect and evaluate ecosystem data
2. Observe differences and similarities between two ecosystems
3. Identify plant phenotypes (plant characteristics) adapted to specific environmental conditions
4. Identify connections between biotic (living) and abiotic (non-living things)

Vocabulary

ecosystem	climax community
adaptation	allelopathy
biotic	mutualism
abiotic	competition
quadrat	parasitism
communities	predation
succession	phenotype
disturbance	natural selection

Background

Through careful observation of the biotic and abiotic factors of different ecosystems, an ecologist can study how plants adapt to different environmental conditions. In this lesson you will identify key **ecosystem** properties and compare them between ecosystems in the region. You will investigate questions such as: How do soils differ in a forest verses a grassland or in a desert verses a wetland? Do plants in one ecosystem have different characteristics than plants in another ecosystem? As you study and compare ecosystems, learn how plants and animals adapt to their environment, and what conditions they need to survive.

Ecosystems are self-sustaining systems in nature that include both the living organisms and the nonliving elements within them. Ecosystems are dynamic; energy, nutrients and water constantly cycle through them. Within each ecosystem there are **communities** made up of **biotic** (living) organisms, including plants, animals, fungi, and bacteria. Interactions between all the organisms tie the ecosystem together into a functional unit.

All ecosystems change over time. This process is called **succession**. Succession can be rapid or slow, but is a continuous process that occurs in all types of ecosystems. The successional "clock" can be reset after an ecosystem is disturbed. Naturally occurring **disturbances** can include fire, flood, landslides, or volcanic eruptions. Human caused disturbances may result from habitat restoration, logging, farming, or any activity that





Ecosystem Comparisons

clears away the current vegetation, fungi, bacteria, and microorganisms that are key to ecosystem function. In the absence of a disturbance, succession generally occurs so slowly that it is difficult to observe or detect it. This type of succession is illustrated when grassland changes to forest, or when a pond fills in over time. If no disturbances interrupt the succession cycle, it eventually comes to a near standstill, a point where the ecosystem is hardly changing at all. This standstill is referred to as the **climax community**.

In this lesson you will examine **abiotic** (nonliving) factors such as air, water, and sunlight and observe how they affect biotic (living) factors in two distinctly different ecosystems. By making detailed site observations, you will connect plants' **phenotype** (physical characteristics) to the characteristics of the ecosystem in which they live. For example, plants are adapted to different levels of sunlight, moisture, temperature, and wind. Low-light environments frequently include plants with larger leaf surface areas to capture more sunlight for photosynthesis. In high-light environments, leaves tend to be narrower to reduce surface area and minimize the loss of moisture through evaporation. Do any plants have spines? Look for these types of patterns when you make your observations. Think of other **adaptations** plants could exhibit. Look at leaf margins (edges), surface area characteristics (e.g. shape, texture, and size) as well as the angle of the leaf to sunlight. How might plants adapt to other conditions and challenges, such as drought, flood, fire, wind, and limited space? Keep in mind that plants must also defend against predation and attract pollinators—all at the same time, and all in the name of survival.

Interactions between organisms can be classified into different types. For example, a relationship where two species both benefit from their interaction with one another is called **mutualism**. The relationships between nitrogen-fixing bacteria and leguminous plants, or and

between pollinators and flowering plants are examples of mutualisms. The opposite of mutualism is **competition**, when two organisms struggle to acquire the same resource. Competition is generally costly to both organisms. Plants compete for sunlight, water, space, and nutrients. They employ several methods for this including to shade out competition, to send out far reaching roots into the soils



space of another species, and sometimes even to produce chemicals (**allelopathy**) to inhibit the growth of their competition. Other interactions can occur between herbivores and plants (**predation**), and parasites and plants (**parasitism**). Some plants can even parasitize other plants.

Individual plants cannot adapt to conditions within their own lifetime. However, over many generations, through **natural selection**, the most "fit" phenotypes (the ones best suited to the environment) will be more successful, and increase in frequency and number. For example, if a narrow-leaved plant germinates in a heavily shaded environment, it is unlikely that the plant will secure enough light to survive and reproduce. If this phenotype is unable to reproduce, it will not persist in this environment. In this way, plant communities are gradually shaped by the ecosystems they inhabit. In turn, these plants affect and change the rest of the ecosystem.





Student Directions

Compare two different ecosystems (e.g., forest vs. grassland, desert vs. wetland), by examining air and soil temperatures, soil moisture, surface litter, wind speed, canopy cover, plant community composition, plant characteristics, evidence of wildlife, and how all these factors come together to make up an ecosystem.

1. Divide into research teams. For 30–45 minutes, following steps 2 through 10, collect and record data about your first ecosystem.
2. On your data sheet, record the date, time, general weather conditions (e.g., sunny, cloudy), and a simple site description.
3. Use a square meter frame or hula-hoop as a **quadrat** (Appendix V). Place the meter square frame or gently toss the hula-hoop into a section of the ecosystem. Wherever it lands marks where you will collect your data. If there are trees or shrubs where you are, use a small object to toss and place the top left corner of the frame where it lands. Calculate, in centimeters, the total area of your quadrat, then figure out the dimensions of 1%, 5% and 10% of the total area. For example, in a one square meter plot, is 1% 10 cm by 10 cm, or 5 cm by 5 cm, or 2 cm by 2 cm? This will help you estimate later. Use the data sheet to record your observations as you work through the steps outlined below.
4. Air temperature: Using your thermometer, take a reading 1 meter from the ground. Allow 3 minutes for the thermometer to register the correct temperature.
5. Light levels: Estimate how much sunlight reaches the ground in your quadrat. To do this look up and figure out what percentage of the sky you can see through the canopy directly above your head if you are standing right at the plot. Record this information.
6. Wind speed and direction: Estimate wind speed on a scale of 0 (no wind) to 10 (strong wind). Use a jar of bubbles to help you “see” the wind strength and direction. Take a compass reading on the direction the bubbles travel.
7. Soil studies:
 - Place your hand on the soil to feel for moisture levels. Stick your finger in 2 cm to check if it is different from the surface. Is it wet (mud on your hand), moist (dark color, cool), or dry?
 - Surface litter: Examine the dead material and decomposition (such as leaves, stems, dead insects, etc.) on the surface of the soil. List what you see and measure the depth (thickness) of the litter layer in centimeters.
 - Take soil temperature readings at 3 cm and 10 cm depths. With a trowel, slice into the soil layer to 3 cm, insert your thermometer and tuck the soil back around it, leaving it for 3 minutes before recording the reading. Repeat this process at 10 cm.
8. Plant studies:
 - Canopy cover: Estimate the percent of your quadrat that is covered by overhead vegetation (trees or tall shrubs). Imagine that you are lying on the ground with your head in the quadrat and look at the sky. Zero percent (0%) cover would mean that no overhead vegetation is visible; complete cover (100%) would mean that you cannot not see the sky above your quadrat. (Continued on next page)



Ecosystem Comparisons

- Percent ground cover: Estimate the percent of your quadrat that is covered in vegetation. Can you see bare ground, rocks, or woody debris between the vegetation? Record in percent the makeup of the ground cover (e.g. forbs/herbs, grasses, moss, etc.) as indicated on the data sheet.
 - Plant observations: How many different species of plants do you see in your quadrat? It is not necessary to identify specific plants by name. Count the number of different plant species with leaves that: are very narrow (less than 1 cm), narrow (less than or equal to 3 cm), and broad (greater than 3 cm wide). Record the total number of species you see. Estimate the height of each type/layer of plant cover (e.g. herbaceous, shrub, tree). Note leaf characteristics (e.g. waxy, fuzzy, smooth), leaf margin type (e.g. wavy, toothed, smooth), and life cycle stage (e.g. blooming, fruiting, shedding leaves) for each type of plant.
9. Evidence of wildlife:
- Look in your quadrat for insects, spiders and other invertebrates. Describe the find or if you are feeling "buggy," try to identify them. Make a quick sketch and record what they were doing, (e.g. eating, flying, sitting under leaves).
 - Look closely for evidence of animals you don't see. Are there chewed leaves, webs, tracks, or insect droppings or scat (animal droppings) visible?
10. Aesthetics: Describe any patterns you observe in textures, colors, or contrasts at your site. When looking for patterns it can be helpful to "soften" your gaze; try not to focus on any one thing but view the landscape as a whole.
11. Spend another 30-45 minutes repeating steps 2-10 in a different ecosystem, then analyze the results of your two studies.

CLASS DISCUSSION

1. In what ways are the two ecosystems alike? How are they different? What causes the similarities and differences between the two ecosystems?
2. What are some connections between biotic (living) and abiotic (non-living) things in each ecosystem?
3. How do you think plants in the two ecosystems influence the light, temperature, and soils around them?
4. What characteristics, such as leaf size, leaf shape, and blooming time, did plants exhibit to adjust to their environment?
5. How do you think plants in the two ecosystems interact or affect each other?
6. In what ways are plants and animals likely to interact in one or both ecosystems? Consider at least three examples. Give an example of a mutualism.
7. What method(s) did you use to estimate heights or percents in your data collection? Did they work well? Is there anything you would do differently next time?



Ecosystem Comparisons

EARLY FINISHERS

Pick one of the ecosystems and make a mind map for it. Put the name of the ecosystem in a circle at the center of a page; add the biotic and abiotic factors you observed, placing each in circles that surround and attach to the center circle with the name of your ecosystem inside.

Search for relationships between the factors and connect the circles with lines. Write the connection or interaction between those two items along the line.

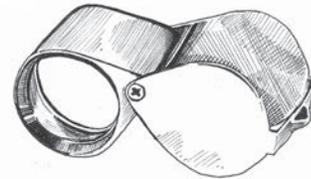
Use the discussion questions as prompts, if needed. Write about one of the interactions from your mind map in detail.

Explore all the possible connections between the two interacting elements, as well as what abiotic factors might influence them.

How have organisms adapted to be successful in the ecosystem?

Self Assessment

- 1** Create visual displays of data (e.g. graphs, tables) comparing observations between the ecosystems.
- 2** Explain similarities and differences between the ecosystems you studied.
- 3** Demonstrate an understanding of the connection between the biotic (living) and abiotic (nonliving) factors of an ecosystem.
- 4** Name adaptations plants might have to survive in each of the following situations: low light, high light, wind, low moisture, and high moisture.



Resources

- Basic website on studying ecosystems: <http://scienceaid.co.uk/biology/ecology/>
- Pidwirny, M. (2006). *Plant Succession. Fundamentals of Physical Geography*, 2nd Edition. <http://www.physicalgeography.net/fundamentals/9i.html>
- Missouri Botanical Garden, Biology of Plants, Plant Adaptations: <http://www.mbgnet.net/bioplants/adapt.html>
- Raven, P. H., Evert R.F., & Eichhorn, S.E. (1992). *Biology of Plants* (5th ed.). New York: Worth Publishers.



Ecosystem Comparisons

Ecosystem Comparisons

Team Members _____

Date _____

		Site 1	Site 2
Location/site and weather description	Time: Site location description: Overall weather description:		
Weather Data	Air temperature: Light: Wind :		
Soil	Soil temperature: Moisture: Surface litter: Rocks: Texture: Cryptobiotic crust: Additional observations (color, consistency):		
Percent Cover	Canopy cover/type and percent: Ground cover/type And percent:		
Plant Observations (characteristics)	# plant with spines: # plants with very narrow leaves (≤ 1 cm): # plants with narrow leaves (≤ 3 cm): # plants with broad leaves (> 3 cm): Height herbaceous layer: Height shrub layer: Height tree layer: Additional observations for each type of plant (leaf characteristics, life cycle stage):		



Ecosystem Comparisons

Wildlife –Direct Observations or Evidence			
Aesthetic –visual patterns	Texture: Color: Contrasts:		

Site Analysis

1. Which site had the greatest number of plant species?
2. How are the plants similar at the two sites?
3. How are the plants different at the two sites?
4. How do you explain the difference the plants between the two sites?
5. How do you think the abiotic elements affect the plants growing at each site?
6. What connections did you observe between living and non-living things in each environment?



An Ecosystem Through an Artist's Eye

"Nature is painting for us, day after day, pictures of infinite beauty."
—*John Ruskin* (1819-1900)



Overview

Students will use drawings to understand the different perspectives gained from making observations on different ecological scales. Students will focus on the local habitat by drawing three different views: one landscape view, one smaller scale view, and one magnified close-up view. This activity encourages aesthetic appreciation for the local landscape while exercising flexible thinking skills and hand-eye coordination. Drawing emphasizes careful observation of detail and patterns in the natural world.

Preparation

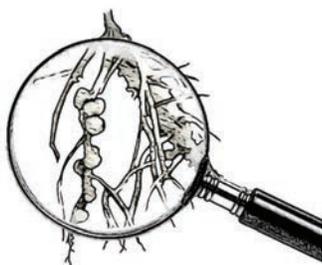
Prepare 5 x 7 rectangular viewing frames for students to use for their artwork. Or, assemble supplies and have students prepare their own before beginning the activity.

Assessments

- 1 Summarize the activity by comparing and contrasting views, and discussing the processes associated with different ecological scales.
- 2 Participate in the activity; work independently and join discussions.

Teacher hints

- Encourage doing this activity in pen for the upper grades; it discourages editing. The object is to practice observation skills and gain appreciation for their surroundings, rather than to produce a perfect drawing.
- Stress to students that this exercise is to help observe what is around them, rather than to judge their drawing abilities. If students are drawing-phobic, have them make blind contour drawings, drawing by not watching their hand on the paper. Remind students that their work does not need to be perfect (this seems to be more of a problem with older students).
- Read quotes from literature of descriptions of landscape perspectives (see Resource section). For inspiration, do an internet search on "New Mexico nature".
- Repeat this activity in different landscapes (desert, grassland, forest, wetland), or in the same place during different seasons. This activity is more challenging in a forested setting with a limited landscape or vista view.
- Between each drawing session, regroup and share what students saw, as well as their feelings about what they saw at each step. This is a good way to keep students on schedule—or some will become so involved in one drawing that they won't finish the activity.
- Have students use their 5x7 frame to draw a template on their paper for each of the three drawings before starting. Stress that their drawing should fill this frame. Also, encourage them to spend the entire 20 minutes drawing. If they finish drawing before the activity is over, they can go back and add more to it.





Student Project

An Ecosystem Through an Artist's Eye

"Nature is painting for us, day after day, pictures of infinite beauty."

—*John Ruskin* (1819-1900)

Materials Needed

- 5" x 7" viewing frame from photo mat board, cardboard or poster board
- pencil or pen
- hand lens or magnifying glass
- optional colored pencils

Vocabulary

abiotic

landscape

macro

microscopic

perspective

ecosystem

perspective

Overview

You will begin to understand the different perspectives gained from making observations on different scales. You will focus on the local habitat by drawing three different views, one landscape view, one smaller scale view, and one magnified close-up view. This activity encourages aesthetic appreciation for the local landscape while exercising flexible thinking skills and hand-eye coordination. Drawing emphasizes careful observation of detail and patterns in the natural world.

Learning Objectives

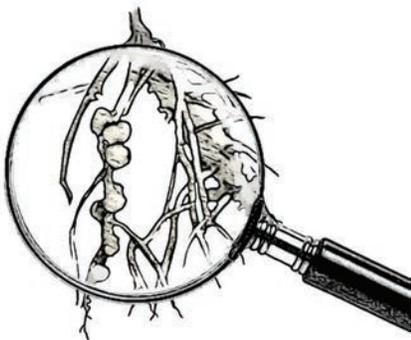
1. Practice observation skills on multiple scales
2. Translate observations to paper through illustration
3. Interpret and compare multiple views of the same landscape
4. Encourage flexible thinking skills

Background

By making observations on different scales, from **landscape** to **microscopic**, you can observe patterns in nature from many perspectives. A nimble mind that can make observations on multiple scales and from many **perspectives** will be able to approach complex problems with greater ease.

As we observe the form of the landscape at different ecological scales, we can contemplate the functioning or processes that occur at those different levels to make our **ecosystems** function as a whole. For example, at the landscape scale, we might observe patterns related to processes such as climate, nutrient and water cycling, and soil formation. At a human scale, we can examine wildlife habitat, erosion, herbivory, and many other functions. On a microscopic scale, we can focus on photosynthesis, pollination, and decomposition.

As you observe patterns in each of the three scales, you will also observe the work of the natural processes that are occurring. At the landscape scale, larger patterns and processes are at work. Look for patterns in the vegetation, notice relationships between topography and vegetation type, and ponder the environmental factors such as climate, soil type, geology, landforms, and water that create the patterns you see in your frame. For example, where do individuals of a particular type of tree occur? Do





An Ecosystem Through an Artist's Eye

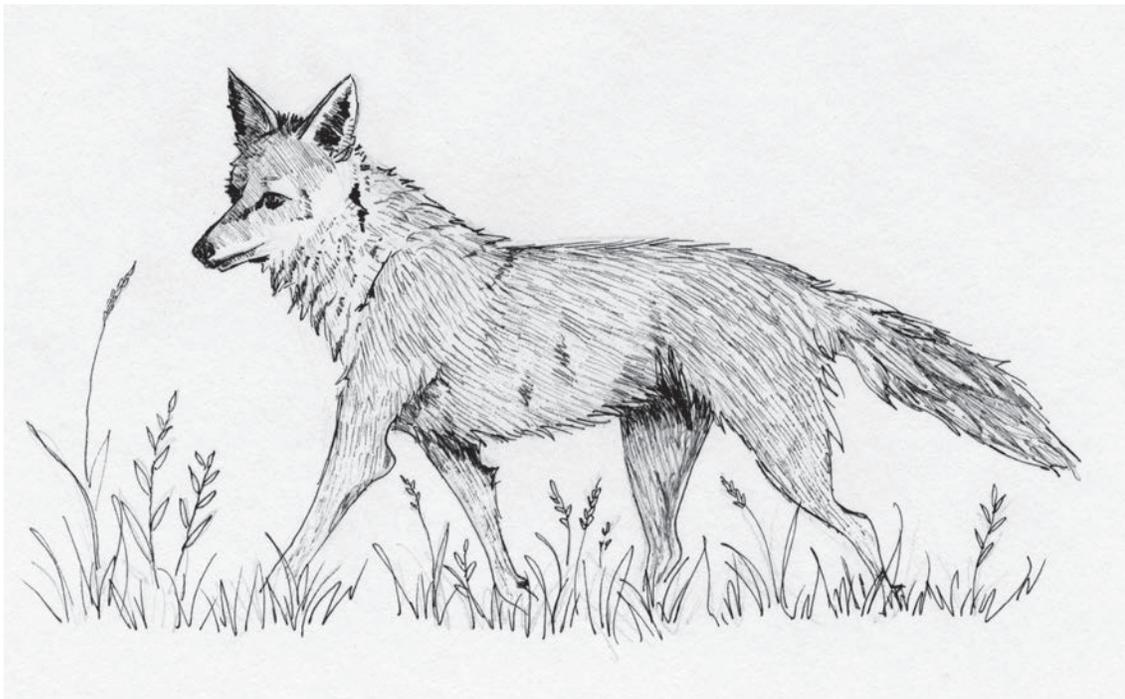
they correspond to other features in the landscape? In the close-up view, do you see plants growing in clusters or individually? Do you have different layers of plants (ground level and canopy)? What kind of colors, textures, and contrasts do you see? Can you see things moving (such as insects) in your view? In the microscopic view, look very closely at one part of one plant (such as the underside of the leaf). Look for patterns and textures, colors and contrasts. Do you see hairs in certain areas, or can you see pores on the leaf surface? Think about what types of processes might create the patterns you see.

When looking at patterns within a landscape, be aware of large scale **abiotic** patterns creating what you see, and also notice the micro-abiotic factors that create patterns. Looking for these small scale patterns can explain why a certain plant grows in one place but is absent from a similar looking area just meters away. Look for patterns and textures, colors and contrasts. Think about what types of processes might create the patterns you see. What patterns and processes might you find at all three scales?

Patterns we observe in vegetation can be directly linked to abiotic factors of the ecosystem, be it on a **macro** or microscopic scale. In this activity, focus on the abiotic

(nonliving) factors you see at a human scale. For example, with a large rock or boulder in a meadow, we might ask, "How does this rock affect the plants that grow in the meadow?" Plants growing close to the rock could take advantage of differences in microclimate, such as moisture trapped by the shade on the north side, additional heat stored in the rock to keep the plant warm through the night, shade on the roots, cooler morning sun/afternoon shade (or the opposite). If the rock is located on a slope, the rock could channel water towards or away from certain areas. The rock could provide relief from harsh winds. The warmth and protection of the rock could be a benefit to insects and reptiles. All of these impacts could be taking place in the space of a couple meters. What other abiotic factors could affect plants growing nearby (examples: slope, soil type, light, water, wind, temperature variances)? How does each plant affect its neighbors?

Use this opportunity for observation and drawing to pay close attention to details and patterns around you. While you draw, formulate hypotheses to explain why you are seeing the features and patterns that you observe.

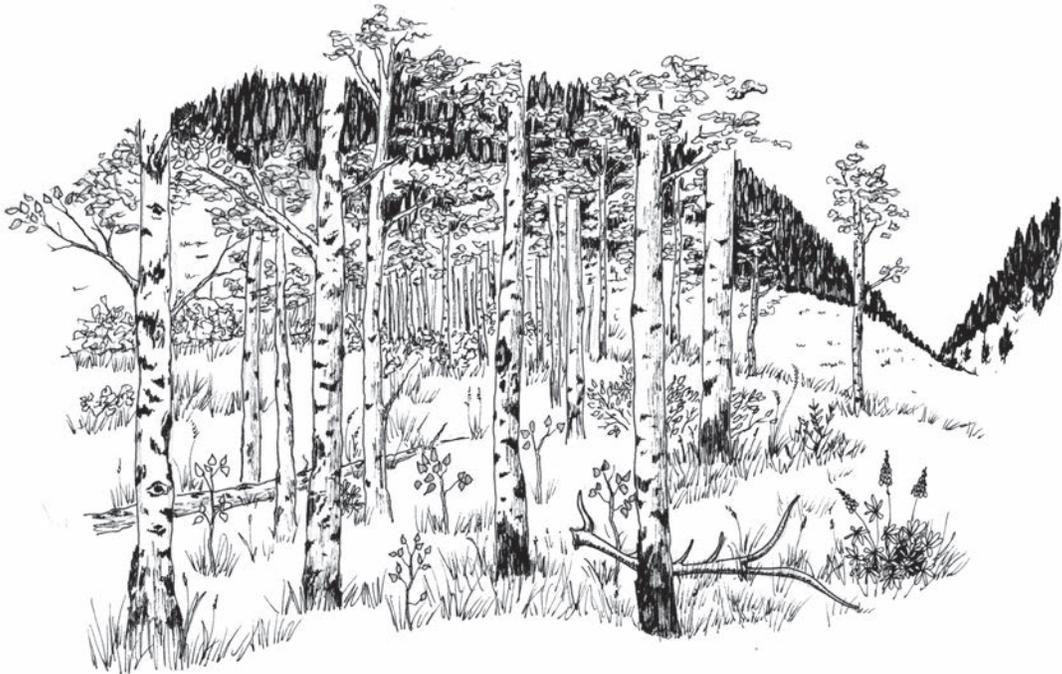




An Ecosystem Through an Artist's Eye

Student Directions

1. Discuss what things you might notice in a landscape or macro view. With your eyes closed, listen to your teacher read an inspiring quote from literature. Imagine how the scene must have looked to the writer.
2. Spread out. Look through your viewing frame at arm's length, select a spot, and draw the landscape view you see in your frame on your paper. Take your time to observe before beginning. Look for and include in your drawing patterns of color, texture and contrast. Regroup and share your drawings and feelings while looking at the landscape.
3. Discuss the process at work in a close-up view and listen to your teacher read a quote. Now select a spot to observe and draw the detail of your landscape close-up. Use your viewing frame to look at an area at your feet and draw what you see. Look for details, differences in size, color, shapes. Regroup and share your drawings and feelings while making observations at the close-up scale.
4. In the microscopic view, pick one plant to look at in greater detail. Isolate an area of the plant by looking through a hand lens and explore in close detail what you see. Fill your drawing frame with what you see in the hand lens. Pay particular attention to patterns, textures, and colors as you draw. Look at your subject, then take a minute to draw, and then look again. Repeat this process until you have sufficient detail. Fill your entire frame with what you see! Regroup and share. Did this view turn up any surprises? What processes are at work to create what you see at this scale?
5. Return to the same location and repeat this exercise during each season and look for changes throughout the year.

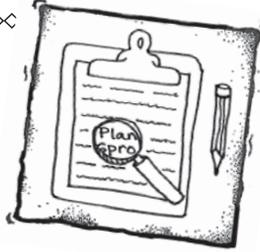




An Ecosystem Through an Artist's Eye

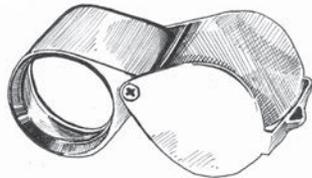
Reflection

Use your drawings as a source of inspiration for a journal entry. Think back to the readings that your teacher used to get you inspired at the beginning of this exercise. Describe one of your views in detail like the author your teacher read to you. Describe your landscape so that the reader can imagine exactly what you experienced. Don't forget to include the smells, weather, and sounds that made your spot special. Which scale do you like the most and why?



Self Assessment

- 1 Summarize the activity by comparing and contrasting views, and discussing the processes associated with different ecological scales.
- 2 Participate in the activity; work independently and join discussions.



EARLY FINISHERS

1. Draw a microscopic view of a leaf and use it to explore plant adaptations through your drawing and inquiry thinking skills. Draw a 5" x 7" frame and fill it with what you see in the magnifying glass or hand lens view.
2. Write and answer this question, "What other thing, in nature or man-made, does this remind me of?" Ask yourself, "Why does it remind me of this?" Was it because it had hairs or fuzz, what about the vein pattern, or margin? Add this to your answer.
3. Now ask yourself, "Could the function of the leaf be similar to what it reminds me of?"
4. Analyze your idea. Could this function help the plant adapt to the environment in which it is found? How would this help the plant to survive or reproduce? For example, say your leaf has tiny hairs or fuzz, maybe it reminds you of a fuzzy blanket. What is the function of a fuzzy blanket? What does this tell you about fuzz on a leaf? What other functions could a fuzzy leaf serve?



An Ecosystem Through an Artist's Eye

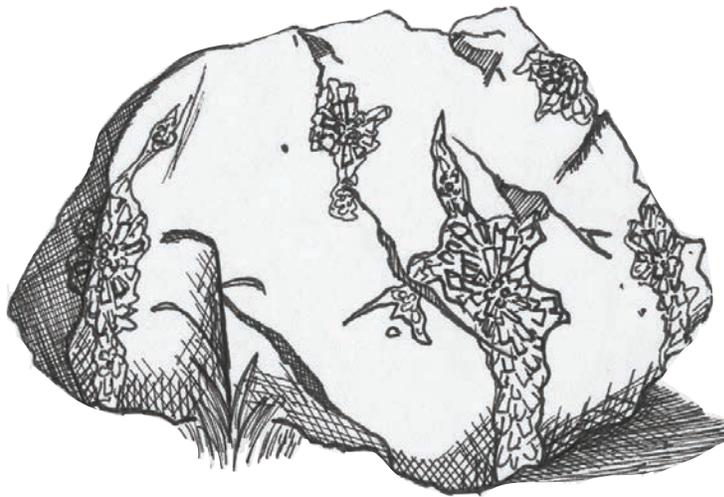
Resources

To bring students' attention to nature in an urban setting:

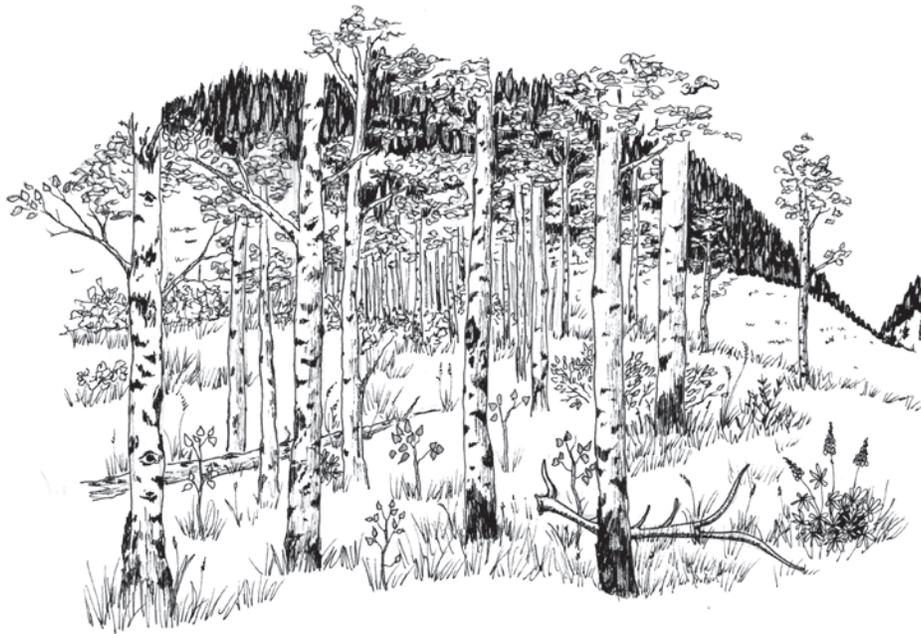
- Mitchell, Joseph. *The Rivermen*. In *Up in the Old Hotel*. New York: Random House, 1993.
- Pyle, Robert Michael. *The Thunder Tree: Lessons from an Urban Wildland*. New York: Lyons, 1998. Print.
- Tallmadge, John. *The Cincinnati Arch: Learning from Nature in the City*. Athens: University of Georgia, 2004. Print.

General Nature Writing:

- Leopold, Aldo, and Charles Walsh. Schwartz. *A Sand County Almanac, and Sketches Here and There*. New York: Oxford UP, 1987. Print.
- Assorted nature writings of John Muir, Aldo Leopold, Henry David Thoreau, Rachel Carson, Wendell Berry, Bernd Heinrich, and others.



Section 3:
**Ecology of
Native Plants**





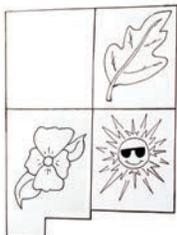
What's Goin' Down Underground



Time Estimate

60 minutes in the classroom
or lab

Best Season



Fall
Spring
Summer

We know more about the movement of celestial bodies than about the soil underfoot."

- *Leonardo da Vinci*, circa 1500's

Overview

Students explore soils by learning about the living relationships that connect the cycles of nutrients, microorganisms, and plants. Examining nitrogen fixation and mycorrhizal associations, and how plants, bacteria, and fungi interact underground in the soil. Students observe evidence of interactions, gain an understanding of the roles bacteria and fungi play in the ecosystem, and the benefits of bacteria and fungi in the soil.

Preparation

1. Collect an assortment of root samples (or have students collect) — include at least one legume, one conifer tree, and one bunch grass. Collect root ends from conifers (junipers, pines, firs, or spruces) from a healthy forest; trees in a landscape setting may or may not have mycorrhizal fungi. Several legumes—such as mesquite, clover, lupine, medicago, and vetch—are commonly found in lawns or weedy areas. To find a bunch grass, the easiest place to go is a grassland, but they can be found in many different habitat types in New Mexico. Blue grama grass is an example of a common bunchgrass. Bunchgrasses are grasses whose stems are joined in a clump or bunch rather than appearing as individual stems like in a lawn. It is beneficial to leave the stems and leaves on your root samples, when possible. It may also be helpful to students to label species of tree roots.
2. Arrange lab: prepare a root sampling bag for each lab group. Use a gallon zip lock bag to contain an assorted sample of the roots mentioned above. Gently knock off excess soil; the roots do not need to be completely clean. Each group will need: hand lenses, data sheets, and dissecting microscopes. Microscopes can be shared between groups.
3. Allow students time to carefully examine at their root samples. After initial observations, encourage them to look closer using the microscopes. They can gently wash root tips in water and dissect root sections and nodules, exposing additional interesting colors and tissue structure.

Assessments

- 1 Name and describe at least one interaction between plants and microorganisms that occurs under the soil surface.
- 2 Cooperate in a group to make observations, record data, and discuss findings.
- 3 Define the term rhizosphere and list at least three processes that take place there.

Teacher hints

- Soil biology is an important and complex subject and this lesson only scratches the surface of the knowledge a good botanist will need. Consider expanding this lesson to study the chemical and physical characteristics of soil, nutrient cycling, and the soil food web and how they relate to native plants. For supplementary curricula materials, see the "Resources" section at the end of the document.
- Definitions for vocabulary words related to this lesson can be found in the glossary if not explained in the text.



What's Goin' Down Underground

We know more about the movement of celestial bodies than about the soil underfoot."
- *Leonardo da Vinci*, circa 1500's

Materials Needed

- root samples (a random sampling that includes nitrogen fixing nodules, mycorrhizae, and roots)
- gallon zip lock bags
- hand lens
- dissecting microscope
- ruler

Overview

In this lesson you will explore soils by learning about the relationships that connect nutrients, microorganisms, and plants. You will study how plants, bacteria, and fungi work together in mutualistic processes (processes beneficial to both organisms) that take place in the soil underground. You will use hands-on skills to observe evidence of these interactions on the roots of plants, gain an understanding of the roles bacteria and fungi play in the ecosystem, and explore some of the benefits of having bacteria and fungi in the soil.

Vocabulary

fibrous roots

taproot

adventitious root

monocot

dicot

nitrogen fixing

legume

rhizobia bacteria

mycorrhizal fungi

hyphae

ectomycorrhizae

endomycorrhizae

rhizosphere

symbiotic

mutualistic

cryptobiotic soil crust

Learning Objectives

1. Gain understanding of soil microorganisms
2. Learn about the nitrogen cycle
3. Use visual observations to find plant/microorganism interactions
4. Describe the processes that you observe on plant roots
5. Describe a mutualism as a biological interaction

Background

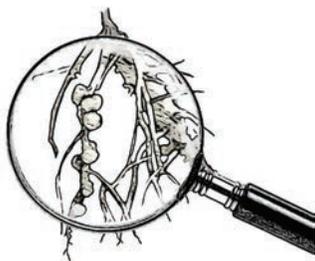
Humans are often enamored with plants due to the beauty and utility of the parts we see and interact with most often—the parts above ground: stems, leaves, flowers, and fruits. These parts provide structure, energy (photosynthesis through the leaves) and sexual reproduction (transmission of pollen through the flowers). But we often forget that the ecosystems we are a part of do not stop at ground level; in fact, the soils beneath our feet are amongst the most biologically diverse and active habitats known to science! A single teaspoon of soil may contain many, many millions of living organisms, from earthworms and arthropods to fungi and protozoa. All of these living organisms interact with one another in complex food webs.

Underground too are the hidden parts of plants—the roots. Plants are unique in that they exist both above and below ground. Think of plants and their roots as being liaisons or ambassadors between the aboveground portions of ecosystems that we can see and the belowground components that beneath our feet. Soils are reservoirs of resources like essential mineral nutrients, and it is plants that make those resources available to those of us who live above ground.



What's Goin' Down Underground

Roots and their interactions with the soil are incredibly important to plants, their function in ecosystems, and their utility to humans and other species. Roots provide essential services such as taking up much-needed moisture and essential mineral nutrients, anchoring the plant and holding



the soil in place, and providing reproduction by some asexual methods. Roots also provide homes to symbiotic bacteria (bacteria living in close physical association with another organism, typically to the advantage of both bacteria and host) and fungi in the soil that are critical to the survival of plants and all species that depend of them (that's pretty much every living thing!).

The most common types of root systems are **fibrous roots** and taproots. Fibrous roots have multiple branches that are similar in size. This type of root system is found on grasses and other **monocots** (plants with a single seed leaf or cotyledon). Taproots consist of an enlarged main root with extremely fine branching roots. Most **dicots** (plants with two seed leaves or cotyledons) have taproots. A taprooted dicot that you are probably very familiar with is the carrot. Although most roots are found underground, there are exceptions, such as **adventitious roots**. Adventitious roots grow off the stem and sometimes help support the stem (as in prop roots) or start a new plant by anchoring an arching branch where it touches the ground. Something that all roots share is their lack of nodes (small bumps where new leaf or stem growth begins).

Plants require soil as a medium for growth and to provide moisture and mineral nutrients. Soil is teeming with life and activity! Within the **rhizosphere** (an area approximately one millimeter thick surrounding plant roots) the biological activity is ten times greater than the remaining soil.

Microorganisms are attracted to and feed on the sugars and other organic compounds that seep from plant roots. In turn, the microorganisms in the rhizosphere layer help to break down and decompose dead plant cells and recycle nutrients. The microorganisms also produce gummy substances that hold soil particles together. The rhizosphere contains a wide variety of organisms including parasites and those that cause disease. However, the rhizosphere also hosts many very important symbiotic associations, two of which we will study in this lesson—nitrogen fixation and mycorrhizal associations.

Nitrogen Fixation-- Nitrogen is a macronutrient, an essential nutrient for plant growth, and for all living organisms. Although nitrogen gas makes up the majority of the atmosphere (80%), nitrogen gas is unavailable for plant (or animal) use. Plants can only take up dissolved forms of nitrogen, typically ammonium (NH_4^+) or nitrate (NO_3^-), that are often in short supply in soils. In the rhizosphere, bacteria inhabit the roots of plants and form nitrogen fixing nodules that capture nitrogen from the air and convert it to a form that plants can use. Nitrogen fixation is the process by which atmospheric nitrogen gas is converted into ammonia gas (NH_3) by a group of bacteria called rhizobia. The ammonia is quickly converted to ammonium and is subsequently available for many important biological molecules such as amino acids, proteins, vitamins, and nucleic acids (to form DNA). In the rhizosphere, the roots of specific species provide the bacteria with a home (a nodule), water, and carbohydrates. In return, the plant receives nitrogen in a useable form right next to its roots. Nitrogen-fixing bacteria are host specific, meaning they have the ability to infect and nodulate only the roots of certain plant species. One of the most common of these associations is between plants of the **legume** family (e.g. peas, beans, clover, vetch, and lupine) and the group of bacteria called **rhizobia** (in the genera *Rhizobium* and *Bradyrhizobium*). It is a common agricultural practice to harvest crops and then plant a species of legume to add nitrogen back into the soil. The legume family contains many plants we commonly eat (e.g., peas, beans, and soybeans) or grow for livestock food (e.g., clover and alfalfa), as well as a diversity of native plants. Nitrogen fixing rhizobia bacteria are commonly added to agricultural legume seed crops and backyard garden plantings to maximize their nitrogen fixing



What's Goin' Down Underground

effects. In native ecosystems, nitrogen fixers provide the majority of the available nitrogen for other plants to uptake. After it is taken up by plants, nitrogen is available for wildlife, livestock, and humans to consume in the vegetation they eat, providing critical building blocks for proteins and DNA in their bodies. Because nitrogen is constantly being lost from the soil and it is primarily replaced by nitrogen-fixers, nitrogen-fixing species are critical to native ecosystem function. However, in some ecosystems, it is possible that the presence of an overabundance of nitrogen could result in a greater amount of nitrogen in the soil making it possible for non-native species that cannot tolerate our nitrogen poor soils to invade.¹

Mycorrhizal associations-- The second important belowground association we will examine is between plant roots and **mycorrhizal fungi**. These fungi, which form an underground net of white cottony threadlike connections between the roots of plants, help capture needed but hard to find nutrients for the plants with which they grow, such as nitrogen, phosphorous and zinc, among others. Some nutrients do not move readily through soil, so plants may have a hard time finding sufficient levels needed for optimal growth within their own root system. Mycorrhizal fungi inhabit the roots of plants to get food (carbohydrates), and in return their hyphae (thin, thread-like growths that spread through the soil), with their large surface area, absorb nutrients that the fungi share with their host plant. This association allows plants to mine larger areas to obtain the nutrients they need. The mycorrhizal **hyphae** form interconnecting networks between soil particles and the roots of plants, and will often network between the roots of many neighboring plants. You can see evidence of some types of mycorrhizae in their above ground reproductive structure—a mushroom! However, not all mushrooms are the fruiting bodies of mycorrhizal fungi and not all mycorrhizal fungi produce large visible reproductive structures.

Mycorrhizal associations occur on almost all plants with the exception of a few species, like crucifers such as broccoli and dame's rocket, and are not as species-specific as nitrogen fixing associations. **Endomycorrhizae** are fungi that grown within root cells are commonly associated with grasses, row crops, vegetables, and shrubs. **Ectomycorrhizae** grow on

the surface layers of roots and are commonly associated with trees. For many native species it is still unknown whether or not they form mycorrhizal associations. It appears that plants with many fine root hairs are not as dependent on this symbiotic association as plants with tap roots.² Mycorrhizal fungi are present in sufficient quantities in most native soils for plants' needs. Mycorrhizal fungi can also be purchased to add to the soil and are sometimes added to nursery plantings that are potted in sterilized soils or for ecological restoration purposes.

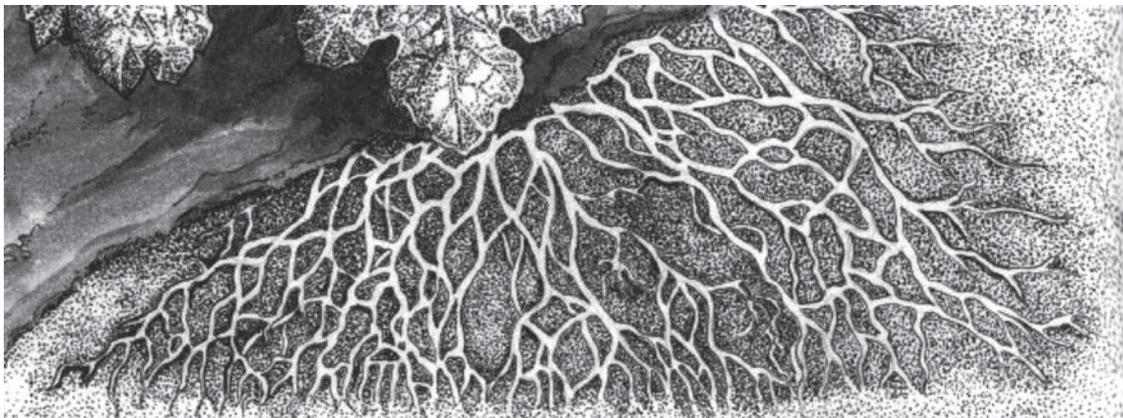
Cryptobiotic soil crust found in arid regions throughout the world play an important role in the ecosystems in which they occur. In the high deserts of the Colorado Plateau (which include parts of Utah, Arizona, Colorado and New Mexico) and deserts of California and Nevada, these knobby black crusts are alive with cyanobacteria, and also include soil lichens, mosses, green algae, micofungi and bacteria. These crusts are characterized by their marked increase in surface topography, often referred to as pinnacles or pedicles. In some cases they are well-developed and may represent 70 to 80 percent of the living ground cover. When moistened, cyanobacteria become active, moving through the soil and leaves a trail of sticky material behind. The sheath material sticks to surfaces such as rock or soil particles, forming an intricate web of fibers throughout the soil. Even after the cyanobacteria die, the mucous is still in the soil, holding the particles together. In this way, loose soil particles are joined together, and the organisms of the crust increase the stability of the soil, decreasing soil erosion. Cryptobiotic soil crusts are extremely susceptible to destruction by crushing and trampling. The organisms are only active when wet. Therefore, in an arid environment, re-establishment of the crust is slow. Once damaged, they may take many years to grow back. Areas that have been stripped of cryptobiotic crusts are vulnerable to erosion, flooding, deflation, dust storms, invasion of exotic weeds that thrive on disturbed soil, and/or chemical impoverishment due to loss of organic material. Not only are the crust-free soils now subject to erosion, the soil particles now removed from these areas can cover adjacent crusts that were not disturbed.



What's Goin' Down Underground

Student Directions

1. Form small groups or teams (2-3) for the lab section. Each group will receive a sample of plant roots to examine.
2. Remove root samples from the bag and spread out on a piece of paper. Observe the roots closely. Divide the roots into similar looking groups. On your data sheet give each group a sample number.
3. Note the roots' general characteristics such as type (taproot vs. fibrous), shape, color, texture (woody vs. fleshy), length, girth. Look carefully for nodules and record in your notes if you find them. Are there any underground structures such as bulbs or corms? Record a description using the above characteristics to help you differentiate the root samples. Use words and sketches to produce a complete description that would help someone identify which roots are which.
4. Examine your root samples more closely using some of the tools available in your classroom. Use a hand lens or dissecting microscope to get a closer look at the details of your roots: root hairs, root tips, color changes, root thickness changes, unusual branching patterns, foreign material attached, and anything else that you observe. Add your observations to your data sheet. As you do this, imagine the job your roots need to do such as taking up water and nutrients, holding your plant and soil in place and think about how the roots you are looking at might be adapted for accomplishing these tasks in the environment in which they are found.
5. Read the background information from this activity. Discuss with your group whether any of your root samples exhibit characteristics associated with rhizobia (nitrogen-fixation) or mycorrhizal relationships. Add this to the "relationship observed" column, and include a quick sketch of what the nodules or hyphae look like.
6. Dissect roots to try to understand abnormalities from the inside. What do they look like? How are they different from normal looking sections of the root?
7. Share your team's findings with the class. Did the teams have similar findings or were the results different? Did the root samples come from a variety of plants? Look at the plant tops. Are there similarities between the roots from different samples that correspond to similarities between the plant tops?





What's Goin' Down Underground

Reflection

How would a restoration ecologist need to consider nitrogen-fixing plants and mycorrhizae when planning to restore a native ecosystem? Would this be different in a prairie versus a forest? How might this differ in your ecoregion versus another ecoregion?



EARLY FINISHERS

1. Learn more about soils, which are a key factor in plant growth and distribution. Look into the chemical and physical properties of soil and how they affect plant growth. Additional soil characteristics that are important to plant growth include: pH, nutrient cycles, particle size, organic matter, and water infiltration.
2. Study the components of the soil food web and how they work together. Diagram a simple web.
3. View a worm composting bin and diagram the soil food web you find there.

Self Assessment

- 1 Name and describe two interactions between plants and microorganisms that take place at the soil level.
- 2 Work as part of a cooperative group to make observations, record data, and discuss findings.
- 3 Define the term rhizosphere and list two or more processes that take place there.



Resources

- Soil and Water Conservation Society (SWCS). 2000. *Soil Biology Primer*. Rev. ed. Ankeny, Iowa
- USGS Canyonlands Research Station, Southwest Biological Science Center, Biological Soil Crusts: <http://www.soilcrust.org>
- Weber State University, Department of Botany, Cryptobiotic Soil Crusts: <http://faculty.weber.edu/sharley/1203/cryptobiotic.html>
- U.S. Geological Survey, Cryptobiotic Soils: <http://geochange.er.usgs.gov/sw/impacts/biology/crypto/>
- USDA Natural Resource Conservation Service: <http://soils.usda.gov/education/>
- Soil Science Society of America: <https://www.soils.org>
- USDA Natural Resource Conservation Service. The Soil Biology Primer: http://soils.usda.gov/sqi/concepts/soil_biology/biology.html
- Portland State University, Ecoplexity: <http://ecoplexity.org/>



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What's Goin' Down Underground

Root Sample Data Sheet

Sample number	General root characteristics (branching structure, color, length, shape, etc)	Observations (root hairs, underground structures, other observations)	Relationship observed? (describe any nodules, etc)



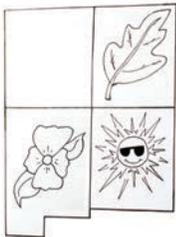
Survival Quest: a Pollination Game

"Bugs are not going to inherit the earth. They own it now. So we might as well make peace with the landlord. -*Dr. Thomas Eisner* (1929--present)

Time Estimate

1 hour; an additional session is required for In the Field!

Best Season



Fall
Spring
Summer

Preparation

1. Use this lesson in conjunction with the lesson "Secret Life of Flowers" for students that need a refresher on flower anatomy and for additional background information.
2. Hints for observing pollinators in the field:
 - Have students wear neutral colored clothing.
 - Schedule observations on a sunny day with low wind.
 - Supply binoculars, nets, collapsible terrarium/insect collection cage, and digital camera if possible.

Overview

In this lesson, students gain a basic understanding of co-evolution as it applies to native plants and their pollinators by studying local flowers.

Teacher hints

- As a starting point for this activity, reach out to local government agencies that manage lands or private conservation organizations that may have suggestions for common pollinator plants in your area. The Xerces Society's Pollinator Resource Center's webpage provides information on native pollinators. You can find lists of local native plants on the Native Plant Society of New Mexico website as well as in Appendix II. If you have started a native wildflower garden at your school, this is a good opportunity to talk about insect diversity and different types of pollinators in your garden project. Time your lesson according to plant phenology in your area and the best time of day to observe pollination.
- The second part of this activity should be completed in a natural area. If you don't have access to a natural area, an alternate activity can be completed using the USDA Plants Database (see resources section for the website address).
- Supply students with a basic guide to insect identification. They will not need to know specific species of insects but it will be helpful for them to classify insects by order (i.e. beetle, fly, and bee) and to differentiate between a moth and butterfly. The University of Iowa Bug Guide for the U.S. and Canada provides a good overview of different types of insects.
- Considering making a short-term collection of insects to observe. Create a long-term monitoring log and record pollinator observations from year to year in a native wildflower garden at your school.

Assessments

- 1 Explain biological mutualism in relationship to flowers and pollinators.
- 2 Gain understanding of co-evolution, and be able to explain the process as it relates to plants and pollinators.
- 3 Relate flowers' traits to specific pollinators that they attract; make predictions of possible pollinators by looking at flowers.



Survival Quest: a Pollination Game

"Bugs are not going to inherit the earth. They own it now. So we might as well make peace with the landlord. -*Dr. Thomas Eisner* (1929--present)

Materials Needed

- botany field guide
- insect field guide
- clipboard and pencil for each team
- hand lens
- binoculars (optional)
- insect net (optional)
- pipe-cleaner

Overview

In this lesson you will explore co-evolution as it applies to native plants and their pollinators by examining flowers out in the field.

Background

Have you ever heard someone mention the phrase "the birds and the bees"? Do you know where that phrase comes from? It comes from plants and how they reproduce! Birds and bees play a key role as pollinators in plant reproduction, by transferring the genetic material from flower to flower.

Pollination is the transfer of pollen from male flower parts (stamen) to the female flower parts (stigma) and is how plants reproduce sexually. Through **co-evolution**, plants and their pollinators have developed a mutually beneficial relationship, adapting their form and function to make both their lives more successful. As such, the lives of plants and their pollinators are tightly intertwined. Without pollinators, the health of our native plants and ecosystems would falter. In addition, pollination also greatly benefits humans. Estimates suggest that one third of the human food supply is dependent on the work of pollinators to produce crops such as blueberries, almonds, melons, pears, apples, and even chocolate!

Not all plants are pollinated by birds or bees. Pollinators can be insects such as bees, butterflies, flies, and beetles, as well as hummingbirds, and mammals such as bats and small rodents. Many plants, such as grasses and coniferous trees, are pollinated by wind. In Southwest New Mexico, the lesser long-nosed bat and Mexican long-tongued bat pollinate cacti and agave. Some plants, such as the peanut, are self-pollinating and may not even require a pollinator, although this is rare in nature.

Plants and their pollinators have developed an intimate ecological relationship during the process of co-evolution. Plants, being stationary organisms (no legs!), need a means to transport their pollen to other plants for sexual reproduction. For many plant species, animal pollinators visit flowers in order to get food in the form of pollen and nectar and in the process, unwittingly transfer pollen to other plants in their travels to other flowers for another feast. Picture a bee diving into a flower, going head first deep down to reach the nectar glands at the bottom of the flower. Stamens hang down from above, dangling dusty pollen, which brushes the hairy back of the bee as it forages for sweetness. As the bee leaves, it unintentionally

Learning Objectives

1. Explore the concept of co-evolution of flowers and pollinators
2. Define a mutualism and describe how flowers and pollinators demonstrate this concept
3. Increase your appreciation for the value of pollinators
4. Examine one of the interconnections between plants and animals within ecosystems

Vocabulary

co-evolution
mutualism
pollination
generalist
specialist



Survival Quest: a Pollination Game

carries that pollen to the next flower, where it dives down to forage again, dropping the pollen it carries there onto the sticky stigma, pollinating the flower. The bee is an innocent bystander, and does not know of the important evolutionary act in which it has just participated.

So, what might a flower look like that does not need to attract a pollinator because it is wind-pollinated? First, it generally has no petals or very tiny petals, since petals are for attracting pollinators and can block the flow of wind. Secondly, wind-pollinated flowers generally have long-dangling stamens with tons of pollen so that when it is carried randomly on the wind the chances of pollen landing on a flower of the same species are better. The stigmas of wind-pollinated flowers are also often large, exerted, and feathery, so they can comb the air for pollen.

Flowers have evolved an amazing array of scents, colors, markings, and shapes that make them attractive to specific pollinators and facilitate the transfer of pollen to the pollinator. Some plants have evolved physical barriers that restrict the access to their nectar to one specific type or species of pollinator. For example, trumpet-shaped flowers favor the extended beak of the hummingbird; these flowers position their pollen to be deposited on the birds' head. A special petal on lupine flowers acts as a trapdoor, limiting access to all but the heaviest of insects, the bumblebees. Hedgehog cactus nectar is located at the base of the petals and bees need to swim down into the anthers in order to get the nectar.

Flowers, in return for receiving pollen transportation services, reward the pollinator with a high quality food. Some pollinators may pursue the highly nutritious sugary substance, nectar. Others may consume the protein rich pollen itself, and still others seek the fatty oils, resin, or wax that certain plants produce. Flowers have evolved certain colors, shapes, markings, and scents to attract a particular type of pollinator. By attracting only specific types of pollinators (pollinator loyalty, so to speak), a plant increases the likelihood that its pollen will be carried from its flowers to the flowers of another plant of the same species—this is required for successful reproduction. Attracting specific pollinators ensures that the flower's valuable pollen is not

wasted by landing on a flower from a different species. By restricting the type of pollinator that accesses its flowers, the plant is also ensuring an adequate food source for its loyal pollinator. Pollination is beneficial to both the plant and the pollinator. We call this type of mutually beneficial relationship in a biological relationship a **mutualism**.

Pollinators in return have adapted physical characteristics that allow them to gather and transport pollen as they seek food. Some insects have fuzzy hair that brushes against the anthers of a flower and carry pollen, and some bees have structures called pollen baskets on their legs specifically for transporting the protein rich food back to the hives.



Plants have developed many interesting and unique methods of attracting pollinators. Some orchids have developed flowers that look or smell like female insects, using sight or scent to trick male insects into visiting and pollinating the flower. Some orchids, such as the lady's slipper (*Cypripedium parviflorum*) have a pouch-shaped flower part, which is easy to enter but, because of strategically located small hairs, limits the pollinator to a single exit, forcing the pollinator to walk directly through its pollen.¹ Moth-pollinated flowers such as yucca tend to be pale colored or white and highly scented, often only opening or releasing its scent at night to attract the night-flying moths. Some flowers such as three leaf sumac (*Rhus trilobata*) smell like rotten meat to attract flies as their pollinators. Many flowers with composite heads such as cutleaf coneflower (*Rudbeckia laciniata*) accommodate butterflies. As butterflies do not hover and need a place to stand, many composites provide a resting place. Each pollinator is attracted to a different style of flower and the flowers are engineered to reproduce successfully with their pollinator.



Survival Quest: a Pollination Game

Student Directions

Part 1: Pollinator Stats

1. Work in teams of two to complete the pollinator data table. Your quest is to find a local native flower that will attract each of the listed pollinators on the table. Use the Flower Trait Chart for guidance in flower shape, color, and other features needed to attract the target pollinator.
2. Look in local field guides (or better yet, in the field) for flowers that display the traits you are seeking to complete your sheet (color, shape, scent, etc.)
3. If you need additional information about bloom times or flower photos, check out <http://plants.usda.gov/> and access flowers by scientific or common name.
4. Try to locate two different native plant flower sources for each pollinator in your chart.

Part 2: The Survivor Quest Challenge

1. Choose an insect or bird pollinator (not wind) from the data sheet. Your challenge will be to feed it for the entire season!
2. Research your pollinator to find out when it is active in your area. For example, a migratory hummingbird might be in your area from Spring to Fall, or a butterfly may have two hatch periods with adults flying in May and July. These will be the target times for you to feed your pollinator.
3. Armed with this knowledge, find flowers that will match the traits that the pollinator is attracted to and will be blooming in the time periods needed. If the pollinator is active for a long period, you will probably need multiple flowers with staggered bloom times to make it through the season.

CLASS DISCUSSION:

1. What might happen if you (and the pollinator) are unable to find the flowers needed at the proper times?
2. What are some of the possible options for the pollinator?
3. What will happen to the plants whose pollinators cannot locate them?



Survival Quest: a Pollination Game

In the Field

1. Put your pollinator knowledge to the test. Work in teams, spread out from other teams, and pick one flower or group of flowers to observe. Use the pollinator observation sheet and start by filling in the "Traits that helped you decide" section.
2. Now back away from your flower and sit quietly observing. One team member can watch through the binoculars while the other acts as recorder. Switch half way through your observation period. Closely observe your flower for 15-20 minutes.
3. After the observation period, answer the remaining questions on your sheet.
4. Pollinators can be affected by weather conditions. Try observing flowers at different times of the day or evening (possibly even at night!). Most insects will be active at midday on a warm day; wind can discourage butterflies and moths. Hummingbirds tend to be more active in early morning and late evening. Moths and bats are more active at night. What if you are not able to observe any pollinators? What does this tell you?
5. Finish by taking a pipe-cleaner and trying to collect pollen from your flower. Take note of where you find it, distances, amounts, and hidden avenues to access it. Does this fit with the rest of your observations?

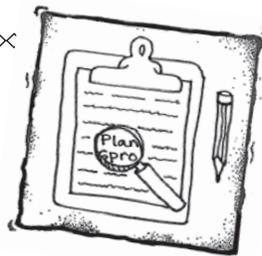


Reflection

Create a unique flower/pollinator relationship. Choose a species to be your pollinator—it could be a bear, human, slug, alien, or whatever you choose.

Now design a flower that will attract your pollinator and only your pollinator. Describe in writing or sketch what your flower looks like. List how it attracts the pollinator, how it limits access to the pollen to only your pollinator, and how the pollen is carried for transfer to the next flower. Remember to make it a mutualistic relationship—what will your pollinator receive in return?

Also consider the following: scientists predict that plant pollinator relationships may be greatly affected by climate change. How might climate change affect the plant pollinator relationship?





Survival Quest: a Pollination Game

EARLY FINISHERS

Design a native plant garden with one or more pollinators in mind. Choose flowers with the traits that attract the intended pollinator. Look also at bloom times and try to include flowers that will bloom in succession over a long period of time. Manage your site for pollinators: refrain from using pesticides, leave older growth standing to provide habitat for over-wintering insects, and allow plants to reseed themselves. Consider constructing nest sites for bees and other pollinators—you can find instructions and suggestions on the Xerces Society website. Monitor the site and create an observation log for future students to assess pollinator activity over time in the garden area.

Self Assessment

- 1** Define the word mutualism and explain how plant pollinator interactions are a mutualistic relationship.
- 2** Explain the concept of co-evolution and how it relates to plants and pollinators.
- 3** Be able to group flowers by trait to predict its pollinator.



Resources

- US Forest Service, Celebrating Wildflowers Website: <http://www.fs.fed.us/wildflowers/index.shtml>
- Assorted wildflower and insect field guides for your region such as Larry J. Littlefield and Pearl M. Burns. 2015. *Wildflowers of the Northern and Central Mountains of New Mexico*. University of New Mexico Press, Albuquerque, NM and Steven J. Cary. 2009. *Butterfly Landscapes of New Mexico*. *New Mexico Magazine*, Palm Coast, FL.
- USDA Plants Database for flower photos and information: <http://plants.usda.gov/>
- The Xerces Society's Pollinator Resource Center. Find information about native pollinator plants for your region, as well as pollinator identification guides and much more: <http://www.xerces.org/pollinator-resource-center/>
- Native Seed Network website: <http://www.nativeseednetwork.org/>
- University of Iowa Bug Guide for the U.S. and Canada: <http://bugguide.net>



Survival Quest: a Pollination Game

Survival Quest: Pollinator Data Table

Native Plant		Bloom dates	Pollinator
1.			Bee
2.			
1.			Hummingbird
2.			
1.			Butterfly
2.			
1.			Fly
2.			
1.			Wind
2.			
1.			Beetle
2.			
1.			Moth
2.			



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Survival Quest: a Pollination Game

Pollinator Observation Sheet (In the Field section)

Names: _____ Date: _____ Time: _____

General Weather Conditions: _____

Location of Plant Observed: _____

Name of Plant: _____

Sketch your flower:

Predict the pollinator for this flower? _____

Flower traits that indicate which pollinators:

- 1.
- 2.
- 3.

Observations of the flower:

Visitors observed? (record all seen)	What were they doing (watch carefully)?	How long did they stay?	Where did they go when they left?	Name or sketch of visitor

Did your observations support your pollinator prediction?

What questions do you still have after your observations?

Pollinator Chart

Flower Trait	Bats	Bees	Beetles	Birds	Butterflies	Flies	Moths	Wind
Color	Dull white, green, or purple	Bright white, yellow, blue, or UV	Dull white or green	Scarlet, orange, red, or white	Bright including red and purple	Pale and dull to dark brown or purple; flecked with translucent patches	Pale and dull red, purple, pink, or white	Dull green, brown, or colorless; petals absent or reduced
Nectar guides	Absent	Present	Absent	Absent	Present	Absent	Absent	Absent
Odor	Strong musty; emitted at night	Fresh, mild, pleasant	None to strongly fruity or fetid	None	Faint but fresh	Putrid	Strong, sweet; emitted at night	None
Nectar	Abundant; somewhat hidden	Usually present	Sometimes present; not hidden	Ample; deeply hidden	Ample; deeply hidden	Usually absent	Ample; deeply hidden	None
Pollen	Ample	Limited; often sticky and scented	Ample	Modest	Limited	Modest in amount	Limited	Abundant; small, smooth, and not sticky
Flower Shape	Regular; bowl shaped—closed during day	Shallow; have landing platform; tubular	Large bowl-like,	Large; funnel-like; cups, strong perch support	Narrow tube with spur; wide landing pad	Shallow; funnel-like or complex and trap-like	Regular; tubular without a lip	Regular; small and stigmas exerted

*Pollinator chart taken from: US Forest Service, Celebrating Wildflowers website, May 16, 2008, <http://www.fs.fed.us/wildflowers/pollinators/syndromes.shtml> U.S. Forest Service Rangeland Management Botany Program, 1400 Independence Ave., SW, Mailstop Code: 1103, Washington DC



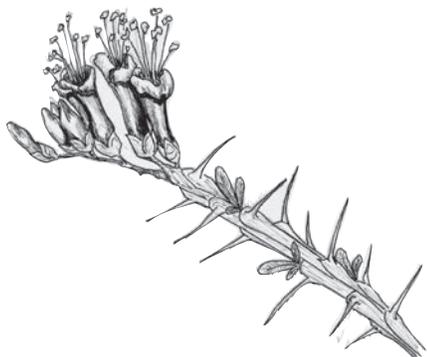
Plant Wars: A Tale of Offense and Defense

"We can complain because rose bushes have thorns, or rejoice because thorn bushes have roses" - *Abraham Lincoln*



Teacher hints

- Use this lesson in conjunction with your studies of evolution.
- See the ethnobotany section of this curriculum for more information about plant medicines.
- **Caution:** Learn and help students avoid the plant *Datura* as it is highly toxic.



Overview

In this lesson, students will explore how plants defend themselves from herbivores and omnivores using physical and chemical defenses. Students will read, research, discuss, observe, and speculate about the chemical defenses of plants, how they work, and how humans use them. They will also look at how other species counteract these chemicals in the intricate dance of co-evolution.

Preparation

1. Locate suitable outdoor sites for plant observations.
2. Introduce the plant observations with class discussion. Ask students to brainstorm: "How do plants defend themselves from insects and browsing animals?" Keep a list of their ideas.
3. Conduct the plant observations during class or assign them for outside of class time. Without giving students any additional background information, have them complete the plant defense observations. Copy just the activity directions for students to carry in their field journal to guide their observation session.

Assessments

- 1 Explain the difference between physical and chemical plant defenses and give two examples of each.
- 2 Describe how co-evolution between plants and herbivorous insects occurs.
- 3 Make detailed observations and use them to make inferences.



Plant Wars: A Tale of Offense and Defense

"We can complain because rose bushes have thorns, or rejoice because thorn bushes have roses" - *Abraham Lincoln*

Materials Needed

- field journal
- copy of *observation guidelines*

Overview

In this lesson you will explore how plants defend themselves from herbivores using physical and chemical defenses. You will read, research, discuss, observe, and speculate about the chemical defenses of plants, how they work, and how humans use them. You will also look at how other species counteract these chemicals in the intricate dance of species co-evolution.

Vocabulary

co-evolution
herbivory
allelopathy
phytochemical
phytotoxin
antioxidant
angiosperm
biological controls

Learning Objectives

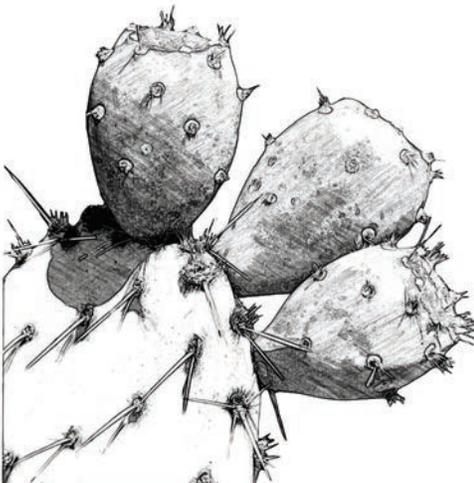
1. Hone observation skills; record data and discuss findings
2. Gain understanding of different methods of plant defenses against herbivory
3. Describe the process of co-evolution between two species
4. Increase understanding interactions between species in plant communities
5. Gain understanding of human interactions with plant chemicals

Background

Unlike animals, plants cannot get up and move around. This presents a number of challenges as they cannot flee to escape predators, they cannot travel to a more hospitable environment or search a far for resources. In this lesson, we focus on how plants innovatively combat these obstacles head-on through both physical and chemical means. We also look at how other species have co-evolved to counteract these defenses.

Plants may not be able to flee from their predators, but they have evolved physical and chemical strategies to defend themselves from attacks by hungry herbivores. **Herbivory** is the process of animals eating plants. If you have ever tried to pick fruit from a prickly pear cactus and had your hands punctured by irritating spines and barbed bristles (called "glochids"), you know that consuming prickly pear fruits comes with a price! The spines on prickly pear cactus are just one of several types of defenses that plants have evolved to deter herbivory.

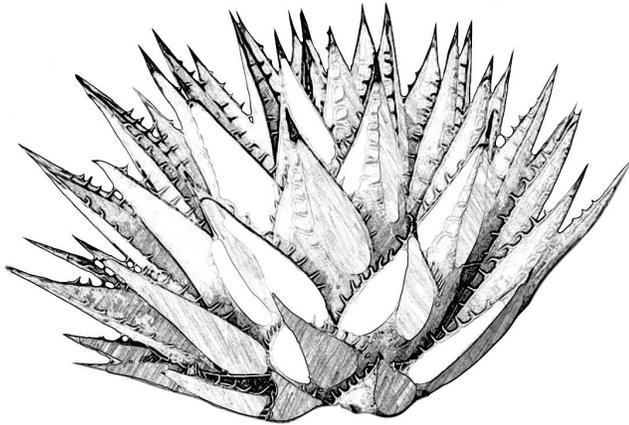
Thorns and hairs are other types of physical defense structures that protect plants' vulnerable and valuable parts. The effectiveness of each depends on the type of herbivore attempting to consume the plant. Large thorns may be





Plant Wars: A Tale of Offense and Defense

more effective against mammalian herbivores such as deer, while hairs are better deterrents to some insect herbivores. Some plants also produce compounds such as waxes and resins that physically alter the external texture of the plant, making feeding challenging. In such cases, an insect may have difficulty gaining traction on a leaf surface or physically biting through the leaf cuticle. Other plants attract and/or



house insects that defend the plant. A particularly famous example of this is the *Acacia*-ant symbiosis, in which ants live inside the large, hollow thorns of the *Acacia* tree and aggressively deter herbivores. Still other plants, such as some species of gooseberries, produce armored fruits that deter animals from consuming of the seed.¹

While all plants share the same basic chemical processes that support growth and metabolic functions such as photosynthesis and respiration, many plants have gone a step further to produce secondary chemicals to defend themselves. These secondary chemicals act as toxins that can disrupt an herbivore's metabolism or make the plant indigestible. When talking about plant defenses you will encounter terms like **phytochemical** and **phytotoxin** (phyto- meaning plant). In order to compete with other plants for space, sunlight, nutrients, and water, some plants have devised some very crafty schemes to keep other plants out of their way.

Some plants produce phytochemicals that disrupt the growth, reproduction, or survival of other plants. This process is called **allelopathy**. Examples of this include the black walnut tree, salt cedar, and creosote bush, which produce a chemical that suppresses or kills other plants

under its canopy. If you have a black walnut, salt cedar, or a creosote bush in your yard or on your school grounds, go out and check if you can find any other plants growing underneath it. Not all phytochemicals are used for defense though. Plants also use chemicals for beneficial interactions with insects, such as producing the colors, scents, and nectar essential to attract and support pollination.

The evolution of **angiosperms**, or flowering plants, coincides with an explosion in the diversity of insect species on Earth. Insects have continually taken advantage of their plant companions over millions of years. The fossil record shows insects have repeatedly adapted their eating behaviors to co-evolve with changing plant characteristics through time. For example, early insects had mandibles (jaw and mouth parts) for biting and chewing primitive vegetation, but as more complex vascular plants evolved, insects adapted more specialized features, such as sap-sucking mouth parts, that could collect the sugary fluids flowing through the more advanced plant tissues. Most recently, with the evolution of flowering plants, we find insects with mouthparts adapted to feed on flower nectar.² This process of two species adapting in response to each other is called **co-evolution**.

The diversification of insects likely provided the selective evolutionary pressure that led to plant defense (and offense) adaptations. For example, some plants have adapted to produce chemicals that inhibit the absorption of nutrients in the digestive tracts of herbivores or act as poisons to kill the herbivore directly. In turn, some herbivores have adapted their metabolism to continue to feed on poisonous plants, in spite of the plant's attempt to deter them with chemical defenses. Such changes come at a cost—some butterfly larvae have become such specialized feeders that they are limited to eating just a single species of plant! The plant still gains some benefit from its poisons, since very few herbivores can tolerate eating it. The specialized herbivore benefits from the very limited competition for food. Can you think of other benefits of this limited relationship to the plants or herbivore? What about the downsides? What happens to these specialized herbivores when the population of their host plant declines?



Plant Wars: A Tale of Offense and Defense

Some herbivores eat a larger variety of plants, but are still limited to species from a single plant family. A common butterfly, the cabbage white, is such an example. The cabbage white larvae feed only on plants in the Brassicaceae (mustard) family such as cabbage and broccoli. This butterfly is often found in gardens and agricultural fields, and is considered a pest since its food needs put it in direct competition with agricultural productivity.

Still other herbivores are generalists, feeding on a much broader range of host plants. The painted lady butterfly is a generalist whose larvae are known to feed on more than 100 different plant species from at least three families. Generalists usually have a broad habitat range—the painted lady is found in Africa, North America, South America, Asia, and Europe and is the most common butterfly in the U.S. It may seem that a generalist has the best survival strategy, but such a lifestyle has downsides too. A generalist must compete for food with many other herbivores, and therefore might need to travel widely to secure enough resources to meet its needs.



A further twist on plant chemicals is that some butterflies that have adapted to eating poisonous plants are able to store the phytotoxins in their own body for their defense, making them poisonous or unpalatable to their predators. The larvae of the monarch butterfly feed on the milkweed plant, storing toxic chemicals found in the plant's sap. The toxic chemicals are passed from the larval stage to the adult

butterfly stage. This makes the monarch butterfly (and larvae) foul tasting to its predators. Birds quickly learn to avoid the orange and black pattern of the monarch butterfly.

Restoration ecologists can take advantage certain insect-plant interactions to control invasive weeds. In order to control some invasive plant species, **biological controls** can be introduced to an area threatened by the invasive species. These biological controls are generally insects that originate in the native ranges of the invasive weed in question and have evolved to specialize only on that particular weed species—thus, they can help keep those populations in check without also feeding on native plants. An example for the Southwest is the use of the Tamarisk leaf beetle to help reduce salt cedar trees.

Phytochemicals also affect humans, since we can also be herbivores or omnivores. Over time, from knowledge passed down through generations of native peoples through the work of scientists worldwide, we have figured out how to use these amazing phytochemicals for both our pleasure and our pain. Some plant chemicals exhibit addictive properties—from opium in heroin to nicotine in tobacco to the caffeine found in chocolates, colas, and coffee.³ Other plant chemicals contain essential oils like citronella and menthol and toxic compounds found in latex and resins. Capsaicin in chile peppers imparts the hot and spicy flavor characterizing New Mexico's cultural/ culinary identity. Yet another group of chemicals contain flavonoids that make up red, blue, yellow and white color pigments. The flavonoids can act as antioxidants, which are thought to be beneficial to human cells. Blueberries, red grapes and strawberries, foods known for high antioxidant levels, contain color pigments from flavonoids. Many plant chemicals are also known for their antiseptic, antiviral, and antibacterial properties, all of which are important to humans.⁴

In the following activity, you will get outside to make observations and to write your own tale of offense and defense.



Plant Wars: A Tale of Offense and Defense

Student Directions

1. Choose an area in your schoolyard, home garden, or a natural area to observe plant defenses. Create a journal page or data sheet of your own. Find one plant exhibiting evidence of physical defenses and one that you think has some chemical defenses. Record the date and location; include the scientific name of the plants and a detailed description, including the habitat.
2. A plant's quest is to survive and reproduce in a dangerous world. Other organisms have similar needs, which leave your plant open to being preyed upon. How do you think your plant defends itself?
3. Record your observations. Add sketches if needed. This requires careful observations. Look for any physical characteristics that you think might be used to deter herbivores. Examine the plant for textures that might be unappealing, like fuzzy leaves or physical structures that could be used to shield vulnerable parts. Make notes on what you find. What kind of herbivore or omnivore do you think is being deterred? Small herbivores like insects may need different deterrents than larger herbivores like mammals. Take these both into consideration.
4. If you can do so safely, pick one leaf from your plant. **Caution—some plants contain skin irritants and toxins; take precautions. Do not touch the sap to your skin or taste anything!** Do you observe any oozing or liquid material coming from the damaged leaf or branch? Note whether it is clear or milky. Smear the substance on a piece of paper. Is it sticky? What does it look like (e.g., color, consistency)? Rip a piece of the leaf or cut across the surface. What do you see? Crush your leaf with a rock on your paper. Grind it well (but don't rip the paper), and smell it. How would you describe the odor? What pigments or colors do you observe on the paper?
5. Does the plant show any signs of wildlife use? For example, describe any chew marks, leaf tunnels, unusual growths, scarring on the stems, or insect eggs. Note their location on the plant. Make predictions or direct observations of what caused these signs. Do you see any evidence of plant defenses (e.g., sealing off wounds, unusual growth patterns)? Continue to use sketches to help record your observations.
6. Look at the immediate area around your plant. Does your plant seem to be successfully competing with neighboring plants for resources? Look for excessive crowding from other plants. Does your plant look droopy, wilted or show unusual coloring (leaves yellowing, purplish or brown colored areas)? If your plant appears robust and healthy without crowding from neighboring plants, why do you think it is not crowded? Maybe you have a landscape plant that people have weeded around. If you are in a natural area, how do you think your plant competes for space?
7. Return to the classroom and re-read through the background information. Does it help you understand your observations?

CLASS DISCUSSION

1. What types of defenses did you observe?
2. Did the background reading help you understand your observations?
3. Does your plant exhibit both physical and chemical defenses? If you observed herbivory damage or crowding, brainstorm different adaptations that might prevent these from occurring on the plants you observed.



Plant Wars: A Tale of Offense and Defense

Reflection

Humans, as part of the ecosystem, participate in many different biological interactions with plants. Name two interactions you have had with plants today. Analyze one in depth. How would it affect the ecosystem if the plant you interact with was no longer part of the ecosystem? How would it affect you? What changes could ripple through the ecosystem? What other organisms would be negatively affected? Would any organisms be positively affected? Identify one way that you can positively affect plants in your day-to-day life.



EARLY FINISHERS

Some plants native to New Mexico are known to be poisonous at some level to humans, wildlife, or livestock. Choose one plant or plant family from the list to the right (or find your own), and carry out additional research. Find out the category of chemical(s) it contains and write about its effects on mammals. Some plants store their poisonous chemicals in only certain parts (e.g., seeds), while others contain the compounds throughout the plant. Include this information in your research write-up.



- Agavaceae** (Century Plant family) – agave
- Amaranthaceae** (Amaranth family) – some amaranths
- Anacardiaceae** (Sumac family) – poison ivy
- Apiaceae** (Carrot family) - water hemlock, water parnsnip, poison hemlock, and wild carrot
- Asclepiadaceae** (Milkweed family) – milkweeds
- Brassicaceae** (Mustard family) – tansy mustard and others
- Chenopodiaceae** (Goosefoot family) – saltbushes, lambsquarter, greasewood, Russian thistle, barilla and others
- Fabaceae** (Pea family) – lupines, milkvetches, sweetclovers, locoweed and others
- Hypericaceae** (St. Johns-wort) - St. Johns-wort
- Liliaceae** (Lily family) – Death camas
- Ranunculaceae** (Buttercup family) – larkspurs, buttercups, and many others
- Solanaceae** (Nightshade family) – datura, Jimsonweed, nightshades, tobaccos and others
- Typhaceae** (Cattail family) - Stinging nettle

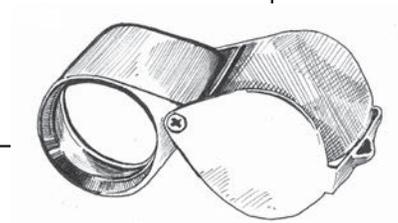


*Student
Project*

Plant Wars: A Tale of Offense and Defense

Self Assessment

- 1** Explain the difference between physical and chemical plant defenses and name two of each.
- 2** Describe how co-evolution between plants and herbivorous insects can occur.
- 3** Make detailed observations and use the observations to make inferences.



Resources

- Armstrong, Wayne P., *Wayne's Word On-line Textbook of Natural History*. Palomar College Arboretum: <http://waynesword.palomar.edu/chemid1.htm> last update April 1, 2010.
- UNM, College of Pharmacy, NM Poison and Drug Information Center: http://nmpoisoncenter.unm.edu/education/pub-ed/pp_tip_pages/plants.html
- New Mexico State, An Annotated Checklist of Poisonous or Injurious Range Plants of NM: <http://aces.nmsu.edu/pubs/circulars/CR-636.pdf>
- The Natural History Museum of London. Seeds of Trade: <http://www.nhm.ac.uk/jdsml/nature-online/seeds-of-trade/index.dsml> - resource - the history and uses of plants used by humans. Search by plant name, use type, or geographical distribution.
- Smithsonian Institution's National Museum of Natural History. Partners in Evolution: <http://botany.si.edu/events/sbsarchives/sbs2008/>
- University of Colorado at Boulder, Biological Science Initiative: http://www.colorado.edu/Outreach/BSI/k12activities/chem_ecology.html - 2 lessons on plant chemical defenses (high school); allelopathy investigation, and plant chemical defenses for herbivory.



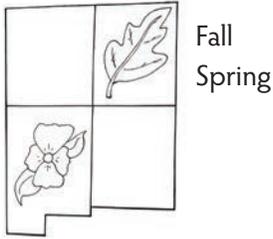
What is a Plant?

"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change." -*Charles Darwin*

Time Estimate

1-2 hours; an additional session is required for In the Field! (optional)

Best Season



Fall
Spring

Overview

Students explore the diversity among plants and plant-like organisms, such as fungi, algae, and lichens, which may be confused for plants. This lesson will emphasize the structural and reproductive differences between the groups and the relationships between these organisms within an evolutionary context.

Preparation

1. Collect examples of the different groups of organisms represented in this lesson. Try to collect at least three species of each type. If a trip to the forest is not feasible to find mosses, ferns, and mushrooms, some of these examples can be purchased at a local nursery or grocery store.
2. Reproductive structures are easier to observe when magnified, so provide a dissecting scope or hand lens.
3. At each station except for the lichens, include a life cycle diagram. The lichen life cycle is omitted because much remains to be understood about lichen reproduction. See the Resources section or biology text books for sources.

Teacher hints

- To simplify the life cycle study, emphasize the similarities and differences in the haploid and diploid generations and modes of reproduction.
- Consider splitting students into groups for the background reading. Each group can be in charge of learning about one group of plants or plant-like organisms, and presenting a short summary of the information about that group to the class.
- Definitions for vocabulary words not defined in the text can be found in the glossary.

Assessments

- 1 Compare and contrast major differences in structure and reproduction between two of the groups of organisms studied.
- 2 Write a definition of a plant.
- 3 Explain the evolutionary relationships and progression of plants and plant-like organisms.





What is a Plant?

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Materials Needed

Hand lenses

Life cycle diagrams (all stations except lichens)

Examples of 3 species from each category of organisms

Datasheet

Paper for drawings

Overview

In this lesson, you will explore the diversity among plants and plant-like organisms, such as fungi, algae, and lichens, which may be confused for plants. This lesson will emphasize the structural and reproductive differences between the groups and the relationships between these organisms within an evolutionary context.

Learning Objectives

1. learn the differences and similarities between algae, fungi, lichens, bryophytes, ferns and their allies, and seed-bearing plants
2. explore plant and plant-like diversity within an evolutionary context
3. effectively use a hand lens and/or microscope to explore anatomical diversity

Vocabulary

lichen

spore-bearing plants

seed-bearing plants

moss

hyphae

sporophyte

mycelium

saprophyte

mycorrhizae

parasite

foliose

fruticose

crustose

spore

rhizoid

cuticle

vascular

angiosperm

gymnosperm

chlorophyll

Background

Have you ever looked at a soft, moist, fuzzy piece of green growing on a tree or on the ground and wondered what it is? Is it a plant? Maybe it is a moss or a lichen or algae. What is the difference and how do you know? What about a mushroom? It is growing out of the soil. Does that make it a plant? What is a plant, anyway?

What makes a plant a plant? First, almost all plants possess **chlorophyll**. Chlorophyll allows plants to make their own food and produce oxygen by taking in carbon dioxide and water through a process called photosynthesis. Second, all plants have cell walls around their cells to help support them, which animals do not have (although some other types of organisms do). Thirdly, plants have a **cuticle**, or waxy coat, on their stems and leaves to protect them from drying out. You will notice that the plant-like organisms share some but not all of these traits.

The story of plants, including bryophytes, ferns, and seed-bearing plants, and other similar and often confused groups of organisms, such as fungi, lichens, and algae, can be woven with an evolutionary thread. This story is sewn by our understanding of the life cycles, structures, comparative DNA analyses, and ecology of different groups of plants.

It is a well-supported idea that life on earth began in the oceans and over time colonized the land. There is considerable debate in the scientific



What is a Plant?

community about which plants were the first to colonize land, giving rise to the evolution of ferns and their allies, cone-bearing plants, and flowering land plants. Algae are widely considered to be the evolutionary precursors of plants, and in some cases, algae are considered plants themselves. But which plants were the first to live on land? Many theories have been advanced. Today, the most recent theories indicate that liverworts are likely the evolutionary predecessors to the higher plants that we know today. This is an ongoing point of investigation, and further research is needed.

As you read the following sections on different groups of plants and plant-like organisms, pay special attention to the similarities and differences that lend to our understanding of the evolutionary relatedness between these organisms. Keep in mind that no **moss** has ever turned into a fern in one generation. This story is one that has been developing for several billion years. Nothing happens quickly when it comes to plant evolution!

Plant-like, but not really plants...

Fungi

Fungi are a wonderfully diverse group of organisms, with great variation in form, habitat, and manner of acquiring necessary nutrients. Many of you quite likely recognize mushrooms, with their typical cap and stalk form, wild abundance of colors, and presence in a variety of habitats. There are many types of fungi other than the mushrooms, including the cup, jelly, teeth, coral, and crust fungi. There are also puffballs, truffles, morels, rusts, smuts, and the unicellular yeasts, all of which are also classified as fungi. An important thing to note about fungi (with the exception of yeasts) is that the part that you generally see and recognize is only a small fraction of the entire fungus. The rest of the fungus is in the soil, tree, leaf, insect, dead wood, or other substrate on which the fungus grows. This part of the fungus exists as very thin, elongate strands known as **hyphae**. Collectively the hyphae are known as **mycelium**, making up the vast majority of the mass of the fungus. A simple analogy can help to explain this. The mycelium is like an apple tree, with its trunk and all its branches and leaves; the "fruiting body" of the fungus that you see is like the apple itself.

Fungi are likely more closely related to animals than they are to plants, though they were originally classified as plants. The two groups have many similarities; both possess a cell wall (animals have none) and both lack the ability to move on the landscape. However, the cell walls of fungi are often made of chitin, the very same biological compound that

makes the exoskeleton of insects and crustaceans, whereas the cell walls of plants are made of cellulose. Fungi can reproduce via the production of spores, a characteristic they share with some more primitive plants. A **spore** is a



walled reproductive cell body capable of giving rise to a new individual, either directly or indirectly. Another major difference is that fungi do not have leaves, do not possess chlorophyll, and consequently cannot photosynthesize. Therefore, fungi must have other means of acquiring nutrients. As a result, fungi are classified into three major groups based on their mode of nutrition: 1) **saprophytes**



What is a Plant?

that live off of dead and decaying matter, 2) **mycorrhizae** (“fungus-root”) that form special connections with plant roots and exchange nutrients directly with roots, providing uptake of phosphorus from the soil and transferring it into the plant roots, that being a major source of phosphorus to most plants, and 3) **parasites** that live off of other living tissue. Fungi play a critical role in the recycling of nutrients, which is incredibly important to the function of ecosystems. Fungi are also a principal food source for a variety of organisms, making them a major player in the maintenance of biodiversity on Earth.

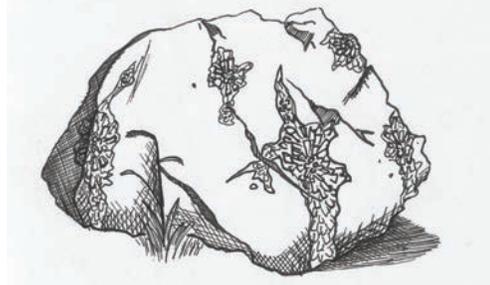
The story of fungi is very directly tied to the migration of plants from the sea to land throughout geologic time. There are many studies that cite the importance of mycorrhizae in this process. Evidence indicates that it was these connections between fungi and plant roots that allowed plants to colonize terrestrial habitats and still access sufficient water and nutrients. Mycorrhizal connections, found in 90% of plant families, greatly increase the surface area of plant roots, increasing overall water and nutrient uptake. Additionally, numerous types of fungi have been found among the fossils of the oldest land plants.

Lichens

Lichens come in diverse forms and are found in almost every habitat on earth, including terrestrial, marine, and aquatic ecosystems. In New Mexico, lichens are frequently seen as the colorful crusts on rocks in arid habitats. The smallest lichens in the world are nearly microscopic; the largest lichens are up to a square foot in size. Some are leaf-like (**foliose**), others have a bunch of shrubby stalks or long, hanging strands (**fruticose**), and others appear to just be a crust on a rock, tree, or soil (**crustose**). Fruticose lichens are quite noticeable in New Mexico, ranging in appearance from shrubby stalks to long, beard like structures hanging downward from tree branches of spruce and fir in higher elevations. At lower elevations you will find short, stubby beard-like lichen on piñon pine. In addition to being found on almost any natural substrate, such as rock, bark, soil, or leaves, lichens can also be found attached to many man-made items, such as cement, asphalt, metal, and even plastic. Unlike most plants, lichens have no roots and

therefore derive all of their moisture and nutrition from the atmosphere around them. Lichens can be different hues of gray, greenish gray, and brown. Some lichens can be quite bright in color, such as red, orange, and yellow.

Lichens are a biological marvel, and an incredible example of symbiosis. They are not a single organism like the rest of the groups explored here, but actually two, and sometimes three organisms living intertwined together so that they are virtually indistinguishable. When they are found separately, these organisms look nothing like they do when combined as a lichen. Lichens always contain a fungus and an organism that can perform photosynthesis, either algae or cyanobacteria, the latter formerly known as blue-green algae. The most basic function of the fungus is to provide a moist habitat for the algae or cyanobacteria. The algae or cyanobacteria perform photosynthesis much like higher plants; the sugars created from photosynthesis are used by the fungus for its nutrition. Lichens are officially classified as fungi.



So who’s in charge, the fungus or the algae? Or do they cooperate equally? At this point, the answer is unclear. Lichens have commonly been described as two organisms living together in harmony, each benefiting equally from the interaction. More recently, many lichenologists have begun to support the idea that the fungus harnesses the algae to do work for it. One lichenologist has said that lichens are fungi that have discovered agriculture. As you explore the world of lichens you’ll have an opportunity to think about this interesting scientific conundrum.

Lichens have great value as habitat for invertebrates and are food for many animal species. Lichens that contain a cyanobacterium have the ability to collect atmospheric nitrogen and make it available to other plants when they decay on the ground. This lichen can play a very significant



What is a Plant?

role in nitrogen cycling in forest ecosystems, impacting these systems in incalculable ways. One widespread species, *Lobaria pulmonaria*, is often called “the lungs of the forest” because of the vast amount of oxygen it produces through photosynthesis. Because they are rootless and receive all of their water and nutrients from the atmosphere, lichens are also highly valued as biological indicators of air quality, as many species’ ranges are dictated by the quality of the air in which they live. The absence of lichen is an indicator of pollution.

The in-between...

Algae

Algae are a very challenging group of organisms to classify, as the word refers not to an entirely related group of organisms, but to organisms with several different ancestries. The classification of algae is a point of continued debate among biologists.

Unlike the seed-bearing plants, algae lack a cuticle and stomata and are therefore restricted to moist habitats. Most algae also differ from plants in that they lack true roots and leaves and the body is not differentiated into highly specialized cells for structural support and water transport, though in some specialized cells do exist. In most cases, algae simply don’t need these specialized cells because they are supported by the water column in which they live. Like fungi, lichens, bryophytes, and ferns, algae reproduce by dispersing spores into their environment; they do not produce flowers or seeds. However, like plants, algae do perform photosynthesis; as a result, many are green, though others are red, brown, or myriad shades in between. Only some algae are very likely to be confused with plants; these may include the larger green, red, and brown algae that are commonly referred to as seaweeds.

Algae are widely considered to be the evolutionary precursor to land plants. This assertion is based on the structural evidence listed in the previous paragraph. In recent years, genetic analysis has supported this idea.

Algae are found in virtually every habitat on earth as long as water is present, even for a very short time of the year. They even live in extreme environments, including hot springs, salt pans, and beneath thick sheets of ice. Algae are a major component in the plankton that forms the base of the marine food chain. Ecologically, they provide very important nutrition for many animal species.

And now for the real plants...

Bryophytes

Bryophytes are small, herbaceous plants that live closely packed in cushions or mats on rock, soil, and trees and on human-made substrates such as asphalt and concrete. They are found in a wide diversity of habitat types around the globe. The three main types of bryophytes are mosses, liverworts, and hornworts. Like other plants, bryophytes have leaves and produce the sugars they need for metabolism through photosynthesis.

Unlike other plants, bryophytes lack the specialized vascular tissue that is found in the bodies of other plants that is used to conduct water throughout the tissues. Because of this, they are restricted to being relatively small in size. Bryophytes do not produce flowers but instead produce spores, like ferns and their allies. Bryophytes also lack roots, and instead have rhizoids that serve to anchor the plant. The entire body of the bryophyte absorbs water, including the **rhizoids**. Bryophytes also lack a waxy cuticle that prevents water loss and only a few have stomata; this generally restricts them to moist habitats.

Bryophytes have a very different life cycle than the higher plants. These life cycle differences are considered support for the idea that bryophytes were the first land plants. The life cycle of plants is divided into two main stages and is known as alternation of generations. This life cycle is defined by the number of copies of chromosomes that are found in the nucleus of each cell during each stage. In bryophytes, the main body of the plant that you see that includes the leaves is known as the haploid gametophyte, meaning it contains one copy of chromosomes. The tiny



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sporophyte is diploid, meaning it contains two copies of chromosomes, one from the mother and one from the father. The sporophyte forms when a sperm from a male organ swims through the watery film on the leaves of a bryophyte and travels to a female organ on the same or different plant. The sperm is entirely exposed to the environment during this time. In higher plants, this life cycle is reversed, with the main leafy part of the plant being diploid and the haploid part only occurring in the pollen and ovule. While understanding this difference may require some time studying the topic, life cycles are a major piece of evidence pointing to the evolutionary relationships between different types of plants.

Bryophytes play valuable ecological roles. In the forests, bryophytes play a major role in regulating humidity, acting as big sponges, absorbing and releasing water into the atmosphere. Bryophytes also have extensive wildlife value, hosting a number of small invertebrates, acting as food for others, and providing nesting and bedding material for birds and small mammals. Even some large animals, such as the mountain goat, rely on bryophytes for a portion of their diet.

Ferns and their allies

Ferns and their allies (plants that are very similar to ferns but generally lack the characteristic frond of a fern, such as clubmosses, spikemosses, quillworts, whiskferns, and horsetails) frequently exist as residents of the shady undergrowth in forests, with an affinity for moist, dark places. Some ferns are aquatic and live in symbiosis with



bacteria. A large diversity of ferns may also be found in other habitats that are not normally moist, including rock faces and open meadows. These plants may be found growing from the ground, on rotting logs, in rock crevices, and as epiphytes along tree trunks and up in the canopy. In rock, different species of ferns are found to occupy very specific niches defined by the chemistry of the rock on which they grow.

There is a very specific reason that these plants are commonly found in moist environments: their reproduction depends on it. All ferns and their allies share a life cycle, similar to the bryophytes, known as alternation of generations, in which they switch between haploid and diploid life forms (see section on Bryophytes for an explanation of these terms). There is, however, a major difference, in that in ferns and their allies, the major part of the plant that you see is the diploid generation. The haploid, gametophyte generation is highly reduced and exists only as a small, heart-shaped plant. This gametophyte is usually 1-2 cm in diameter and looks much like a leafy liverwort or hornwort. On the gametophyte are male and female organs. In order to begin growing as the fern you recognize, sperm from one gametophyte must swim through the watery film in the soil to fertilize an egg on another gametophyte. After fertilization, the diploid sporophyte that you recognize as a fern begins to grow. It is for this reason that ferns and their allies are largely found in moist environments. Many scientists agree that this major reduction in the haploid gametophyte part of the life cycle is evidence that ferns are an evolutionary link between bryophytes and other land plants.

Ferns and their allies share additional characteristics. Much like the bryophytes, they all reproduce using spores and never produce flowers or seeds. Ferns and their allies all have **vascular** tissue that helps them to stand upright and be able to conduct water and nutrients throughout their tissues. Ferns have a thin leaf cuticle that aids in preventing desiccation and stomata that allow gas exchange to occur. Many ferns and their allies possess thick-walled spores that allow persistence in drier conditions.

Ecologically, ferns and their allies play a valuable role in the ecosystems in which they are found. Ferns can act as nurse plants to aid in the establishment of tree seedlings in



What is a Plant?

a forest, providing a moist, shaded environment to support their growth. They serve to anchor moist soils and slow erosion. They also provide habitat for a variety of organisms that live among their fronds. Numerous species of invertebrates and some vertebrates consume their nutritious spores.

Seed-bearing plants

The diversity in form of seed-bearing plants is dramatic. This group includes everything from the smallest herbaceous plants like the pond-dwelling duckweed to the tallest trees such as ponderosa pines and Douglas firs. All plants that are not algae, bryophytes, ferns, or fern allies fall into this category. These include the flowering plants (**angiosperms**), the cone-bearing plants (**gymnosperms**), and some lesser-known groups of organisms, namely the cycads and ginkos.

Examining the structures and life cycles of these plants helps us to understand how they relate to other plants evolutionarily. These plants contain many adaptations that aid in their persistence on land. They possess a vascular system that allows for water and nutrients to be transported throughout the body to the tissues furthest from the roots. They have a waxy cuticle that covers the leaf surfaces and decreases water loss, and stomata to help exchange water vapor and other gases into the environment. Seed-bearing plants also have entirely internal fertilization, in which the sperm fertilize an egg within an ovule. As a result, the haploid gametophyte generation exists only within the

pollen grains and ovule; everything else that you see is the diploid sporophyte generation. This process of internal fertilization and lack of need for a watery environment in which sperm can swim to the egg has allowed for a great diversification in form. As a result, plants have been able to colonize most corners of the globe, including very harsh environments with blasting heat and very little water. Ferns and their allies, bryophytes, and algae exist very widely, but only a few species can tolerate the conditions that some of the more drought-resistant seed-bearing plants can.

Ecologically, seed-bearing plants are a principal part of the foundation of the food system that feeds all humans and other animals on the earth. The ecological roles of seed-bearing plants are so incredibly diverse that it's difficult to even begin to write about it. From habitat to food resources to soil stabilization to atmospheric cleansing, they do it all!





What is a Plant?

Student Directions

1. Your teacher has established 6 stations, each highlighting one of the groups of organisms discussed above. Ideally, stations will be visited in the following order: fungi, lichens, algae, bryophytes, ferns and their allies, and finally seed-bearing plants. If you can't start at the first station, try to visit the stations in order, as it will serve to emphasize the evolutionary relationship between each. As you visit each station use the following directions as a guide for your explorations.
2. Begin by reading the background information for the station that you are investigating. Make special note of the structures that define that group of organisms and how those structures indicate something about the evolutionary relationship between groups of organisms.
3. Make a sketch drawing of the example organisms at each station. Be sure to look closely at each and make note of the significant structures you read about in the background information that set each group of organisms apart from the others. Refer to the background information for clues about these noteworthy structures. Write the name of the structure on your drawing and draw an arrow pointing to it.
4. Choose one example organism and look closely at the reproductive parts through a hand lens or dissecting microscope. Draw a close up of what you see through your hand lens/dissecting microscope and label the structures.
5. Examine the life cycle of the group of organisms you are exploring. Each life cycle contains a lot of information. Note that the true plants undergo alternation of generations. The organisms that are not true plants do not undergo alternation of generations. List the life stages that are haploid and the life stages that are diploid. Note that in the seed-bearing plants, there is one stage that is triploid. While this may seem like an obscure way to show differences between the organisms, it is in reality central to understanding how life cycles changed in the process of plant evolution.
6. At each station, fill out the boxes in the attached datasheet. This datasheet summarizes the major characteristics that are used to define each of the groups of organisms that you are exploring. You will need to refer to the background information to find some of the answers.



What is a Plant?

In the Field!

Go to a habitat area that you have on or near your school grounds with a diverse assemblage of organisms, native or otherwise. With a partner, find as many organisms as possible from each of the groups of organisms as possible discussed in this lesson.

When you find each organism, ask yourself the appropriate question.

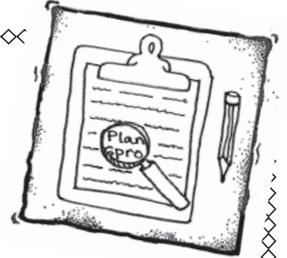
- Why is this a fungus?
- Why is this a bryophyte?
- Why is this an algae?



Use the time in the field as an opportunity to review what you know about each group of organisms. Get out some field guides for these more obscure groups and see if you can match the ones you are finding to the photos in the book.

Reflection

Draw a colorful picture of plant evolution. You should include algae, bryophytes, ferns, and seed-bearing plants. Be sure to depict each group of organisms in an appropriate habitat. As you draw each group of organisms, be sure to keep in mind that the original plants only lived in aquatic environments. Lichens and other fungi occupy a completely different branch on the evolutionary tree; you do not need to include them in your drawing.



Self Assessment

- 1** Which group of organisms is best adapted to dry, terrestrial environments, and why?
- 2** How do fungi differ from plants?
- 3** How do algae differ from plants?
- 4** Describe how lichens are an excellent example of biological symbiosis.





What is a Plant?

Resources

Life cycle diagrams

- Algae: <http://www.resnet.wm.edu/~mcmath/bio205/diagrams/botun05d.gif>
- Angiosperms: <http://www.mun.ca/biology/scarr/Angiospermae.html>
- Bryophytes: http://www.cavehill.uwi.edu/bio_courses/bl14apl/images_bryos/moss_life_cycle.jpeg
- Ferns: <http://sciencelearn.org.nz/Contexts/Ferns/Sci-Media/Animations-and-Interactives/Fern-life-cycle>
- Gymnosperms: <http://www.ck12.org/biology/Gymnosperm-Life-Cycle/lesson/Gymnosperm-Life-Cycle/>
- Sporophyte and gametophyte relationship in bryophytes, ferns, and seed plants: <http://utweb.ut.edu/hosted/faculty/wprice/seedpl08.pdf>
- Fungi (Basidiomycetes): http://www.bio.brandeis.edu/fieldbio/Fungi_Miller_Stevens_Rumann/Pages/fungi_life_cycle_anatomy_page.html

- Tree of Life Web Project; A collaborative website with many beautiful photos that diagrams the evolutionary relationship between different groups of organisms: <http://tolweb.org/tree>
- Arora, David. 1986. *Mushrooms Demystified, Second Edition*. Ten Speed Press. Berkeley. 959 pp.
- Brodo, Irwin M., Sylvia D. Sharnoff, and Stephen Sharnoff. 2001. *Lichens of North America*. Yale University Press, New Haven, Connecticut, 795 pp.
- Michael Guirey's seaweed site contains excellent background information on marine algae: <http://www.seaweed.ie/index.html>
- Welcome to the World of Algae site: <http://www.botany.uwc.ac.za/algae/index.htm>
- An excellent online book introducing bryophytes and their ecology: <http://www.bryoecol.mtu.edu/>
- A thorough resource on bryophytes hosted by Southern Illinois University Carbondale: <http://bryophytes.plant.siu.edu/index.html>
- The Liverwort Tree of Life Project. Interesting information about the evolution of land plants and the taxonomic relationship of bryophytes to the higher plants: <http://www.biology.duke.edu/bryology/LiToL/LwtsonGreenTree.html>
- A concise history of plant evolution and the colonization of land, with specific reference to the fossil record: <http://www.xs4all.nl/~steurh/engplant/eblad1.html>
- An interesting story of early plant evolution during the Devonian period: <http://www.devoniantimes.org/opportunity/forests.html>
- A website with links to others that provide basic information about lichen biology and identification: <http://ocid.nacse.org/lichenland>
- Reference about mycorrhizae and their role in land plant colonization: <http://www3.interscience.wiley.com/journal/123233992/abstract?CRETRY=1&SRETRY=0>

WHAT IS A PLANT? STUDENT DATA SHEET

	Photosynthesis?	True leaves?	True roots?	Spores or seeds?	Specialized vascular tissue?	Cuticle and stomata?	Unicellular or multicellular?	Major generation haploid or diploid?	Internal or external fertilization?
Fungi									
Lichens									
Algae									
Bryophytes									
Ferns and their allies									
Seed-bearing plants									

TEACHER ANSWER KEY

	Photosynthesis?	True leaves?	True roots?	Spores or seeds?	Specialized vascular tissue?	Cuticle and stomata?	Unicellular or multicellular?	Major generation haploid or diploid?	Internal or external fertilization?
Fungi	N	N	N	spores	N	N	both		
Lichens	Y	N	N	spores	N	N	multi		
Algae	Y	N	N	spores	N	N	both	varied	external
Bryophytes	Y	Y	N	spores	simple	some liverworts	multi	haploid	external
Ferns and their allies	Y	Y	Y	spores	complex	Y	multi	diploid	external
Seed-bearing plants	Y	Y	Y	seeds	complex	Y	multi	diploid	internal

Section 4:
**The Good, The Bad,
and The Ugly**
Native, Non-native, and Invasive Plants





Field Journaling: Observations from a Special Spot

"To see a wren in a bush, call it "wren," and go on walking is to have (self-importantly) seen nothing. To see a bird and stop, watch, feel, forget yourself for a moment, be in the bushy shadows, maybe then feel "wren"—that is to have joined in a larger moment with the world."

- *Gary Snyder*, *Language Goes Two Ways*, (1930-present)



Overview

A field journal can be used to record observations and questions, to make drawings, and to pursue ideas. This lesson is an introduction to using a field journal for all of these things and more. Students can use their field journals to support their study of native plants and ecosystems. It can be a handy reference for places they have visited, new terms they have learned, and plants that they have identified.

Teacher hints

- Begin your unit of study on New Mexico's native plants by introducing students to writing about personal observations in nature. A field journal can be an important tool for nature study. It can foster writing skills and provide a portfolio of information, a source of questions for scientific study, an inspiration for future projects, and a place for reflection.
- Share some plant related field journal entries from Lewis and Clarks' Voyage of Exploration or excerpts from other explorers with your students. Show them journal entries for them to see how drawings are used to enhance their writing (see link in the Resources section).
- Before beginning, read students a few passages from Aldo Leopold's book, *A Sand County Almanac*. If possible, have a few copies available for students to read further on their own. Consider assigning passages for students to read at home.
- For students who are reluctant to write, encourage sketching. Ask them to add a few words about their drawing, maybe notes on size or color. Ask them to record the weather and the date. Each time have them include a little bit more written detail about their drawings. Pretty soon they will be writing!
- When you take students outdoors for journal writing, be the timekeeper. Have them observe quietly for 10 minutes before they start to write. Then allow them 20 minutes to write and draw. Give them a couple minutes of warning before time is up to allow them to gradually return to the group after their time alone. Allow 15 minutes for sharing.
- Have students record journaling prompts from the directions and have students tape these to the inside cover of their journal. Encourage them to refer to this list whenever they have trouble starting.
- A field journal is an excellent way to integrate science with studies of language, history, and art.

Assessments

- 1 Record one observation in detail or several small observations.
- 2 Make observations using more than one sense (e.g. smell, touch, hearing).
- 3 Focus on your project and be courteous of other students.





Field Journaling: Observations from a Special Spot

Materials Needed

- field journal
- pencil
- colored pencils, crayons, or paints (optional)

Vocabulary

observation



Background

Developing **observation** skills takes practice. Using a field journal regularly can help you hone your observational skills as well as record and reflect on the experiences you have in the natural world. You can use writing, drawing, and take photographs to make entries and guide the observation process. There is no right or wrong ways to keep a field journal – each person will bring her or his own unique style. The more time you spend recording in your field journal, the more you will see and notice around you, and the more fun it will become! If you keep detailed notes, you will be able to record seasonal and annual changes going on around you. Use your field journal throughout your native plant study and it can become a useful reference. It's a great way to combine creativity and love of nature. A field journal is a great place to record observations you make in the natural world.

Great naturalists and scientists throughout history have kept extensive field journals, many of which continue to be used for scientific inquiries today. For example, the journals of Lewis and Clark provide excellent information and illustrations of the flora and fauna and climate of the regions they explored

"To see a wren in a bush, call it "wren," and go on walking is to have (self-importantly) seen nothing. To see a bird and stop, watch, feel, forget yourself for a moment, be in the bushy shadows, maybe then feel "wren"—that is to have joined in a larger moment with the world." - *Gary Snyder*, *Language Goes Two Ways*, (1930-present)

Overview

A field journal can be used to record observations and questions, to explore your feelings, to make drawings, and to pursue ideas. A field journal can contain lists, poetry, data, and sketches. This lesson is an introduction to using a field journal for all of these things and more. You can use your field journal to support your study of native ecosystems. It can be a handy reference for places you have visited, new terms that you have learned, and plants that you have studied and come to know.

Learning Objectives

1. Practice observation skills using sight, sound, smell, and touch
2. Use multiple styles of writing to record nature observations
3. Make observations of seasonal changes and patterns over time
4. Use a field journal as a tool to gather, analyze, and interpret data in field research

over 100 years ago. The journals of famous naturalists Henry David Thoreau, Aldo Leopold, Rachel Carson and many backyard naturalists have been used to track environmental changes, as well as to inspire naturalists and to inform scientists. Vernon Orlando Bailey (1864-1942), namesake for Navajo yucca (*Yucca baileyi*), was a famous naturalist who made field investigations throughout the United States, Canada, and Mexico, including intensive biological surveys of New Mexico and other states.

Use your journal as a portfolio to keep information learned in studying nature, a place to record "I wonder" questions to pursue, and for inspiration in your writing and artwork. As you get older, your field journal will be a great place to look for fond memories of cool places you have visited, interesting critters or phenomena you have observed, and poetic thoughts you have recorded. In addition, looking back on your journal is a great way to track how many new things you have learned as time flies by. Your journal may be an excellent record of your history when you become a famous scientist, but first and foremost, your journal is for you.



Field Journaling: Observations from a Special Spot

Student Directions

Part 1: Make your journal:

1. Create a field journal to collect your work and to record your thoughts, questions, and observations while studying nature. Use a composition book, spiral bound book, "Rite in the Rain" journal, or make your own.
2. Personalize your journal by decorating the cover and include your name and dates the journal will cover.
3. Always bring your field journal to class with you and add your thoughts, discoveries, and questions. In addition, take it on field trips, and record your observations when you are outside of class.
4. With every journal entry, always begin by recording the date, time of day, location, and the weather.

Part 2: Choose a special spot:

1. Find special spot such as a natural area close to the school or near your house. This should be a location you can return to and visit throughout the year. Select your spot by yourself and take note of where you are so that you can return at a later date. Settle into your spot and quietly spend at least 10 minutes just observing, without writing. Really get to know your spot: look at it, smell it, feel it, and listen. Who else is there with you?
2. Look closely at a leaf margin or a bit of soil, far away at the horizon and distant movements; and in the nooks and crannies in between.
3. Listen carefully for loud and softer sounds, to the wind, insects and birds. What else do you hear?
4. What sensations do you feel? Coolness or warmth, something soft, hard, sharp, fuzzy?
5. Explore the smells—of the ground, plants, and the air.
6. What feelings do you have while you sit in your spot?
7. What is happening at your spot? Are there processes or food webs you can observe?
8. Who or what has been at your spot before you? What signs show you they were there?
9. How is your spot part of a larger area surrounding it?
10. Enter your observations in any form that you want—you can make lists, write an essay, jot down thoughts, write a poem, create a drawing, or any combination of the above.
11. Make sure you have noted the date, time, and the location of your special spot so you can return for later observations.

CLASS DISCUSSION

1. Share your observations. How were they similar or different?
2. Did you discover anything about your spot that surprised you?



Field Journaling: Observations from a Special Spot

In the Field

Take your field journal on all your field trips. When you first arrive, make general observations and record them in your journal. During your trip, focus on one thing that catches your eye to write about further. At the end of your trip look over your entry and add any details that you would like to remember about your trip. Don't forget to record the date and add general information about the location and weather.



Self Assessment

- 1 Record at least one observation in detail, using words and drawings.
- 2 Make observations using more than one sense.
- 3 Focus on your project and be courteous of other students.



EARLY FINISHERS

While at your special spot, use an "I wonder" statement to generate ideas to investigate further (for example: I wonder why there is only one oak tree in the field?) Jot down some possible answers and explanations for your inquiry (e.g. there is only one oak tree because someone planted it, or a deer ate the others as seedlings, or fire burned all but one oak acorn). Use observations about the area to form your hypotheses. Try to generate ways to test your ideas or research the answer to your question. Enlist your teacher for help if needed.

Reflection

Create a story based on your observations. Use your knowledge of plant ecology and your imagination to develop a story of the site history of your spot. How might the history of this spot explain the vegetation and other characteristic features you observe there now? You can even write it from the perspective of something living there (such as: an insect, tree, moss, or a bird).

Resources

- The journals of the Lewis and Clark expedition online (see actual journal entries): <http://lewisandclarkjournals.unl.edu/>
- Leopold, Aldo, Charles Walsh Schwartz, and Aldo Leopold. *A Sand County Almanac. With Other Essays on Conservation from Round River*. New York: Oxford UP, 1966.
- The journals of Henry Thoreau (typewritten excerpts): http://www.library.ucsb.edu/thoreau/project_main.html
- National Wildlife Federation article about Thoreau and phenology: <http://www.nwf.org/nationalwildlife/article.cfm?issueID=117&articleID=1510>
- Great visual examples of nature journals: <http://www.newhorizons.org/strategies/environmental/matsumoto.htm>
- Leslie, Claire Walker and Charles E. Roth. 2000. *Keeping a Nature Journal: Discover a Whole New Way of Seeing the World Around You*. Storey Publishing, North Adams, MA.
- Field journal resource: <http://www.amnh.org/nationalcenter/youngnaturalistawards/resources/fieldjournal.html>



Nurture a Native Garden Project

Part 1: Research and Planning

"Why try to explain miracles to your kids when you can just have them plant a garden?" - *Robert Brault*, gardener (contemporary)

Time Estimate
Several class sessions

Best Season

		Winter
		Fall

Overview

Explore the definition of the term "wildflower" and explore people's perceptions of the word. Research native flowering plants for your local habitat. In this lesson, students embark on a native plant garden project by working through the planning stages in the first of three lessons. This lesson offers service-learning opportunities to share knowledge with your community.

Teacher hints

- For your planting projects use local seed sources and native plants whenever possible. Beware of "wildflower" mixes; many contain species that are not native to your ecoregion, or even native to North America in some cases.
- For Part 1 of the activity have students write down their definition of a wildflower before presenting the lesson.
- Continue this lesson as a multiyear project. Classes can add to the garden and do long term monitoring on the project. Gather data and survival rates from past planting to assess the long term results. Results can be repeated and compared from year to year, or work with a different plant species. Students can collect seed from the garden for future seedling projects or as a fundraiser to sell.
- Species recommendations for your ecoregion can be found in Appendix II Species List by Ecoregion and local field guides and on the Native Plant Society of New Mexico and on the Native Seed Network webpages. Use the map feature on the Native Seed Network to locate your ecoregion and see a list of native species that grow there. Where community data is available, use species that naturally co-occur in communities.
- Refer to the glossary to define vocabulary words.

Assessments

- 1 Give the common and scientific name of 2-3 wildflowers that grow in your ecoregion.
- 2 Give one reason to conserve native plant species.
- 3 Work as part of a group to prepare a project presentation (example: oral, report, or poster).



Preparation

- Collect plant species lists from natural areas and field guides for you ecoregion. Consult with natural resource agencies, native plant societies, parks and natural areas, and extension offices for additional help with species lists.
- Assemble a variety of wildflower seed packets or labels for student teams to use in research. Packets can be found at garden centers, plant nurseries, and mail order. Find mixes that state the species contained.
- Site preparation is covered in "Nurture a Native Garden Project Part 2". It is best to start this process as early as possible, once a site has been identified.



Nurture a Native Garden Project

Part 1: Research and Planning

"Why try to explain miracles to your kids when you can just have them plant a garden?" -
Robert Brault, gardener (contemporary)

Materials Needed

- plant species lists and field guides for your ecoregion
- computer/internet
- wildflower seed mix packets with ingredients lists
- graph paper
- clipboard
- compass
- measuring tape

Learning Objectives

1. Gain appreciation for local flowering species and their place in the ecosystem
2. Use research skills to compile a list of 8-10 native flowering plants from your ecoregion
3. Increase plant knowledge and identification ability over time
4. Work as part of a team to plan a native plant garden

Vocabulary

native species
wildflower
invasive

Overview

What is a wildflower? Explore the definition of "wildflowers" and people's perceptions of the word. Put together a journal page of 8-10 native flowers that you like. Work as part of a team to plan a native garden for your schoolyard. Share your project as a community service activity

Background

"**Wildflower**" is a term with different meanings for different people. To some wildflower describes the mix of weeds blooming in a vacant lot, to others the beauty of the flowers produced by native plants, and to still others a cultivated mix of small flowering plants. This activity will help to define the term "wildflower," as well as view the word "wildflower" with a critical eye.

Garden stores, mail order suppliers, and upscale gift shops are all sources of "wildflower" seed mixes. Unfortunately, these mixes are often the source of seeds that can become **invasive** in your region. Some wildflower mixes are labeled Eastern or Western, but rarely are they specially mixed for one state let alone one ecoregion within a state, or even better yet one plant community. The problem arises with the way the seed mixes are used. Manufacturers of these seed mixes are probably intending them for yards and flower beds, but many times they are not used for these intended purposes. Many people view wildflowers as something beautiful and at the same time beneficial to the environment. They end up being spread at country weddings, memorial services, to beautify pasture land, or to re-seed construction sites. In these cases, the seed is left to spread into unintended locations and natural areas, and possibly start invasive plant problems where previously none existed. Oxeye daisy (*Leucanthemum vulgare*), an introduced species from Eurasia, is such a plant; it has become a common weed in many places throughout North America.

Why should you care about introduced wildflowers? Introduced plants can crowd out **native species**, affect critical ecosystem interactions, and disrupt the balance of natural systems. Not all introduced plants cause problems, but some easily become, and yet others have the capacity to become

(continued on next page)



Student Project

Nurture a Native Garden Project

Part 1: Research and Planning

invasive. The average person does not usually weigh these factors when deciding whether to spread wildflower seed.

How can you help raise awareness in your community? One thing your class can accomplish is to start a native plant garden at your school, as a demonstration for your local community. Why create a native plant garden? It can supply the aesthetics of beautiful flowers and become an integral part of a restored ecosystem. A schoolyard native plant garden may not supply the complexity or diversity of a natural ecosystem, but it will support the

local ecology by providing habitat for native pollinators and other invertebrates, small mammals, birds, and some reptiles and amphibians. A well-planned native garden will require few outside resources (e.g., water, fertilizer) once it is established. Creating the garden and maintaining and monitoring the site over time will supply an outdoor laboratory site for continued classroom use and research. Establish the garden in a highly visible location and it can be a demonstration garden, promoting the beauty and function of native plants to your school and community.





Nurture a Native Garden Project

Part 1: Research and Planning

Student Directions

Part 1: Research:

1. What is a native wildflower? Write a definition using your present knowledge. After this lesson is presented, look up wildflower in the glossary and compare the glossary's definition with your original definition of a wildflower.
2. This activity prompts you to make a pictorial bouquet of native flowers specific to your local ecosystem. Follow the steps below to identify 8-10 native flowering plants to include. Choose flowers that you find attractive, in a variety of colors and shapes.
3. Start by compiling lists of native plants found in your ecoregion. Sources of species lists may come from Appendix II Species List by Ecoregion and local field guides and the Native Plant Society of New Mexico and the Native Seed Network webpages.
4. Narrow your list to species that are well suited to grow in your local ecosystem. Look at the ecology or cultural information sections of field guides for help. Be sure to pay attention to requirements and preferences like elevation and moisture.
5. Assemble a field journal type page to showcase your 8-10 flowering species in a pictorial bouquet. Draw the flowers or use color photos (taken yourself or printed from copyright-free digital library sources). Arrange and adhere your bouquet in the middle of the page, and arrange field notes around the outside of the bouquet. Give the common and scientific name, habitat information, and pollinator if known for each of your species.
6. Now compare your native plant flowering bouquet with the species lists found in purchased wildflower seed mixes.
7. Work in teams to research one of the purchased wildflower seed mix packets. List the flower species from the ingredients list. Research each plant's range, and note whether it is native to your ecoregion. When finished, create a simple bar graph that shows the number of native to non-native species results. Share with the class and discuss: how many of the different wildflower seed packets would be suitable to plant in your ecoregion?
8. Revisit your definition of a native wildflower. Has your definition changed? Rewrite a definition to better represent your current knowledge.
9. Class discussion: "wildflower" can be a misleading term that is open to interpretation. How would you change the term or the image to better define it? How would you educate the public of your image change and why it is necessary?



Nurture a Native Garden Project

Part 1: Research and Planning

Student Directions (continued)

Part 2: Site Planning

1. Divide into teams that will each perform a task: (1) map the school grounds, (2) create a species list for your native garden, (3) identify native garden sites, (4) perform baseline plant survey of sites, (5) market the project to school administrators, and (6) locate seed or plant sources for your garden.
2. Team 1: Map the school grounds, identifying locations of possible garden sites. If you have a small area to work with use measuring tapes and graph paper to make a scale map. If you have a large area you might use pacing to make an estimated map or approach the school office to see if they have a school map that you could use as a template. Create a master map (by hand drawing or on the computer); make several copies.
3. Team 2: Research flowering native plants to include in your garden. Create a list of 10-15 native plants that are suited for your schoolyard ecosystem. Look at sun/shade, moisture levels, and soils. Additional criteria could include species that are commonly available in your area, grow relatively easily from seed, are aesthetically pleasing, and are important nectar sources for local pollinators. There may be a natural area nearby that can act as a reference site, where you can get an idea of what species will thrive in your garden.
4. Team 3: Identify one or two suitable sites for the native garden. Sites could be a little-used patch of grass, an underutilized corner, neglected garden spot, or the entrance to your school. Try to make it a place that people will visit and consider if it is a spot that teachers will allow students to visit alone. Make sure to find out if the school has plans for a new building or ball field and do not put your garden there. Check with the maintenance staff at your school and make sure they are on board. You don't want them to mow your garden! Observe and make detailed notes on each of your target sites. How much direct sunlight does it get, and for how many hours a day? What are the soil moisture levels at wet and dry times of the year?

Make special notes about building overhangs or water sources nearby. In addition, look for a site that can be enjoyed and appreciated by the student body and school visitors. Mark your two top choices on a copy of the map created by the mapping team.
5. Team 4: Conduct a baseline plant population survey of the two sites identified by the site location team. Identify plant species presently growing at the site. Add the location of all native plants (if there are any) to the map created by the mapping team. Include a key of plant species on the map.
6. Team 5: Market the native wildflower garden to your principal and the school groundskeeper. Give them an overview of the benefits of a native wildflower garden, your class's planning work, and a proposal for taking on a native wildflower garden project. Use Powerpoint or visuals during your presentation. Conclude your presentation by asking for their approval to continue with the native plant garden.
7. Team 6: Using the list of 10-15 native wildflower species, locate sources of native seed, propagules, or potted plants. The Native Seed Network is a good source. Also, your local watershed council or conservation district may be able to give you recommendations of seed and plant material sources. Contact the sources in person, by phone, or by email to introduce yourself and your school. Give them a brief introduction about your project and what you hope to accomplish. Many providers will donate or give discounts to school projects. If you receive a donation, be sure to follow up with a thank you note.
8. After all the teams have completed their projects, come together as a class to make decisions. Each team should share their work with the group. As a group, pick your final choice for the site and species to include. Keep the school groundskeeper apprised of your final site location and ask for their continued support.



Nurture a Native Garden Project

Part 1: Research and Planning

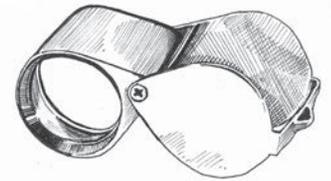
EARLY FINISHERS

Take on a community service aspect for this project:

- Write and submit a news article for your school or community paper about native wildflowers and your school native wildflower garden project. Make the article informational by stressing the importance of native plant communities for local pollinators or benefits of a native wildflower garden.
- Educate the public about the drawbacks associated with wildflower mixes used in wild areas. Create a marketing campaign to get the word out. Posters, letter to the editor, and speaking to community groups, are some possible ways of getting your message out.

Self Assessment

- 1** Give the common and scientific name of 2-3 wildflowers that grow in your region.
- 2** Give one reason to conserve native plant species.
- 3** Team participation in the project; working together with other members, finishing assigned duties, and helping out where needed.



Resources

- U.S. Forest Service Celebrate Wildflowers website: <http://www.fs.fed.us/wildflowers/index.shtml>
- Native Seed Network species list by ecoregion: <http://www.nativeseednetwork.org/ecomap?state=USA>
- Native Plant Societies: look online to find a chapter near you.
- USDA Plants Database: <http://plants.usda.gov/>



Nurture a Native Garden Project

Part 2: Starting Propagules and Growing Plants

"The creation of a thousand forests is in one acorn." - *Ralph Waldo Emerson* (1803-1882)

Time Estimate
6-8+ weeks (continuing project)

Best Season

	Winter (in greenhouse)
	Spring (dependent on region)

Preparation

Gather or purchase supplies needed well in advance of starting this project. Potting soil can be harder to locate in the winter months.



Overview

Part 2 of this native garden project will focus on starting propagules by seed germination or rooting cuttings, and growing plants for your native plant garden. In the process students will learn about seed germination or rooting techniques and basic plant care.

Teacher hints

- Review appropriate background information for each section before starting (seed treatments, cutting preparation, planting, plant care, hardening off, and transplanting).
- Set up a student watering schedule for potted plants.
- Extend the science inquiry section by requiring students to write up a scientific report on their experiment. The reports can be saved or summarized for future classes to re-test or build on the experiments and contribute to the ongoing research for this activity.
- Keep potted plants in trays to minimize watering messes.

Assessments

- 1 Demonstrate knowledge of seeds, seed germination, preparing and planting cuttings, and adaptations as they apply to local species.
- 2 Participate in an experiment, gaining skills in science inquiry steps.
- 3 Follow through on a long term project requiring attention to detail.



Nurture a Native Garden Project

Part 2: Starting Propagules and Growing Plants

"The creation of a thousand forests is in one acorn." - *Ralph Waldo Emerson* (1803-1882)

Materials Needed

- native wildflower seeds
- ziploc bags
- permanent marker (e.g. Sharpie)
- pots
- trays
- potting medium
- watering wand
- fertilizer

Overview

Part 2 of this native plant project will focus on starting seeds or rooting cuttings and growing plants for a native wildflower garden at your school. Learn about preparing seed or plant material, germinating, planting, and how to care for plants.

Background

A **propagule** is a portion of a plant such as a cutting or a seed from which a plant may grow. Essentially, new plants can be produced through three methods; the spreading of rhizomes or underground roots, rooting the cuttings of plant materials, or seed germination and growth. A **cutting** is simply a section of a plant originating from the stem, leaf or root that is capable of developing into a new plant. **Seeds** are the reproductive units of flowering plants. They are typically made up three parts: the **embryo** (immature plant), **endosperm** (stored food supply), and **seed coat** (outer covering). The function of a seed is to protect and nourish the embryo and to assist in the dispersal of plants to new locations.

Seeds require optimal conditions for **germination** in order to ensure survival for the fragile young seedling. Most plant seeds mature in late summer or fall, but seeds will not germinate until the following spring when weather conditions are favorable. This lag time between when a seed is produced and germination is called **dormancy**. Seeds rely on specific cues from their environment to tell them when conditions are right to begin growth. In order to break dormancy, seeds may require warmth, cold, moisture, and certain levels of light, or specific combinations of these factors, depending on the species and habitat conditions. Some seeds are even fire dependent, requiring high temperatures or in some cases, smoke, to release them from the resinous materials that protect them.

Seed dispersal is important for both the new seedling and the parent plant to have optimal growing conditions. If all of its seeds fell right at the base of the parent plant, the area would become too crowded for all the plants to survive and the offspring would be in direct competition with their parent for resources such as water, light, and nutrients. The parent plant is genetically programmed to promote its offspring's success so it is successful in passing on its genes, its main mission in life. For a plant population to remain healthy it must move new plants into favorable growing conditions. This is called seed dispersal. Plants exhibit many different methods of

Learning Objectives

1. Understand the biology of seeds, seed dispersal, forces of nature that work on seeds, and seed adaptations
2. Start and grow native plants from seeds
3. Prepare a site and plants for a native plant garden

Vocabulary

propagule	seed coat
cutting	dormancy
seed	scarification
embryo	stratification
endosperm	harden off
germination	



Student Project

Nurture a Native Garden Project

Part 2: Starting Propagules and Growing Plants

dispersing seed, using wind, water, animals' fur, birds, feet, or insects to get from place to place. Can you think of any plants that use humans as their primary dispersal agents?

Under natural conditions seeds will germinate when they are ready, but for seeds started indoors we can manipulate conditions to prompt seeds to germinate at other times. Seed treatments are used, when propagating seeds, to mimic natural processes for breaking dormancy and to eliminate the barriers to germination. There are three general types of treatments (and many variations) used

to break seed dormancy of native plants: 1) cold-moist stratification; 2) scarification; and 3) other special treatments including heat, alternating between warm and cold, harvest timing, and the use of chemical plant hormones. These last methods are only used in special circumstances and won't be addressed in this lesson. Some seeds have double dormancy and require combinations of treatments. You will need to do research on the species you have chosen for your garden to determine what kinds of seed treatments you will need to do.

1. Cold-moist stratification is a technique used to fool plants into "thinking" spring has arrived and it is time to germinate. Many plants evolved in areas where winters are cold and moist, followed by a spring that is warm and moist, and those are the conditions that we must mimic in order to convince these species that it is time to germinate. To do this, you can put seed in a mixture of moist sand, peat, soil, or vermiculite in a cooler, or if it is cold enough, outside, in a temperature of about 5 degrees Celsius. Much cooler and the seed will freeze; much warmer and it might not receive enough chill to germinate. They should begin to germinate in 1-2 weeks. Thus, the seed is stored under native habitat temperature conditions commonly mimicking local winter conditions. The moisture level should be similar to a damp sponge. It is common to use a 30 day period of cold-moist stratification, although some species may need as little as 1 day or as much as 90 days (or up to 6 months for some alpine species). Following the time in the cold, transfer your seeds to a warm (20 degrees Celsius) environment mimicking spring and continue to keep them moist. Many native plants such as sedges, buttercups, native lilies, and others require cold-moist stratification, though not all do.



2. Scarification is the act of breaking through the seed coat. This can be accomplished by rubbing sandpaper across the seed coat, by pouring hot water onto the seeds, using an acid to break through the seed coat, or using a razor blade to nick the seed coat. Different scarification techniques are used depending on the permeability and thickness of the seed coat. More often than not, scarification is an easy process of gently scratching the seed coat with sandpaper. Acid scarification is used for seeds with tough, thick seed coats. The acid acts as a mimic of the conditions the seed encounters when passing through an animal's digestive tract. Soaking seed in near-boiling water breaks down the waxy cuticle associated with some species. Nature takes care of this process on its own. How do you think it does this?

It can be very important when germinating and growing native plant seeds in artificial conditions to work in as clean an environment as possible to minimize failures due to rot and diseases. To start, always wash your hands before handling seed. It is advisable to buy sterile media (e.g. peat, potting soil) or, if unavailable, sterilize it yourself in a 400 degree oven for one hour.

By physically treating the seed to conditions that mimic nature, we are able to accelerate the germination process when growing seeds in the classroom or greenhouse setting. If the seeds were planted in the field in the fall, the physical and biological processes they encountered on the soil will naturally break dormancy to allow the germination process the following spring. Sometimes it will take a seed years to break dormancy in nature.



Student Directions

Growing Native Plants

Use your list of local native plants to grow identified from the activity in "Nurture a Native Plant Garden Part 1".

Locate sources of seed or propagules.

Consider collecting from local plant populations, purchasing propagules or asking for donations.

Seed and Propagule Treatment

1. For seeds, follow the general guidelines below or any specific instructions you received from the source of your seed. When rooting local vegetative material, research the proper preparation and planting of cuttings. Consider potential rhizomous plants that could be divided and multiplied in a nursery setting. Consult www.nativeplantnetwork.org for specific treatments for your species.
2. Seeds planted directly outdoors in the fall will not need pre-treatment.
3. Scarification—Only if your species requires scarification (does it have a hard, impermeable seed coat?) Lightly rub your seeds with sandpaper until you have a small spot where water can get into the seed. You do not need to (and should not) remove the entire seed coat. You can check for a breach in the seed coat with a hand lens.
4. Stratification—For cold-moist stratified seed. For very large or very small seed: fill a Ziploc bag 2/3 full with sterilized sand, vermiculite or peat and moisten so it is damp but not flooded. Mix seeds in with the saturated medium in the bag and seal. Be sure your medium stays moist the whole time. Medium and large seed that you will want to plant in individual pots should be stratified in germination boxes with moist blotter paper.
5. Label the bags with a permanent marker and include species name, date, treatment regimen, and seed source.
6. Refrigerate the bags for at least 30 days unless the instructions you found for your species indicate otherwise.
7. If you don't know the preferred method of treatment, do an experiment with several different methods (i.e. scarified vs. not, 14 days of cold vs. 30 vs. 60) and compare the results from your experiment to determine the best technique. Write down and save your protocols for future classes.
8. Continue to the planting directions on the next page after completing the discussion.

CLASS DISCUSSION

What natural process are we imitating by using sandpaper to penetrate the seed coat?

How is seed scarification connected to the processes of the larger food web?

Which seeds require moist-cold stratification and which do not? Why do you think that is?

What is the shortest length of time required for stratification and what is the longest?

How long can you keep seeds in cold-moist storage? How can you relate what treatment the seed needs to the local climate patterns?



Nurture a Native Garden Project

Part 2: Starting Propagules and Growing Plants

Planting Seeds

1. Fill 4" pots or conetainers (trade name for tall cone-shaped pots) with damp potting medium. Plant one or two seeds in each pot. Carefully cover the seed and gently press it into the potting medium. You will need two pots each for the science inquiry section. If you are starting extremely small seed, too small to work with individually, use the following method. Once the seed has been through stratification, gently spread the seed mixture on the top of your potting media in a tray to make soil contact. Be careful to not cover your seed with potting soil.
2. Label your pots with your name on a plant tag or masking tape.
3. Place your pots in trays and gently water with a fine mist.
4. Place plants in a greenhouse if available, a south-facing window, or under florescent lights for 12 hours per day.
5. Check your plants daily, keeping them moist but not wet. If your plants are in a greenhouse make a watering schedule and take turns with your classmates.
6. Watch for germination, and adjust your watering schedule to your plant's recommendation once they are established. Generally, wetland plants will need more moisture than upland plants.

Harden-Off Plants

1. A couple weeks before planting out the seedlings, prepare them for the outdoors by a process called hardening-off. Plan your outdoor planting date after the last frost date for your region. Gradually move plants outdoors into a protected area two weeks prior to your planting date. Bring them back in at night or cover them with frost cloth for the first couple of nights, and on nights that you expect a frost. Slowly introduce the plants to direct sunlight by increasing the hours they are exposed over the two week period. At the end of the hardening off process the plants should be accustomed to the number of hours of sunlight that they will be exposed to in the garden (this will vary from shade to full sun).
2. Your seedlings are now ready to plant out in the native plant garden.

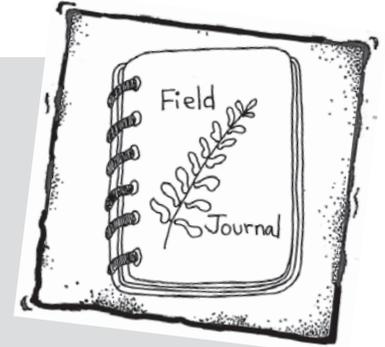
CLASS DISCUSSION

Compare germination rates for those species that require treatment to those that do not require treatment.

Can seeds be planted too close together, or too far apart?

If you grew multiple species, which germinated the fastest? Did your species all require treatments? What natural processes do each of the treatments mimic?

Why is it important evolutionarily for seeds to require these treatments prior to germination? From what does it protect them?

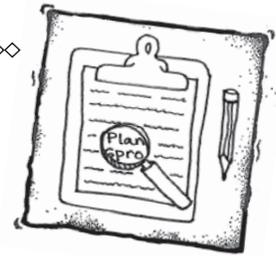


In the Field

Start the native garden preparation for your transplants. Draw a map of the garden area on graph paper. Indicate which areas you will plant with each species. Check online to find out the full size of the species that you will be planting in the garden, so your spacing will be right when they are fully grown. An overcrowded garden can be a frustrating maintenance project in the long run. Mark on the map where to place the plants. Use your map on planting day to guide where to plant. You can always adjust the map as inevitable changes are made on planting day. Begin site preparation as early as possible. If you start in the fall, cover the site with overlapping pieces of cardboard, plastic, or several thicknesses of newspaper. Hold this down with a generous layer of compost or autumn leaves. This will smother the weeds and grass, and amend the soil in preparation for your transplants in the spring.

Reflection

This project requires many steps, covers a great deal of time, and requires working in pairs and teams in a cooperative environment. What part of this project did you find the most fun or rewarding? What parts did you find most difficult? What did you learn about your strengths and weaknesses during this project? What did you learn about your working style over the course of this project? How does this fit with working in a team environment? What do you think are the benefits and weaknesses of working as part of a group? What could you do to make this a more positive experience? How do you feel your project will impact future generations?



EARLY FINISHERS

1. Chart the growth of your plants: when did they germinate, get their first true leaves, or reach a certain height? Compile the information in graphs with labels.
2. Explore seed germination rates. Count out a specific number of seeds and write down the number (50 or 100 seeds makes for easy math). Keep track of the number that germinate and record that number. What percentage of your seeds germinated? What trends do you see? Do some of the seeds germinate faster than others? If so, why? Why might some species have high germination rates while others have low germination rates?



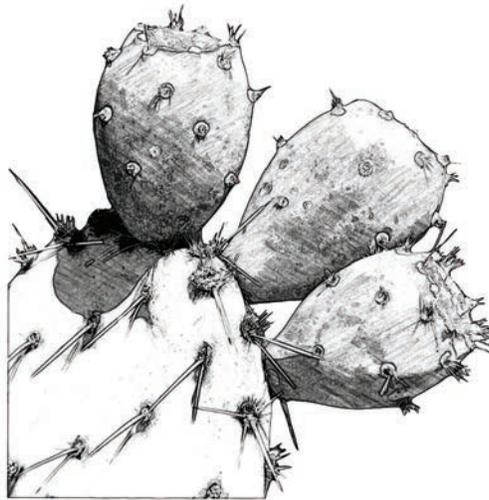
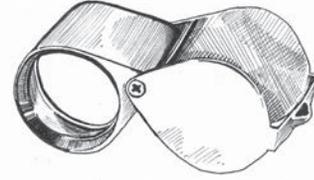
Student Project

Nurture a Native Garden Project

Part 2: Starting Propagules and Growing Plants

Self Assessment

- 1** Discuss your understanding of seeds and their adaptations to the local environment.
- 2** Successfully participate in a group science inquiry experiment. Develop a hypothesis, gather and analyze data, make conclusions.
- 3** Submit a well-written report of your science inquiry project. Discuss individual and classroom data and its significance.



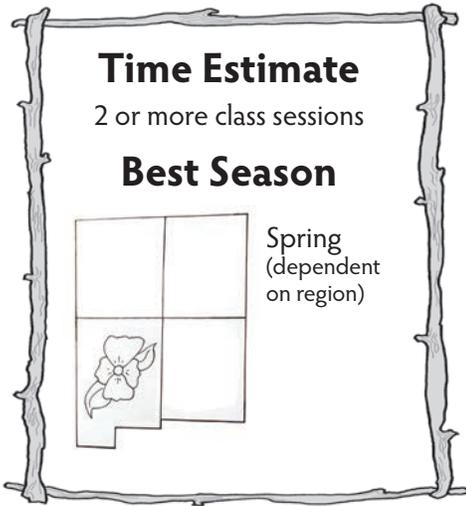
Resources

- A Partnership for Plants in Canada – additional lessons about growing native plants: http://www.bgci.org/canada/edu_act_class/
- *Wild Ones: Native Plants, Natural Landscapes Landscaping with Native Plants Guide* – reasons, ethics, design, seed treatments, planting, local genetics: <http://www.wildonesrrvc.org/Documents/Membership/WildOnesHandbook2004.pdf>
- *American Horticultural Society Plant Propagation: The Fully Illustrated Plant-by-Plant Manual of Practical Techniques*. Alan Toogood, editor. DK Publishing, Inc. New York.
- Native Plant Network: www.nativeplantnetwork.org



Nurture a Native Garden Project

Part 3: Planting and Celebration



"To own a bit of ground, to scratch it with a hoe, to plant seeds and watch their renewal of life - this is the commonest delight of the race, the most satisfactory thing a man can do."

- Charles Dudley Warner (1829-1900)

Overview

Plant out the fruits (or flowers) of your labor in your native plant garden! Students learn transplanting techniques, how to organize and carry out the planting day, and planning a garden celebration. The third stage of this project connects students with community through a service-learning project.

Teacher hints

- Empower your students by offering them specific leadership roles in this stage of the project.
- Facilitate leadership by guiding students into planting day committees, working with students to outline individual duties, and helping them create reasonable timelines. Act as an advisor or mentor to the project. Be sure everyone is included and has a role that feels good.
- Additional community service connections: buddy up with an elementary school class and use the student storyboards to help instruct the young students on transplanting.
- After finishing planting, walk through the planting area and do some quality control to ensure that the transplants were well planted. Check for exposed roots and for plants that are in holes that are too shallow or too deep. Make sure plants are marked so they can be easily watered while they are adjusting to their new environment in the first couple years.
- Emphasize the importance of safety first at your work site including the safe use of tools, equipment and lifting techniques.
- Continue this project from year to year; hold a garden birthday party where everyone adds gifts to the garden through art projects, new plantings, or general maintenance. Extend the project by working with other schools or natural areas to add wildflower areas at their site. Collect and use your own seed. Sell seed or transplants as a fundraiser for the garden.

Preparation

1. Plan far in advance for this day. You will need to (or have your students) research to determine the best time to transplant. This may vary by the species you have and the region in which you live. Contact local nurseries, extension services, or watershed councils for advice on this.
2. Prepare for pre-planting activity by making a copy of transplanting steps (see copy page at end of lesson). Cut this list into strips, each with one step, and put the slips of paper into an envelope for each team of students. The transplanting steps are listed in the correct order on the copy page. You may wish to refer to this list as a key when helping students.
3. Encourage your students to create illustrated transplanting storyboards as part of a community service-learning project, as well as to reinforce their learning.
4. Research if your location may need fencing to deter browsing by wildlife in your garden. Possibly, the maintenance staff would be willing to construct an appropriate fence.

Assessments

- 1 Students draw and describe in a cartoon storyboard, or write out simple step-by-step directions, how to plant a transplant in the garden.
- 2 Students write a job advertisement and description for their role in the planting day celebration as if they were going to hire someone to do the job they did. Be sure to have a list of qualities that would make someone good for the job (e.g. organized, attention to detail, experience with native plants, etc.).
- 3 Students discuss the benefits of their project to the local ecosystem and to the community.



Nurture a Native Garden Project

Part 3: Planting and Celebration

Materials Needed

- transplanting sequence instruction slips
- storyboard template
- drawing materials
- shovels
- pin flags
- gloves
- water
- mulch
- celebration supplies

"To own a bit of ground, to scratch it with a hoe, to plant seeds and watch their renewal of life - this is the commonest delight of the race, the most satisfactory thing a man can do."

- *Charles Dudley Warner* (1829-1900)

Overview

Plant the fruits (or flowers) of your labor in a schoolyard native plant garden! Learn transplanting techniques, organize, and plant your garden area. Take a leadership role by organizing project committees and a garden celebration. Share your project with your community through your celebration, media coverage, or working on a planting project with a buddy class at an elementary school.

Background

In the Nurture a Native Garden Project thus far you have learned about local native flowering plants, seed starting techniques, and how to grow transplants. In this third and final lesson you will plant your garden and celebrate your hard work and the birth of this garden with your community.

By creating a native plant garden that is adapted to local conditions, you are helping local ecosystems and the critters who use them. The native garden will provide habitat for wildlife and pollinators, and use fewer resources, such as water and fertilizer, than a garden of non-native ornamental plants. Native plants are adapted to local soils and climatic conditions (although these are changing as the climate changes). Like all new gardens, the newly planted native plants will appreciate a little added care the first year or two and will always require weeding and maintenance as vigorous non-natives try to invade. Learn and follow proper planting techniques so you will maximize the chances that your plants will survive. To protect the new plants from competition, hold moisture in the soil, and make new plants easier to find, be sure to **mulch** or spread a protective layer of compost, leaves, or other natural materials around the base of your plant. Don't forget to water throughout the first and possibly second summer, to establish healthy plants for the future.

There are several things that you can do to ensure the long term success for your project. Work with your teacher to create a plan for continued maintenance. Future classes can water, weed, and mulch established plants. Native gardens can use help defending against competition from invasive plant species. You can also collect seed and increase populations each year by growing additional **transplants**.

Learning Objectives

1. Work as a group: form committees, plan project, outline individual responsibilities, create a timetable, and complete your planting project
2. Learn and demonstrate proper planting techniques
3. Creatively share the project with other students and the community
4. Increase your knowledge of the local ecosystem

Vocabulary

transplant
mulch

(continued on next page)



Nurture a Native Garden Project

Part 3: Planting and Celebration

Work with the grounds maintenance staff and come up with a long-term plan to keep the garden happy and healthy. Encourage them to eliminate pesticide use on your schoolyard in order to protect local pollinators and wildlife that will be attracted to your plantings.

No matter the size of your project, planting day should be a celebration of your successes and a dedication for your native plant garden. Consider including a nature reading, original poetry, a song or art work at your celebration. A large celebration could extend to the entire school or even be a community event. Invite guests such as your parents,

principal, superintendent, the mayor, retired teachers, and your City Council and encourage them to help with the planting. Use the celebration as a service to educate the community on the benefits of a native plant garden. Create a guide to the native plants in the garden, or design a mural of the blooming plants to be enjoyed year round. Invite the media to cover your event and take pictures and submit a story to your school paper. Don't forget to acknowledge donors or volunteers that have helped make your project possible. Also remember to have fun! Your native plant garden is a great accomplishment and contribution to your native ecosystems and to your community!

Student Directions

Pre-planting activity

1. Work in teams of 2-4 students. Each team will receive an envelope of transplanting steps. Work as a team to arrange the slips in the correct order. When you are finished, check your order against the teacher's key.
2. Create a cartoon storyboard of transplanting steps to use with elementary students. Draw a simple illustration and number each step of the process in the boxes of the storyboard. Laminate the storyboard for outdoor use. Use the storyboards during a community planting or donate them to a young elementary class for a gardening project.

Organizing the planting

1. Assemble a planting map. Use the maps from Part 1, and add an overlay that marks the planting locations for your transplants. Take into consideration the mature size of the plants and space the planting sites accordingly. Be sure to keep in mind light requirements. As some of your species grow taller over the years, what areas will become shady? How does this affect which species you should plant there? Mark the sites on the ground with labeled pin flags (color coded flags work well if transplanting assorted species), making sure they correlate to the map.
2. Gather needed supplies: shovels, watering containers, mulch, pin flags, gloves, and planting map.

Planting day

1. Plant out your plants in spring when soils are dry enough to work. If you are unsure of timing, consult with local gardening experts (e.g. Extension Service, or garden nursery staff). Harden-off transplants starting 2 weeks before your proposed planting date (see "Native Garden Project Part 2" for instructions).
2. Gather all supplies and plants in the garden area. Review planting steps and walk through a planting demonstration.
3. Use the planting map to match the species to the planting location. Color coded pin flags will help you locate exact spots.



Planting day *(continued)*

4. Start with planting sites in the middle of the garden and work towards the outer edges. This will help to prevent accidentally trampling plants. Return the colored pin flag next to the new planting to help people avoid stepping on them.
5. Remember to take your time while planting. This is not a race. It is important that the transplants are handled with care and placed in a properly sized hole, with no large air pockets or exposed roots, in order to ensure better survival.
6. Label plants with plant tags and mark the locations on the garden map. An accurate map will be essential for future monitoring of the site.
7. Set up a student watering schedule to help the new plants establish and get them through the dry summer months. Check with the groundskeeper; they may be willing to help over summer break.
8. Some native plants can be started by direct seeding in the fall or early spring. Use this method to supplement your plantings or if you are working in a very large area. Also, trees, shrubs and bulbs can be best planted in the fall.

Celebration

1. Make planting day a celebration or plan a garden dedication. As with most large projects, they can be easier if broken into smaller parts. Divide the class into committees and delegate responsibilities. Keep the celebration simple; pick and choose what best fits your class and resources. Below are ideas you might consider, plus add your own.
2. Invite the media to your planting day or act as your own press coverage. Take photos and submit an article to your local paper. Don't forget to include the who, what, where, when, and why.
3. Have a ribbon cutting ceremony and invite the school board, school administrators, and staff. Choose a class representative and an invited guest to cut the ribbon together.
4. Make a sign for your garden site.
5. Create a local wildflower booklet or brochure to go with your garden.
6. Videotape or photograph before, during, and after, write a summary, and put together a project scrapbook.
7. Conduct a fundraiser for future garden maintenance expenses. Make and sell packets of native wildflower seed mix to parents and teachers.
8. Include an information sheet with the seeds that explains the importance of using local native plants. Include a list of the plant species in the mix.
9. Can you think of other ways to commemorate your project?

Suggestions for a long-term commemoration of the project

1. Adopt a buddy class from an elementary school and invite them to your planting day and celebration.
2. Alternately, visit their school and help them plant a native plant garden. Lead a wildflower craft project or create a game to use for the day.
3. Commemorate your garden project artistically: create a mural (paint on a wall that is adjacent to the garden area, or on canvas to hang indoors), make mosaic stepping stones, build a bench or a cob garden art structure, make a fabric or paper artwork quilt for the school hall, make a scrapbook and include student garden-inspired art work, or hold a poetry contest.

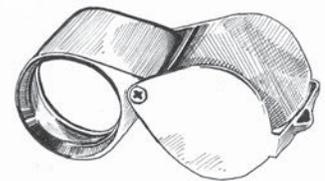


EARLY FINISHERS

Investigate different mulching materials. Set up a test plot in your garden area that has similar soil and sunlight conditions. Plant a row or transect of 24 plants of the same species and condition, 2-3 feet apart depending on the size of the plants. Test 6 different mulching materials using four plants along the transect for each material. Mulch ideas might include: woodchips, gravel, compost, cardboard, plastic, straw, and others. Be sure that all the test plants receive the same amount of added water over the test period. Monitor for several months, or years, if possible. Gather data on the size and vigor of the plants, as well as the effectiveness of excluding weed growth at the base of plants.

Self Assessment

- 1** Rate yourself as a committee member. Did you participate in making decisions, volunteer for a task, complete your task by the timetable, and work well with others?
- 2** Give instruction or demonstrate the steps to transplanting plants into the garden.
- 3** Describe the benefits of the native plant garden to the local ecosystem.



Resources

- Leopold, Aldo. 1949. *A Sand County Almanac*. Oxford University Press, USA.
- *Wild Ones: Native Plants, Natural Landscapes Landscaping with Native Plants Guide* – reasons, ethics, design, seed treatments, planting, local genetics: <http://www.wildonesrrvc.org/Documents/Membership/WildOnesHandbook2004.pdf>



Preplanting activity instruction slips

make a copy, cut into strips, and place in an envelope for each team of students.

Dig a hole (as deep as and wider than the pot) and place the soil carefully to the side.

Support the top of the plant with your hand across the top of the pot, being careful not to crush the plant, and turn the pot upside down.

Gently squeeze or tap the pot to release the plant.

Tease the roots out, if they are tightly coiled around in a circle, loosen the roots to encourage new growth.

Place the plant in the ground so that the crown (where the stem and roots meet) is right at the soil surface, not above or below.

Make sure the roots are pointing down and out (not up) especially at the tips.

Refill the hole with the dirt removed when digging, making sure to fill in all around the roots.

Gently press the dirt around the plant to fill air holes and completely cover the roots.

Mulch around the base of the plant to conserve moisture and suppress weed competition.

Water.

Stand back and admire your work. Wish your plant luck out there in the wild!



*Student
Project*

Nurture a Native Garden Project

Part 3: Planting and Celebration

Storyboard Template



Weed Explosion

"A weed is a plant whose virtues have not yet been discovered" - *Ralph Waldo Emerson*



Time Estimate

Classroom: 60 minutes

Hands-on: 3-4 sessions over a
2 week period

Best Season



Fall
Spring

Assessments

- 1 Use math skills to complete data tables, figure percentages, and graph data
- 2 Name 4-5 characteristics of invasive plants
- 3 Discuss the difference between eradication and control and where each is appropriate
- 4 Identify several ways that invasive plants are introduced and strategies to prevent their spread

Overview

Students will learn the characteristics of invasive plants, how they affect species and ecosystems, and the human impacts of their invasion. They will explore invasive characteristics of two common weeds, dandelion and bull thistle. Students will study dandelion germination rates to demonstrate how prolific one dandelion plant can be. They will also create a mathematical simulation model and graph for bull thistle introduction and expansion.

Preparation

Introduce students to the factors that limit the spread of plant populations; natural limits (e.g. disease, predators, geographic, soil, and climatic limitations) as well as human limits (e.g. herbicides, pulling). Brainstorm with your students to create your own definition of a weed, and discuss the related terms from the vocabulary list. What makes a weed an invasive plant? Are all weeds invasive? Are all non-native species weeds? Are there any native species that are weeds? Lead the class into listing the characteristics of what makes a plant a weed. Do invasive plants have the same limiting factors as native plants, why or why not?

Teacher hints

- Vocabulary words not defined in the text can be found in the glossary.
- Noxious weeds are defined under the Federal Plant Protection Act of 2000, as well as by most states. Students can explore noxious and invasive species as defined both federally and by their state, and learn about the different classifications of weeds.
- The USDA's Introduced, Invasive, and Noxious Plants webpage has information on federally-listed noxious weeds as well as links to state-listed noxious weeds.
- Note: There are 2 Weed Explosion Activities, (1) Dandelion Germination Test and (2) Bull Thistle Introduction Scenario

Hints for Dandelion Germination Test (Activity 1):

- Look for dandelion seed heads during spring and early fall. They should be readily available on the school grounds, nearby disturbed areas, roadsides, or gardens.
- Review dandelion identification, it is important that all students collect the same species of weed seeds. Other common yard weeds have flowers and/or seed heads that look similar and can be mistaken for dandelions.
- Students will need to count the number of buds, flowers, and seed heads on the plant they use to collect their sample for Part 1. This information will be needed to make predictions for Part 2.



Weed Explosion

"A weed is a plant whose virtues have not yet been discovered" - *Ralph Waldo Emerson*

Materials Needed

Part 1: Dandelion Germination Test

- shallow planting tray
- sterile potting soil
- dandelion data sheet (make your own)
- zip lock plastic bag

Part 2: Bull Thistle Scenario

- bull thistle worksheets
- graph paper
- colored pencils
- calculator

Overview

What is a weed? What makes a weed an invasive plant? Learn how invasive plants affect ecosystems, how to prevent invasive introductions, and how introductions are managed. Look at two invasive species, bull thistle, found throughout the United States. See first hand how prolific one dandelion plant can be. Use a simulation to model a bull thistle introduction and create a graph to show its growth and spread over a five year period. Watch how a single seed falling onto bare ground can create a weed explosion when left unmanaged.

Learning Objectives

1. Become familiar with weedy vocabulary
2. Learn the traits that allow a species to become an invasive
3. Identify ways that invasive plants can disrupt the balance of an ecosystem, as well as cause economic damage
4. Use mathematical skills in making predictions, data collection, and graphing

Vocabulary

native

non-native

weed

noxious

invasive

exotic

introduced

seed-bank

germination

eradication

biennial

perennial

annual

Background

Invasive plants are a growing threat to native plant populations worldwide. Disturbances to ecosystems can result from natural causes such as wildfires, disease, or normal succession cycles, as well as result from human causes. Whenever land is cleared by natural disturbance, such as fire or storms, or by human activities such as cultivation, logging, or development, and then left bare, there is an opportunity for invasive plants to take a hold. Erosion also creates bare ground making an easy landing and **germination** spot for wayward seeds.

Due to our modern, mobile, global society, people and their disturbance activities are the prime cause of the spread of invasive plants. Humans often contribute to the spread of invasive plants without even being aware of it. Exotic plants are brought for ornamentals into gardens from all parts of the world, with little knowledge of the consequences of their impact on the local ecosystem. Weed seeds can come mixed in with the seeds of crops, or with other imports. Seeds can travel embedded in the tread of car and bike tires, and even on your shoes. Humans are not the only means of spreading seeds; wildlife and pets can carry seeds on their fur, eat and deposit them in their feces, and birds deposit seeds along fence rows and under trees. Seeds can even catch a long ride on the feathers of migrating birds.



Weed Explosion

It can be difficult for scientists to predict which plants will become invasive and which will not. Not all introduced plants become invasive. Those that do generally share a variety of characteristics that allow them to be successful invaders. These plants are usually generalists, tolerating a wide range of environmental conditions. They are able to reproduce quickly, tend to produce abundant seed, and disperse their seeds with ease--all traits that give them a jump on slower growing **native** plants. Their large numbers of seeds frequently overwinter in the top layers of soil to form a **seed bank** that can carry over for years. The seeds in the seed bank wait until the conditions are perfect for germination, and then grow rapidly. Introduced plants that become invasive also have few natural population controls in their new environment. In moving to a new place, they leave behind the diseases, parasites and predators that may have helped to control their numbers in their own native ecosystem. In fact, many species that become invasive are not particularly common in their homeland, but once they escape disease and predators, their populations are unchecked and can explode.

There are many terms to describe introduced species that often can be misleading or confusing. **Invasive, introduced, weed, non-native, exotic, and noxious** are all words that are frequently used to describe plants that are not native to an ecosystem. However, not all of these plants become invasive and cause problems. Most landscaped yards are filled with beautiful plants that do not endanger native ecosystems; these plants can be called introduced, non-native, or exotic. Weed is a generic term that is commonly used to refer to troublesome plants, but the term weed can also be used to describe any plant that grows where you do not want it. Many native plants could be considered weeds if they grow where people do not want them. The term "noxious weed" actually has a legal definition: "any plant designated by a Federal,

State, or county government as injurious to public health, agriculture, recreation, wildlife, or property."¹ Why should we be concerned about invasive plants? Invasive weeds have been identified by many land management agencies as the number one obstacle to promoting healthy ecosystems.² Invasive plant populations can rapidly expand to dominate natural plant communities, destroy wildlife habitat, reduce plant and animal diversity, and cost millions of dollars to control or in losses of land productivity.



One example of an invasive species that has a severe impact on riparian corridors especially in the southwest region is salt cedar (*Tamarisk* spp.) Salt cedar trees change the chemistry of the soil, deterring other plant growth and can create a monoculture, growing in dense, nearly impenetrable clusters. More water is consumed with the higher density of trees, lowering the water table. Dense stands of salt cedar can be highly flammable, increasing wildfire hazards. Salt cedar can effectively alter the natural functions and processes of the riparian area. Restoration efforts are especially hampered on riparian corridors where

dams control water flow. Flow regulation favors salt cedar, while native vegetation such as cottonwood and willow thrive under natural flooding conditions.

In order to slow the devastating economic and environmental effects of weeds, invasive plant management is usually broken into two categories -- control or **eradication** (complete elimination). Many weeds are so common and widespread that there is little hope of eradicating them from the landscape. Instead the focus on these species is on maintaining control and limiting new expansions. Early detection of new invasive species is handled differently. By training people to recognize these early detection species, and with sufficient effort to remove them when they are found, eradication may be possible.



Weed Explosion

Methods to control invasive plants are grouped into four categories: prevention, mechanical (mowing and fire), biological (releasing insect or disease predators and parasites), and chemical (herbicides) control. Prevention is the least expensive and the least harmful to the environment but involves extensive coordination throughout the state to be sure that public and private land managers and users are aware when a plant species is a threat. Mechanical methods of control generally involve interrupting some stage of plant life cycle by hoeing, mowing cutting, burning, or mulching to kill the plant or to prevent seed production. Biological control methods often use an herbivory to the plant (e.g., importing a beetle that specializes on eating a certain weedy species) or disease-causing organisms to control specific plants. Chemical control uses herbicides to kill the plant or chemical means to suppress seed germination.

Challenge yourself to identify ways that you may inadvertently spread invasive plants, and what steps you could take to prevent their spread. Try to control weeds with the least toxic method to protect yourself and the environment. If everyone were conscious of invasive species and helped to control their introduction and spread, our native ecosystems and our economy would benefit greatly.

In the first activity, you will take a close look at a familiar weed, the common dandelion. You will estimate the number of seeds produced by each plant and test the germination rate of the seed. Later, in the second activity, try your hand at simulating the population explosion of bull thistle.





Weed Explosion

Activity 1: Dandelion Germination Test

Step One: Seed Collection and Counting

1. Use the common dandelion (*Taraxacum officinale*) to compute germination rates on your own. Dandelions have a spring blooming season and a secondary fall bloom period. Proper plant identification is important; review your plant identification before collecting seed heads. Other common yard weeds can have similar seed heads that can be mistaken for dandelions.
2. Work with a partner, locate and carefully pick an entire mature seed head and place in a Ziploc bag to prevent seed loss. Count the number buds, flowers, and seed heads present on the plant and record the number.
3. Return to the classroom. Make a prediction of how many seeds are on your seed head (each person should make their own prediction) and record your predictions.
4. Carefully remove from the baggie and count the seeds (save all the seeds!) and record the number. Counting hints: Work on a sheet of dark colored paper. Use forceps, toothpick, or a pencil point to push seeds to the side as you count them (keep them on the paper). Make a tally mark for each 10 seeds and then total your tallies at the end (otherwise it is easy to lose count). Compare to your actual count to your prediction. How close was your prediction?
5. Share seed count numbers between the entire class; were the numbers similar or do they vary greatly? What could be some of the reasons for this?

Step Two: Planting and Monitoring Germination

1. Plant all of the seeds from your seed head into the planting tray. Mark the tray with your name(s). Half fill a pan with moist sterile potting soil. Spread the seeds fairly evenly over the soil surface, firmly patting the seeds into the soil. The seeds will need good contact with the soil to germinate but should not be covered. Mist with spray bottle to make the soil damp but not soggy. Place plastic wrap over the tray to retain moisture. Why might you want to use sterile potting soil instead of garden soil?
2. Place trays in a sunny windowsill. Keep moist and check periodically for sprouting seeds. Keep a tally of the seeds that germinate and remove them with a tweezers. This will ensure that you do not count the sprouts more than once. Record the number each time you remove sprouts. Continue gathering sprout data for 2-3 weeks (dispose of the seedlings responsibly – don't spread invasive plants!).
3. Tally the final number of seedlings. Calculate the percentage of the seeds that germinated using the total number of seeds planted. This is your germination rate.
4. Use your germination rate to make additional predictions. Take the number of buds, flowers, and seed heads from your original plant to predict the how many seeds one mature plant could produce. Record the number. Why is this number a prediction and not concrete data?
5. Extend the activity to monitoring one dandelion plant for an entire season. Flag your plant and visit daily, pick all flower heads and buds, and keep a tally of how many you collect. How many seedlings can one mature dandelion plant produce? Figure this by multiplying the number of flower heads by the number of seeds per flower head, then multiply this by your germination rate. Is this an accurate number, why or why not?



Weed Explosion

CLASS DISCUSSION: Compare data. How much variance was there among the different dandelions? What could be the reason for the differences? How many of the seedlings do you think would actually survive outside, and why? How could you gather data on total annual production? How could you test the seedlings for survival rates? What else do you wonder about regarding your dandelion patch?

Activity 2: Bull Thistle Scenario

Introduction: Bull thistle (*Cirsium vulgare*) is native to Eurasia and is now widely established across North America. It has large spines on hairy leaves and large purple flower heads. Bull thistle can be found in almost all parts of the United States and is thought to have been accidentally introduced multiple times through contaminated seed sources. It is commonly found in disturbed areas and will spread into farmland, pasture, rangeland, and recently logged sites. Found in sunny locations, it can displace native and cultivated grasses and forbs. Bull thistle is a **biennial** and produces seed on mature second year plants. After seed production the plant dies.

Scenario: A Bull thistle was introduced to a state park when a seed head was accidentally caught on the frame of a visitor's car. Bull thistle seed heads contain anywhere from 100-300 seeds each and plants can produce anywhere from 1 – 400 seed heads. Both of these figures depend on many factors such as nutrition, soil, competition, and water available to the plant throughout its life.

In our model, the bull thistle is introduced to a healthy grassland ecosystem. In this scenario, the thistle will have to compete for several resources and will produce only 20 seed heads per adult plant. Research shows that 95% of the seeds that bull thistle produces are viable and capable of germinating. In our grassland, only 15% will germinate the first season. This reduced germination rate could result from a healthy vegetation layer covering the ground that prevents many seeds from coming into contact with soil. In this environment, only 1% of seeds that germinate will survive the rigors of nature to become tiny seedlings. Survival can be challenging even for an invasive plant species. All plants need sufficient water, sunlight, and nutrients to make it through the summer, and in our model, only half will live through that first

summer. The seedlings that do survive will start to grow and make a rosette (whorl of basal leaves), increasing their footprint and giving the plant more space to collect the necessary resources. Once a bull thistle becomes a rosette, it develops sharp spines on the leaves that deter many animals from eating it. These spines help to increase the chance of survival, and 97% of these rosette stage plants will now survive to maturity and produce seed.

Bull thistle seeds have feathery appendages that allow for wind dispersal, but easily detach when the seed is mature. This means the vast majority of mature seeds fall near the parent plant, but some of the seeds are transported by wind and establish plants in new locations. Scientists who study invasive plants use advanced models to calculate distances that seeds can travel under optimal conditions. These studies suggest that up to 10% of bull thistle seeds may travel more than 27 meters with relatively little wind.

What happens to the remaining viable seeds that did not germinate? Under the correct conditions, this seed can be stored in the upper layers of the soil or thatch, waiting to sprout when the conditions are right. This natural storehouse of seeds is called the seed bank. Seeds may remain dormant in the seed bank for different durations, depending on physical factors such as the seed coat and exposure to the elements. Some invasive plants such as field bindweed have seeds that can survive in the seed bank for 60 years! Bull thistle seeds have a relatively short life in the seed bank, remaining viable for no more than five years. In our model, 50% of the seeds in the seed bank will germinate in the following year; the other 50% will remain in the seed bank.

Find the information in the text above to complete the life history table on the next page.



Weed Explosion

Life History Table	answers
1. Plant maturity (annual, biennial, perennial)	
2. Average number of seeds in a seed head	
3. Number of seed heads per adult plant in this model	
4. Percentage of new seeds that are viable	
5. Percentage of viable seeds that will germinate	
6. Percentage of germinated seed that will establish seedlings	
7. Percentage of seedlings to survive 1st year to become rosettes	
8. Percentage of rosettes that become 2nd year adult plants	
9. Distance that seeds can travel by wind on relatively calm day	
10. Percentage of seed bank seeds that will germinate each year	

Life History Table Answer Key

Life History Table	answers
1. Plant maturity (annual, biennial, perennial)	Biennial
2. Average number of seeds in a seed head	200
3. Number of seed heads per adult plant in this model	20
4. Percentage of new seeds that are viable	95%
5. Percentage of viable seeds that will germinate	15%
6. Percentage of germinated seed that will establish seedlings	1%
7. Percentage of seedlings to survive 1st year to become rosettes	50%
8. Percentage of rosettes that become 2nd year adult plants	97%
9. Distance that seeds can travel by wind on relatively calm day	27 meters
10. Percentage of seed bank seeds that will germinate each year	50%

Data taken from: <http://www.fs.fed.us/database/feis/plants/forb/cirvul/all.html>

References:

Zouhar, Kris. 2002. *Cirsium vulgare*. In: Fire Effects Information System, [Online].
 U.S. Department of Agriculture, Forest Service, Rocky Mountain Research
 Station, Fire Sciences Laboratory (Producer). Available: [http://www.fs.fed.us/
 database/feis/](http://www.fs.fed.us/database/feis/) [2008, November 5].



Weed Explosion

Student Directions

1. Work with a partner or individually.
2. First complete the life history table needed to complete this exercise. Bull thistle is a biennial, a plant that lives for two years and does not produce seed until the second year. For our calculations, the mature plant dies the second year after producing seed. This information is key to your calculations,
3. Use the life history table to compute the formulas for the worksheet. Double check your formulas before continuing.
4. Year 0 on the worksheet represents the bull thistle introduction (a seed arriving in hay) and is filled in for you. Use your formulas to complete the remaining years on the worksheet.
5. Graph your results by hand or use a computer. Make a line graph of the size of the adult plant population over time as well as the accumulating seed bank. Add a caption to your graph, and label the axes to show units and scale.
6. Map how far the bull thistle could spread over a 5-year period, if wind disperses the seed. Directions are on the worksheet. Use graph

paper and place a dot on the midpoint of your paper to represent your first plant. Assume there are no landscape barriers to seed dispersal. How far could the thistle's offspring spread from the original parent plant? Use an appropriate scale for your graph paper and draw a circle around your initial plant showing the distance that the seeds will travel each of the five years of the model. Your map will show circles that enlarge each year as the seeds travel outward. Use meters as the scale to compute this spread.

7. Looking at your graph; compute the total square



meters that the bull thistle could cover at the end of the 5-year model. How does this compare to the size of a football field?

CLASS DISCUSSION

What happened to the numbers of adult bull thistle plants over the 5 year period? What happened to the number of seeds in the seed bank?

What kind of growth curve do the graphs show?

Can you explain the dip in the numbers in the early years? Do you think you would see a similar growth pattern in perennial or annual weeds? What advantages or disadvantages do you see for plants that are annuals, biennials, and perennials?

What would happen if some students came in year three and helped out by pulling half of the adult plants? How would that slow the spread of the species?



Weed Explosion

Bull Thistle Introduction Model

(Year 0 is filled in for you)

year	1. #new seeds	2. #viable new seed	3. #new seeds germinate	4. #of seeds in seed bank	5. # seed bank seeds germinate	6. total # of seeds that germinate	7. Become seedling	8. #rosette plants	9. #adult plants
0	4000	3800	570	0	0	570	5	2	0
1									
2									
3									
4									
5									

Column 1 = Calculate the number of seeds from one adult plant

Column 9 * _____ (the number of seed heads per plant) * _____ (the number of seeds per seedhead-average) = column 1

Column 2 = How many of those seed are viable?

Column 1 * _____ (% of new seeds that are viable) = column 2

Column 3 = Number of viable seeds that will sprout in our grassland

Column 2 * _____ (% of viable seed that germinates) = column 3

Column 4 = Number of seeds in the seed bank

(Take previous year column 2 _____ minus previous year column 3 _____) + (previous year column 4 _____ minus previous year column 5 _____)

Column 5 = Number of seeds in the seed bank that germinate this year

Column 4 * _____ (the % of seeds in seed bank that germinate) = column 5

Column 6 = Total number of seeds that germinate this year

Column 3 + column 5 = column 6

Column 7 = Number of germinated seeds that become seedlings

Column 6 * _____ (% of germinated seed that will establish seedlings) = column 7

Column 8 = Number of seedlings that establish year old rosette plants

Column 7 * _____ (% of seedlings to survive first year) = column 8

Column 9 = Total number of 2 year old adult plants

Previous year column 8 * _____ (% of rosettes that become 2nd year plants) = column 9

Weed Explosion

Bull Thistle Introduction Model (Answers Key)

year	1. #new seeds	2. #viable new seed	3. #new seeds germinate	4. #of seeds in seed bank	5. # seed bank seeds germinate	6. total # of seeds that germinate	7. Become seedling	8. #rosette plants	9. #adult plants
0	4,000	3,800	570	0	0	570	5	2	0
1	0	0	0	3,230	1,615	1,615	16	8	1
2	4,000	3,800	570	1,615	807	1,377	13	6	7
3	28,000	26,600	3,990	4,037	2,018	6,008	60	30	5
4	20,000	19,000	2,850	24,628	12,314	15,164	151	75	29
5	116,000	110,200	16,530	28,464	14,232	30,762	307	153	72

Formulas:

Column 1 = column 9*4,000

Column 2 = column 1*.95

Column 3 = column 2*0.15

Column 4 = (previous year column 2 minus previous year column 3) + (previous year column 4 minus 5)

Column 5 = column 4*0.5

Column 6 = sum of column 3 and column 5

Column 7 = column 6*0.01

Column 8 = column 7*0.5

Column 9 = previous year column 8*0.97

Column 1 - Figure the number of seeds from one adult plant (column 9*4,000 or 1*200*20=4,000)

Column 2 - How many of those seed are viable (column 1*0.95)

Column 3 - What percent of viable seed will sprout in our grassland (column 2*0.15)

Column 4 - Number of seeds in the seed bank (previous year column 2 minus column 3 + previous year column 4 minus 5)

Column 5 - The number of seeds in the seed bank that germinate this year (column 4*0.5)

Column 6 - The total number of seeds that germinate this year (sum of column 3 and column 5)

Column 7 - The number of germinated seeds that become seedlings (column 6*0.01)

Column 8 - The number of seedlings that establish year old rosette plants (column 7*0.5)

Column 9 - The total number of 2 year old adult plants (previous year column 8*0.97)



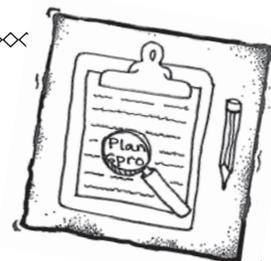
Weed Explosion

In the Field!



Take part in an invasive weed removal project. Local parks and public lands are in need of your services. Think about how a class full of energetic weed pullers can make a huge difference. And, you won't have to take any tests or quizzes while you are out there! Consider making it a long term project. Adopt an area and return for monthly weed patrols, and you will make a lasting impact in the health of local ecosystems for your community!

Reflection



Ask yourself, why should you be concerned about invasive weeds? What are some ways to prevent invasive weeds from spreading? What are some natural factors that might limit the growth of weeds? How do humans inadvertently spread weed seeds? What could you do to help prevent the spread of weeds? What are some of the ecological consequences of the spread of invasive weeds? What are some of the economic consequences? Name some factors that might limit the viability of seeds in the seed bank? Can you think of any reasons weeds are beneficial?

EARLY FINISHERS

- Visit the USDA Introduced, Invasive, and Noxious Plants webpage: <http://plants.usda.gov/java/noxiousDriver> and compile a list of invasive plant species for your state. Pick one invasive weed species that occurs in your area to research. See if you can find a place where this weed grows and familiarize yourself with it so you can teach others. Educate your friends, family, and teachers by creating a weed guide on a school bulletin board with photos and descriptions.

Self Assessment



- 1 Use math skills to compute weed germination rates, survival rates, and to make graphs.
- 2 Name 5 characteristics common to most invasive plants.
- 3 Discuss the difference between eradication and control and when each is appropriate.
- 4 Explain two ways that invasive plants can damage an ecosystem.
- 5 Identify one way that people spread invasive plants and one or two strategies to prevent that method of spreading.

Resources

- USDA PLANTS database for pictures: <http://plants.usda.gov/> and Introduced, Invasive, and Noxious Plants webpage: <http://plants.usda.gov/java/noxiousDriver#federal>
- California Dept. of Food and Agriculture. Encyclopedia Data Sheets, Thistles. <http://www.cdffa.ca.gov/phpps/IPC/weedinfo/cirsium.htm>
- Moab Area Travel Council; information on tamarisk: <http://www.discovermoab.com/tamarisk.htm>
- The New Mexico State University Data base: <http://weeds.nmsu.edu/databasesearch.php>



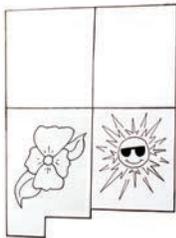
Measuring and Monitoring Plant Populations

"An experiment is a question which science poses to Nature, and a measurement is the recording of Nature's answer."
- *Max Planck* (1858-1947)

Time Estimate

30-45 minute introduction
60 minute field session
an additional session is
required for *In the Field!*

Best Season



Spring
Summer

Overview

When botanists and ecologists work in the field, it is not practical or possible for them to count and measure every single plant out there. If this is the case, how do they collect accurate data on plant populations? Field biologists use different methods of sampling portions of a larger population or plant community to collect data that is representative of the whole. The data can then be used to describe the overall population or habitat. This lesson will introduce you to several methods of sampling plant populations and the different types of data that can be collected.

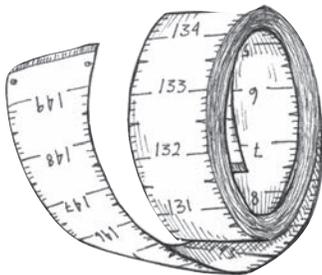
Preparation

1. Students should complete the exercises in the How to Estimate Percent Cover worksheet before attempting the lesson.
2. Students will conduct a plant population survey to sample one common (abundant) and one uncommon (rare) plant within the survey area. Choose an area to support such a set up. A natural meadow would supply an area for several student teams to work.
3. Break the class into teams of two to four students. Each team will conduct a survey in the same general area. Students can then compare and discuss results.

Teacher hints

Differential education - ways to adjust the level of this lesson:

- To introduce more difficulty, add additional sampling methods for more advanced students to compare.
- To simplify the lesson, reduce the sample size or reduce the types of data collected.



Assessments

- 1 Students are able to explain what sampling is and discuss the strengths and weaknesses of using sampling as compared to a census to measure plant populations.
- 2 Students can describe two or more methods of sampling plant populations and discuss their applications.
- 3 Students can describe two or more types of data to collect and their applications.



Measuring and Monitoring Plant Populations

"An experiment is a question which science poses to Nature, and a measurement is the recording of Nature's answer."
- *Max Planck* (1858-1947)

Materials Needed

- metric measuring tapes
- quadrat frames (Appendix V)
- clipboard/data sheet/pencil
- wooden stakes
- compass
- field guides

Overview

When botanists and ecologists work in the field, it is not practical or possible for them to count and measure every single plant. If this is the case, how do they collect accurate data on plant populations? Field biologists use different methods of sampling portions of a larger population or plant community to collect data that is representative of the whole. The data can then be used to describe the overall population or habitat. This lesson will introduce you to several methods of sampling plant populations and the different types of data that can be collected.

Learning Objectives

1. Become familiar with methods of sampling plant populations and their applications
2. Explore different plant population attributes that can be measured (e.g., percent cover, presence/absence, counting individual plants) and their applications
3. Use a sampling protocol to collect different types of data and compare two plant populations
4. Analyze data and interpret results

Vocabulary

transect

plot

quadrat

percent cover

plant population

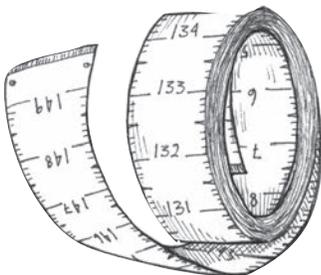
frequency

azimuth

Background

Botanists and ecologists sample **plant populations** for many reasons, including monitoring or "keeping tabs" on a population of rare plants, comparing the results of habitat treatments in an experiment, or determining the impact of an activity (e.g., building a new road through a sensitive habitat, wildfire, or grazing) on a plant population.

When you are out in the field there are many aspects of a plant you can measure and monitor. For example, on an individual plant, you could measure its height, the number of leaves, flowers, or fruits it has, or the number of other species within a certain distance of it. These are examples of measurements that indicate the vigor of individual plants. For a population of a certain species, you could record the total number of individuals, the amount of area it covers on the ground, how many reproductive individuals versus those not reproducing, and many other traits. Within a plant community, you could count the number of species, how many individuals of each species there are, how those species are





Measuring and Monitoring Plant Populations

distributed over the landscape, the slope of the land, the **azimuth** (which direction the slope faces), and many other traits. Given limited amounts of time, money, and with specific objectives, how does an ecologist decide which types of data to collect and how and when to collect

them? It depends on the question of interest for the study or experiment. Some common types of data collection to meet different objectives are listed below.

Presence/absence: Is the species of interest present or not? This is likely the fastest and easiest type of data to collect. However, it only lets the researcher know if the species is present or absent. It does not provide information about its abundance relative to other species, or distribution within the habitat.

Frequency: This tells us the percentage of **plots** within a larger sample area in which the species is present. For example, if ten plots are placed in a meadow, and species A is present in one of the ten, it has 10% frequency. This measure of the plant population does not indicate how abundant the plant is. In the example above, even if there are five of species A in one out of ten plots, species A's frequency within the sample is still only 10%. Similarly, if Species A is found in only one plot of ten, its frequency will be the same regardless of if it takes up 100% of the area in that plot, or is just found taking up less than 1% in a little corner. Advantages of frequency data are that it is quick to collect, easy to compare between species, and similar results can be obtained in different seasons of the year (e.g., if a seedling of species A or a mature plant of species A is present, the data will be the same).

Percent cover: This is a measure of the proportion of the ground (often within a plot or **transect**) covered by the body of a plant (from a bird's eye view). This method is extremely useful for plants that spread clonally (e.g., grasses or aspen), or for plants that may produce multiple stems that appear to be multiple plants or where counting individuals is unreasonably time consuming. This is a very useful measure for comparing the abundance of different

species. One drawback of measuring cover is that it can vary drastically for an individual plant over the course of the growing season and can be more difficult for researchers to make an objective and accurate measure. This measure is commonly used in plant community research involving multiple species. This method works best for species that are evenly distributed through the area to be sampled and works less well for species that are very patchy or found only along the edges.

Population estimates: If a population is too large in extent or number to feasibly measure or count every individual, sampling is used to estimate the size of the population without actually counting every plant. During sampling, a representative portion of the population is counted and then this data is extrapolated to estimate the size of the entire population. For this method to be legitimate, the part of the population that is counted (the sample) must be selected carefully, in an unbiased manner and must also be representative of the rest of the population as a whole. Frequently, randomization is used to choose the sample, so that every part of the population has an equal chance of being chosen for sampling.

Census (complete population counts): This is the preferred method when possible. No statistical analysis is required and therefore any changes in counts from year to year are real. A drawback to this method is that it can be extremely costly in person power, time, and money.



Measuring and Monitoring Plant Populations

What determines which sampling method one should use and the type of data to collect? Factors including population size and distribution, the area to survey, the time available, and the ecosystem characteristics (e.g., density of vegetation, slope, etc.) must be considered. The researcher may select one of many possible sampling methods and layouts to use during the survey, including the following:



Photo points: A picture is worth a thousand words! With this method, the surveyor takes photos in the four cardinal directions (north, east, south and west) from a set of permanently marked points within the area of interest. The photo points should give a good visual assessment of the entire area. Photo points can then be revisited over time, the photos re-taken, and compared to the initial (baseline) photos to evaluate change over time.

Transects: These can be long, narrow strips or wide belts that traverse the landscape. The area within the boundary of the transect is sampled and transects are placed randomly or in intervals across the area to be sampled. Target species within the transect can be counted or **percent cover** of any or all species present can be assessed. Transects can also be a line (essentially, a very narrow belt); in this case, often the presence of all species that occur along the line or at specific intervals along the line are recorded. Long transects may be easier to establish in some habitats (e.g., prairie) than others (e.g., dense forest). The longer a transect is, the more likely it is to capture variation within your population.

Transects are especially useful when the target species you are trying to monitor is patchy on your landscape. Transects are usually placed parallel to one another on the landscape and then run at the same **azimuth** (angle). The number of transects needed to describe a larger area will depend on how variable the habitat is, the size of the transect, and the size of the area to be sampled.

Plots: Plots are often square, although they can also be round or rectangular, areas within which data are collected. Square plots are often called **quadrats**. The size of plots can vary with sampling method, though one meter square plots are common. As with a transect, if the purpose of the plots is to describe a larger area, the plots need to be randomly placed (e.g., using a set of random numbers as coordinates to position plots in a grid overlain on the site). The number of plots needed to describe a larger area will depend on how variable the habitat is, the size of the plot, and the size of the area to be sampled.

Once you have collected your data, the next step is data analysis. Until you do this you just have a bunch of numbers on a piece of paper. Your analysis will be guided by the objectives of your study. If the purpose is to compare two (or more) parts of a plant population, perhaps to test a hypothesis, the data collected needs to be evaluated to determine if a statistical difference exists, and how likely it is that any observed difference has not just occurred by chance.



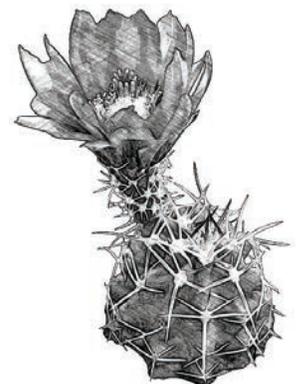
Measuring and Monitoring Plant Populations

Student Directions

1. Work in teams of 3-4 students.
2. Choose one common and one less common plant species that you will sample in your survey, or decide to sample all species. Make sure you can recognize younger and older or flowering and non-flowering individuals. Decide as a class whether the entire class will use the same two plants, or whether each group will do different ones. This monitoring exercise will answer the question of how common our chosen plant species are within our survey site.
3. Set up a 50 meter long transect in your study area. Make sure you are not biasing the placement of your transect. In your groups, develop a method to randomize the direction (**azimuth**) of your transect. Use a compass to lay out your transect. Be sure that your transect intersects populations of your common and uncommon plants.
4. Once your transect is established, collect data every 5 meters starting at the 5 meter mark along the transect line by placing the bottom left corner of a 1 meter square quadrat frame at the meter mark and lining it up with the tape (if the bottom left corner is at 0 m, the bottom right corner should line up at 1 m, etc).
5. At each sample point (5 m, 10 m, etc.) collect three types of data (presence/absence, percent cover, and a complete census) for both the common and uncommon plant species. Collect your last data at 50 m, so you have a total of ten samples.
6. Compile your data in a spreadsheet. Calculate the **frequency** (% of plots in which your species is found) at which each species was present in your sample of ten plots. Calculate the average, maximum and minimum percent cover for each species. Average your census data for each species. Do the same techniques yield similar or different results?

CLASS DISCUSSION

1. Which type of data most accurately represents the difference you think you observed between the common and uncommon plants? Weigh the efficiency and speed of data collection against the usefulness of the information you collected.
2. Which methods were best for the plants you studied?
3. How could you change your methods to collect more accurate data?
4. How might you change the data you collect if you had a different research question?





Student Project

Measuring and Monitoring Plant Populations

In the Field!

Conduct a plant population survey on your school grounds. The object of your survey will be to compare native plant populations to non-native plant populations. As a class decide, to focus on percent cover, frequency, number of species (species richness), or some other population measure. Consider your survey objective and the topography of the area to be surveyed to choose the most appropriate sample method to use and type of data to collect. Make sure you can differentiate between all the plants you will encounter in your survey. You can learn to identify them or just give them your own names as long as you can tell them apart consistently. Divide into teams with each team surveying a different area of the school ground. Collect your data, and then come together as a class to do the analysis.



Reflection

What did you learn about measuring plant populations? Why do you think there are so many different methods used? Why would you want to change the sampling protocol to best fit a situation? Should the sampling method influence your interpretation of the data? Would you have greater confidence in some methods of data collection than others?



Self Assessment

- 1** Explain what sampling is and discuss the strengths and weaknesses of using sampling as opposed to a census to measure plant populations.
- 2** Name two or more methods of sampling plant populations and discuss their applications.
- 3** Name two or more types of data that can be collected and their applications.



Resources

- Elzinga, C. L., Salzer, D.W., & Willoughby, J.W. Measuring and Monitoring Plant Populations. Bureau of Land Management. BLM technical reference manual 1730-1, BLM/RS/ST-98/005+1730: <http://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf> (this document is large and takes time to download)
- Cornell University and Penn State University, Environmental Inquiry for high school students, Invasive Species: <http://ei.cornell.edu/ecology/invspec/>



Measuring and Monitoring Plant Populations

Estimating Percent Cover

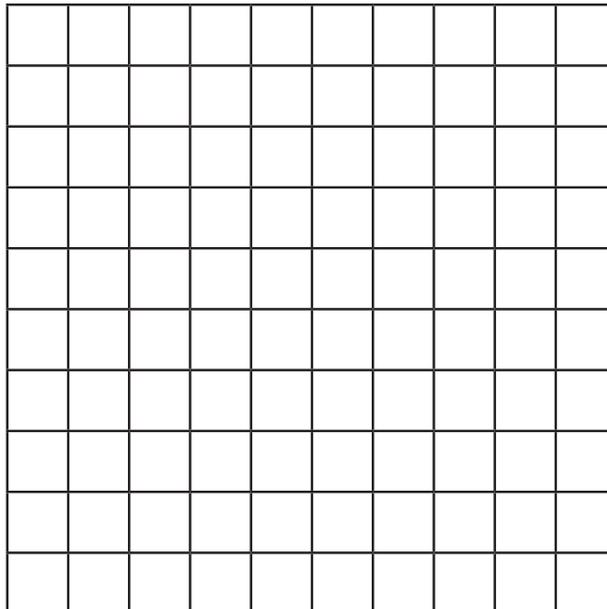
Percent cover is a measurement used by botanists and ecologists to describe and quantify plant communities and habitat. It refers to the proportion of the ground that is covered by a specific habitat component, which could be a certain plant species, or bare ground, or the canopy of a tree overhead. Because percent cover is not tied to a specific measurement unit (like inches or centimeters), it is easy to compare across different sample unit sizes and shapes.

A good starting point is to evaluate the percent cover of plant species or types of plants within a 1 meter x 1 meter quadrat frame (see diagram below). The first step is to orient yourself to the proportion of the area in the quadrat that equals 1%, 5%, or 10%. For a 1 meter x 1 meter (100 cm x 100 cm) frame, the total area is 10,000 square centimeters.

Therefore:

- 1% of 10,000 is 100 cm², or the area of a square that is 10 cm x 10 cm in size.
- 5% of 10,000 is 500 cm², or about the area of a square that is just over 22 cm x 22 cm in size.
- 10% of 10,000 is 1000 cm², or the area of a square that is 31.5 cm x 31.5 cm in size.

Example: 1 meter x 1 meter quadrat



Each square is 10 cm x 10 cm, or equal to 1% cover.

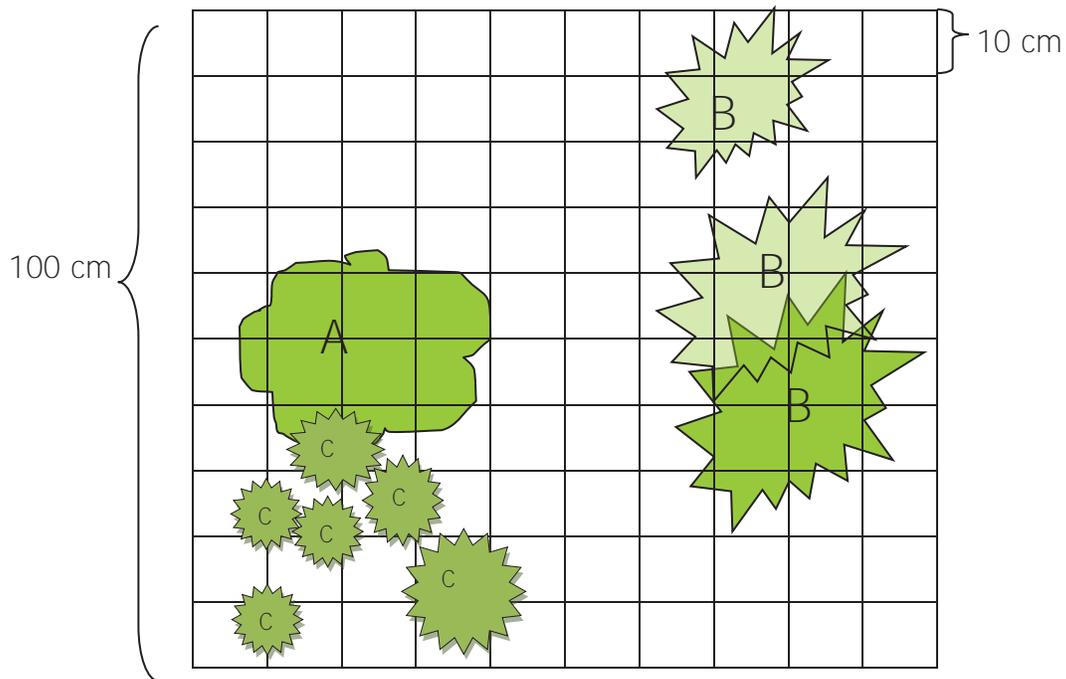


Student Project

Measuring and Monitoring Plant Populations

Try measuring the dimensions of your hand, then figure out the percent cover it would occupy in your one meter square. What percentage would a typical 8.5" x 11" piece of paper such as your datasheet, be?

Now, apply what you've learned to estimate the actual percent cover of plants on the ground. Using the diagram below, estimate the cover of the three plants, A, B, and C, within the quadrat. Again, remember that this quadrat has guidelines that are 10 cm apart, or in a 10 cm grid. Plants are never square, so you will have to visually move around and mentally "squish" the plant area into the grid to estimate its cover.



What percent cover do you estimate for Plant Species A? _____

What % cover do you estimate for Plant Species B? _____

What % cover do you estimate for Plant Species C? _____

What is the total % vegetative cover for the plot? _____

As you get more practice in estimating the percent cover of plants of different shapes and sizes, you will get much faster at the process. In some cases you may have overlapping plant layers, and you may end up with a total cover that exceeds 100%.

Section 5:
Ethnobotany





Who Walked Here Before Me

"You must live your life from beginning to end; no one else can do it for you."

- Hopi Tribe

Time Estimate
1-2 hours

Best Season

		Winter
		Fall
		Spring
		Summer

Overview

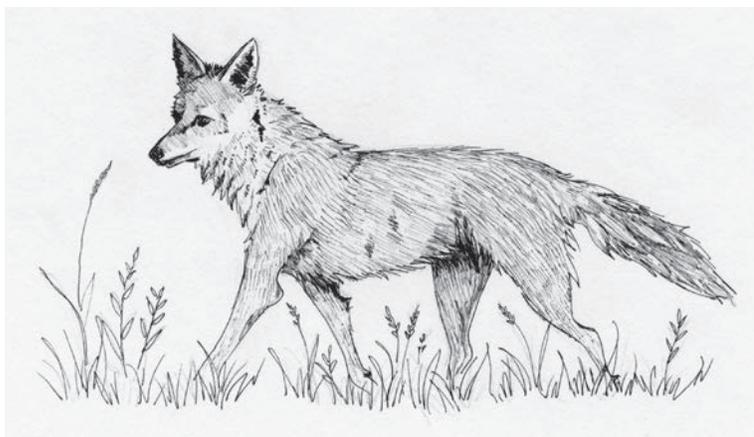
Students will learn about the Native American cultures in your region by studying their connection with the natural world. They will study how Native Americans were tuned into the yearly natural cycles of their ecosystems. By investigating how native plant species were used for food and other applications, students will gain insight into the ingenuity and resourcefulness required to thrive using resources gleaned from natural ecosystems. Students can connect to a sense of place by exploring the culture, the people and the plants of New Mexico and how they are entwined in a delicate and beautiful dance together.

Preparation

1. Students will need access to computers and the internet.
2. Consider vetting a list of species from Appendix IV for which the information needed in the activity is accessible for each plant.

Teacher hints

- Appendix IV New Mexico Ethnobotany Plant List gives examples of plants that tribes used for various purposes.
- Encourage students to research the ecology of the native food plants to give them an idea of when the plants were being harvested and consumed. The activity works best when plants used throughout the harvest year are chosen.
- Vocabulary words not defined in the text can be found in the glossary.



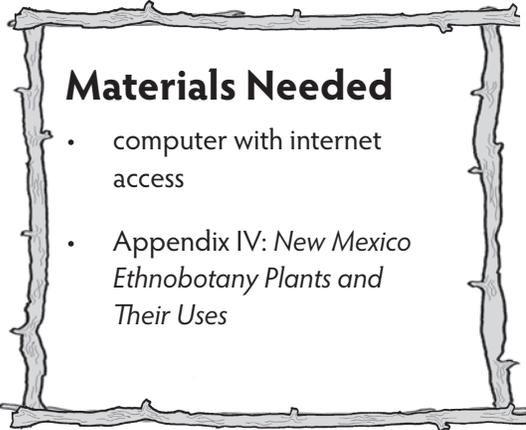
Assessments

- 1 Name one important food plant from your area and describe in detail its role within the culture of people historically and today.
- 2 Name at least one Native American tribe that lives and/or lived in your local area.
- 3 Describe the cycle of a harvest year for a Native American tribe from your area.



Who Walked Here Before Me

"You must live your life from beginning to end; no one else can do it for you."
- Hopi Tribe



Materials Needed

- computer with internet access
- Appendix IV: *New Mexico Ethnobotany Plants and Their Uses*

Overview

Learn about the Native American cultures in your region by studying their connection with the natural world. You will study how local tribes were tuned into the yearly natural cycles of their ecosystems. By investigating how native plant species were used for food and other applications, you will gain insight into the ingenuity and resourcefulness required to thrive using resources gleaned from natural ecosystems. Connect to a sense of place by exploring the culture, the people, and the plants of New Mexico and how they are entwined in a delicate and beautiful dance together.

Vocabulary

- ethnobotany
- traditional knowledge
- culture
- seasonal round
- edible
- staple food
- famine food

Learning Objectives

1. Define ethnobotany and understand the ethnobotanical resources of local native plants
2. Gain insight into the connection between people, ecosystems, traditional knowledge, and resource management where you live
3. Develop a greater understanding of and respect for other cultures by examining their connection with ecosystems and plants in particular
4. Explore native plants used for food
5. Introduce the concept of a harvest year as it applies to a tribe from your area
6. Identify how native people managed landscapes to promote resource availability
7. Identify tribes in your local area, their present day locations, and historical ranges



Background

Ethnobotany is a word that you will commonly hear to describe people's use of plants. The word can be broken down into the root words, "ethno" meaning **culture** and "botany" which is the study of plants, hence the study of people and plants. This word can encompass the historical uses of plants, as well as the present day use. The use of plants may have changed over time, but plants still play a very important role in providing people with food, fiber, building materials, and medicines.

New Mexico has a rich history and presence of Native American culture throughout the state. The earliest people were hunters and gatherers



Who Walked Here Before Me

who relied upon wild animals and wild plants for food, medicine, fiber, and various implements. Later as communities were settled and an agricultural way of life began, the people turned to cultivated plants for their food base and cotton for their clothing needs. Even then they continued to harvest native plants for a multitude of uses and the availability of useful plants depended on where the people settled.

The exact migration history of these tribes into what are today's modern communities is not clear. Possibly, settlement patterns are related to the availability of plants needed for daily life. For instance, plant and animal diversity providing ample sources for food, fiber, construction, and medicine and agricultural opportunities may have been key in drawing the Pueblo people of the Four Corners region eastward in the 12th and 13th centuries. The Puebloan communities are direct descendants from the inhabitants of ancient ruins found through the central Rio Grande Valley and to the northwest.¹ The Historical Range Map shows a general historical distribution of Native Americans throughout the state. The Present Native Nations Lands map shows current Native American communities. Both maps are provided at the end of this lesson.

Tribes lived in yearly cycles that were determined by the seasonal changes of the landscape. Patterns of movement and activity reflected the location and seasonal availability of particular foods and resources. This annual cycle of activities, movements, and harvests is called a **seasonal round**. Through these seasonal rounds, native cultures were inextricably linked with seasonal changes. The Puebloan communities unlike nomadic Native American tribes were able to stay within a smaller region, satisfying most of their needs throughout the seasons along the Rio Grande River corridor.

Historically, **staple foods** were foods that were readily available and made up the dominant part of the diet, supplying a major part of nutritional needs for survival. Native people depended on **famine food** sources that were readily available in times of scarcity. In this lesson, we will take an ethnobotanical look piñon pine (*Pinus edulis*), an important staple food for New Mexicans in the past and present.

Piñon pine ethnobotany: Historical

Historically, native people of New Mexico were the custodians of a once vast piñon pine and juniper "orchard" that provided them with food, fuel, building, tools, and medicine. The great piñon woodlands where prehistoric villages were located provided basic nourishment for the people prior to their cultivation of corn. One early favored collection method was to unscrew the pitch covered cones from the branches and carry them home



to open by heating or drying. This method of collection early in the season avoided competition with piñon jays and other birds and animals. Once the cones opened and the twenty or so nuts in each cone were picked out, the empty, dry, pitchy cones made excellent kindling. Flower formation is dependent on moisture in late winter and early spring, and the cones and nuts do not mature until late summer. A bumper crop can be expected only about every six years. But surely in the past, as now, the Native Americans were still able to find some canyon or mesa where at least a few nuts could be collected. Containing over 3,000 calories per pound, piñon nuts must have constituted the most valuable wild plant food source for people living in or in the vicinity of the piñon-juniper ecozone. Some Native Americans parched piñon nuts and ground them with corn meal to make a flour. Others mixed nuts with yucca fruit pulp to make a pudding and chewed secretions from the trunk of piñon pine trees. Miscellaneous historical uses of piñon pine are numerous. Red pottery paint was obtained by mixing the resin of old and new trees and a blue-green or turquoise paint was fabricated from boiling piñon gum. Also, pitch was mixed with ground lichens or mineral colors to make a paint medium. As an all-purpose glue made by warming the pitch, piñon resin was used for setting turquoise in jewelry and attaching sinew to the back of bows. Piñon glue in conjunction of a wrap of wet sinew was used to secure stone points and feathers to arrows.¹ The pitch of piñon pine was also used to cause vomiting and to waterproof containers and as a dermatological aid on open sores.



Who Walked Here Before Me

Piñon pine ethnobotany: NOW

In recent times Native Americans have collected piñon nuts, setting up temporary camps in the woodlands when seeding begins and beating or shaking the nuts onto blankets or canvas. The nuts would be roasted on a stone griddle on site, then carried home in jars or sacks, where they would be kept for several years. In a good year a surplus could be easily acquired for home use, trade, and in modern times a cash crop. Piñon nuts are the most sought after wild plant food by contemporary Native Americans as well as other New Mexicans. At San Juan Pueblo it is the only plant product that family members still gather as a household activity. Piñon pitch is still used medicinally by Rio Grande Puebloans, powdered and sprinkled in wounds as an antiseptic or mixed with warm candle wax and placed on sores to draw out infection. They also chewed pitch as a gum or swallow pitch to clear a head cold.¹

In the last hundred years, people have been confronted with the reduction of traditional lands, destruction of valuable farmland, and the introduction of a cash economy. Agricultural activities conducted by Native Americans often is not much different from agricultural practices found elsewhere in the United States. Typically, large fields of monoculture crops are grown and harvested with modern machinery and techniques. Though some Native Americans prefer to garden in the old way, cultivating a mixture of food crops in a single plot, and tolerating or even encouraging useful wild species among the crops.¹ Tribes still practice some traditional management techniques and cultural practices to maintain their connection with the land.

In these modern times, we, as a culture, are beginning to realize how important retaining this **traditional knowledge** is, not only for the Native American culture from which it came, but as skills and knowledge essential to the survival of all humans in an uncertain future. For Native Americans, collecting their food and fiber plants was not as simple as exploring the landscape and harvesting what they needed. New Mexico's native people were wildland managers that used generations of acquired skills to manage and sustain what grew around them and to create habitat for species that were essential to their culture's survival. Important species were managed with techniques

that would ensure sustainable harvests for generations to come, to provide food, shelter, medicine, fiber, dye, and ceremonial items. This knowledge is key to understanding how New Mexico's ecosystems once functioned and how they have changed through time.

The chart on the following page shows some of the management techniques used by early New Mexicans and explains the purpose of each technique.

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Gathering and using plant materials remains an integral part of many Native American cultures today. Often cultures mark important plant harvest events with celebration ceremonies, connecting culture, spirituality, and the land. Some tribes employ modern land management technologies such as using GPS and GIS to help map and monitor traditional resource gathering sites. Today private land ownership often limits the areas that Native Americans can use for gathering, but securing access to continue traditional gathering is a high priority for many tribes. This may take the form of collaborating with public land agencies to secure gathering rights, as well as purchasing lands to set aside for this purpose. Limited access is only one impediment to gathering plants. Others that you might not readily think of include environmental hazards such as toxic chemicals and herbicides. By far, the most common problem limiting ability of native people and others to gather plants is loss of suitable plant habitat from drought, draining of wetlands, land development, and the introduction and spread of invasive weeds. As you can imagine, for cultures entwined with the rhythms and cycles of the natural world, the gifts of nature were highly cherished. The land was cared for by all; for if the land was over-harvested or depleted it could mean hardship for many generations. How is this different from how land is managed today? Can you think of any lands today that are managed for the common good? How does the management of these lands change over time? (Federally owned lands are an example of community owned land, but the management of the lands changes frequently depending on the politics of the current administration.) Do you think that public land is valued as highly as land that is privately owned? Why or why not? Think about how present American culture influences how we value land today.



Who Walked Here Before Me

Management Techniques	Application
Fire	Keep fields open for hunting and decrease competition, increase fertility/stimulate new growth; facilitate harvesting, control insects, recycle nutrients
Weeding, clearing brush and rocks from cultivated sites	Remove poisonous plants, reduce competition for desirable plants; facilitate bulb and root digging; encourage growth of edible (fit to be eaten as food) weeds
Pruning	To promote long straight new growth for basketry and other materials
Sowing seeds	Spreading extra seed at harvest, broadcasting after burning, waiting for harvest until after seed production to facilitate plant increase
Conservation	Never took all blooms of harvest plants; collected cactus stems were broken at joints; only nonflowering branches of shrubs were collected; annual salad green were collected well above root, allowing plant growth to continue; when yucca roots collected, the seed pod would be buried
Tilling or cultivation	Using digging sticks to harvest roots, tuber, and bulbs; leaving small bulbs for future collecting; Used ditch banks and unplanted strips at edges of fields for useful natives such beeplant, purslane, goosefoot, ground cherry, Indian tea, blue trumpets, sunflower
Water conservation and irrigation	Mulch, acequias- irrigation ditches, stone check dams, stone-lined reservoirs, and rock-outlined catchment systems (grid gardens)



Edible Native Plant Activity

In this activity you will study native plants used as food in your local area from a historical perspective. Each group will study one common native plant used for food. Then groups will come together as a class to compile the data and create a harvest calendar which shows which plants were harvested and used at various times of the year. *(directions follow)*



Student Directions

1. Determine which tribes lived and live in your local area. Native American tribes are incredibly diverse and each has its own unique culture and way of using native plants, animals, and other resources.
2. Break into teams. Each team will research one edible plant from your local area (see list in Appendix IV). Try to coordinate the effort to choose plants that are harvested at different times of the year.
3. Using the data collection sheet provided, research the answers to all the questions. Use the suggested resources at the bottom of the worksheet. If more information is needed, consider working with a research librarian for local sources, contacting historical societies or local museums, conducting web searches, and using websites associated with the Native American tribes in your area.
4. Connect the story of these plants in relationship with each other and the cultures that use them. Each plant story will now become part of a larger seasonal picture that highlights how native plants can be an important part of a peoples' diet and how this works into the greater story of culture.
5. Across the top of a white board make a column for each season of the year. Under each season, write the name of the plants that would be harvested at that time and what habitat that the plant would be found in. Two examples for the AZ/NM Plateau would be: 1) spring, Rio Grande Cottonwood buds, riparian corridors; and 2) late summer, piñon pine nuts, juniper-piñon zone. Remember some plants have different parts that can be harvested at different times of the year. Some plants are collected for storage for winter. In this way you create a calendar showing the general idea of what the tribe would be eating throughout the year.
6. Use the information that you have gathered and think about where each food comes from around your local area. How far apart might the tribe have travelled from one harvesting location to the next? Can you think of places nearby that may have been sites used for harvesting various foods and materials? This basic information will give you a glimpse of the distances travelled by a local tribe throughout the cycle of a year in order to fulfill its needs.
7. Use your creativity to put together a visual calendar of the harvest year (from information on the white board). Document ecosystems of the different resources and when the tribe would have to move to that area to harvest. A circular calendar, which represents an unending cycle, is often used to depict the harvest year. You can also choose another creative way to portray the cycle.

CLASS DISCUSSION

Historically, how did tribes know when it was time to move to a new area for harvesting? What would happen if it was a bad growing year and the harvest of certain plants was scant or non-existent? Were some foods more valuable than others? How did tribes know which plants to eat and which to avoid?

Do you think you could be resourceful enough to hunt and gather a nutritious diet to avoid illness? What would you need to learn in order to do this? Can you give at least two reasons why it is important to really know about the sources of your food today even though you do not gather it yourself?



Reflection

One way that traditional knowledge about plants was passed from generation to generation was through stories told by elders. These stories often included animal figures and a moral. Create a story for your plant that will encourage respect for your species for generations to come. Convey the importance of your plant (see worksheet questions) as you weave in creative story with characters, a setting, and a moral. Your story can be written or a more traditional oral story. If you choose an oral story, you may want to make a simple storyboard to help you remember all the parts. Think about ways a storyteller can make a story more interesting for the audience (using different voices for the characters, props, costumes, comedy, or a twist ending).



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EARLY FINISHERS

Create an ethnobotanical herbarium of plants used by local tribes. Preserve specimens for future classes to use. Collect one sample to put in a plant press (only collect if the plant is common—follow the guidelines in the plant press activity in Section 1). If plants are unavailable or rare, assemble the herbarium with pictures or illustrations. Include the researched ethnobotany information on the herbarium sheets.

Self Assessment

- 1 Name one important food plant from your area and describe in detail its role within the culture of people historically and today.
- 2 Name at least one Native American tribe that lives and/or lived in your local area.
- 3 Describe the cycle of a harvest year for a Native American tribe from your area.



Resources

- National Museum of the American Indian, Smithsonian Institute. American Indian collections research: <http://www.americanindian.si.edu/searchcollections/home.aspx>
- Native American Ethnobotany Database: <http://herb.umd.umich.edu/>
- Plants used by American Indians for food, medicine, shelter tools, and other applications: Moerman, Daniel E. Native American Ethnobotany.
- Ethnobotany documents: <http://unesdoc.unesco.org/images/0014/001458/145847e.pdf>
- Appendix IV New Mexico Ethnobotany Plants and Their Uses
- Appendix II Native Plant by Ecoregion
- **Information sources for Ethnobotany Worksheet:**
- Appendix IV New Mexico Ethnobotany Plants and Their Uses
- University of Michigan – Dearborn, Native American Ethnobotany. A Database of Foods, Drugs, Dyes and Fibers of Native American Peoples, Derived from Plants: <http://herb.umd.umich.edu/>
- USDA NRCS Plants Database: <http://plants.usda.gov/> and associated links
- Appendix II Ecoregion Species List
- Local Native Plant Field guides



Who Walked Here Before Me

Ethnobotany Worksheet

Names: _____

Look at native plants used for food in a historical and present day context and use the information to weave a story used in the lesson.

Species name:	
Describe your species:	
Habitat and range:	
What tribe(s) used this species?	
What was/is the plant used for? (can be multiple uses)	
What part(s) of the plant were used?	
What time or times of year was the plant harvested in your ecoregion? What signs did people look for to indicate the timing and location of harvest?	
How was the plant gathered? What harvesting tools or methods were used?	
How was the plant prepared? (cooking and serving methods)	



Who Walked Here Before Me

Where populations of the species actively cultivated and/or managed? If so, how?	
Are there any stories, folklore, myths, or cultural ceremonies associated with the plant? Describe.	
How does this plant fit into the ecosystem? (consider: wildlife, invertebrates, pollinators, soil life, decomposition, nutrients, sunlight, water, habitat) Ask the question, "What does this plant depend on, and, who depends on this plant?"	
Do people still use this plant today for similar purposes? How have its uses changed over time?	

Look at your own food practices or ceremonies in the context of your own life; Thanksgiving Day, saying grace, Pueblo Feast Day, Passover Seder meal, significance of Easter eggs, Japanese tea ceremony, traditional foods for your family, and others.

Name one food ceremony that you take part in:	
What is the significance of the ceremony?	
What special food(s) is/are associated with the ceremony?	
What is the cultural origin of the ceremony?	
What foods are characteristic of your local culture?	
Are any local native species commonly used in your local cuisine?	

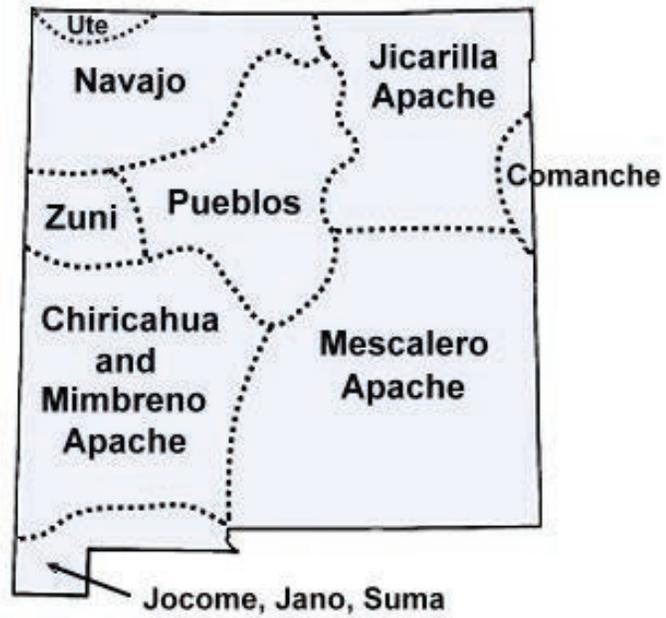


Student Project

Who Walked Here Before Me

Historical Range

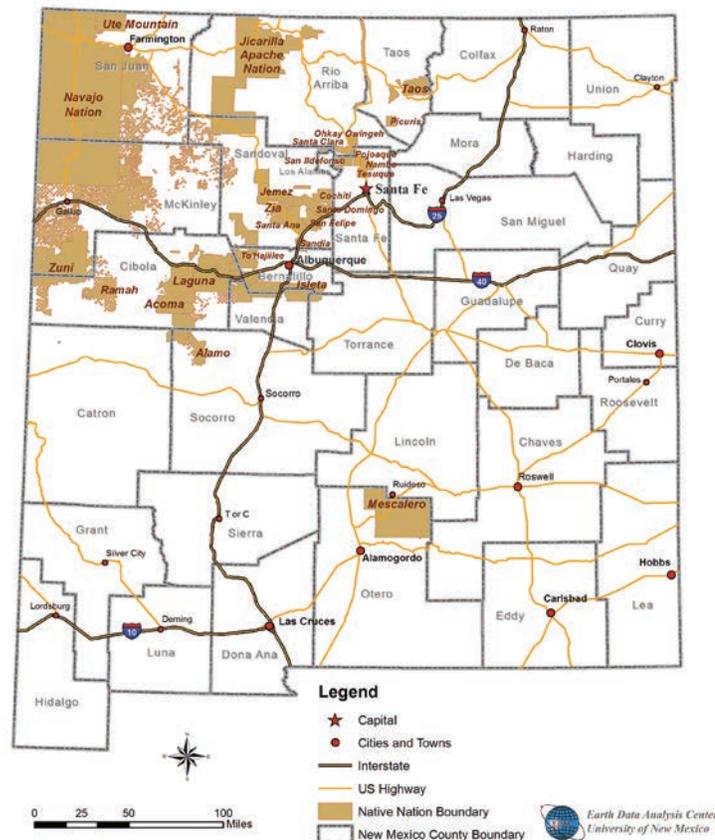
Source: Native Languages of the Americas: Preserving and promoting American Indian languages Website: <http://www.native-languages.org/nmexico.htm>



Native Nation Lands New Mexico

Present Native Nation Lands

Source: Earth Data Analysis Center Website: http://edac.unm.edu/2011/08/nm_native_lands/





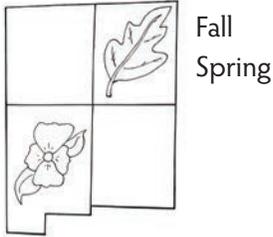
Burden Basket: Plant Materials



Time Estimate

1-2 hours, not including field collection

Best Season



Fall
Spring

"Humankind has not woven the web of life. We are but one thread within it. Whatever we do to the web, we do to ourselves. All things are bound together. All things connect."

- *Chief Seattle, Duwamish* (1780-1866)

Overview

This lesson introduces native plant fibers and their uses, with a focus on cordage, baskets, and decorative techniques. Students will look at traditional weaving materials, techniques, and gain an appreciation for basket function and design. Students will then collect, prepare, and construct cordage or a simple burden basket practicing techniques and using various plant materials.

Preparation

1. Scope out locations to take the students on a gathering trip. Materials can be found in many locations: long grasses can be collected from vacant lots or roadsides; willow, cattails, rushes, and sedges can be found in most wet areas. Challenge the students to make use of what they can find growing locally. City gathering requires creative thinking. Certain cultivated vines may be readily available in urban areas. Ask permission before collecting any plants. Or, ask students to collect plant material from home to bring into class.
2. **WARNING: Make sure everyone can identify harmful plants (e.g. poison ivy, stinging nettles, poison hemlock, etc.) if they grow in your collecting area.**
3. Work with students to create ethical collecting guidelines for the class to use. Be sure that the students discuss such things as: responsible harvesting, cutting rather than pulling plant materials (unless it is invasive), avoiding over-collecting, and asking permission from landowners.

Teacher hints

- Complete "Who Walked Here Before Me" lesson prior to doing this activity to get background understanding of the cultural importance of native plants in the lives of native peoples.
- Consider inviting a traditional basket weaver to visit your class. Ask them to share their baskets, techniques, and materials collecting tips. In return, share your project with your guest. Consider searching the internet for "images of Puebloan baskets" and "images of Southwest Native American baskets" for inspiration if a weaver is not available.



Assessments

- 1 Describe what makes some plant materials more useful as fiber plants.
- 2 List two native plant materials that are valued to use for their fiber.
- 3 Define cordage, explain how it is constructed, and list some of its uses.
- 4 Name several traditional uses for basketry.



Burden Basket: Plant Materials

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- *Chief Seattle, Duwamish* (1780-1866)

Materials Needed

- pruners/clippers
- plastic bags
- gloves
- dish pan
- spray bottle
- old towels
- colored raffia or yarns for decorative design (optional)
- project direction sheet(s)

Overview

This lesson introduces native plant fibers and their uses, with a focus on cordage, baskets, and decorative techniques. You will study traditional weaving materials, techniques, and gain an appreciation for basket function and design. Now jump in and try it yourself! Go on a collecting walk to gather and prepare materials to either make cordage or construct a simple burden basket, practicing the techniques and using various plant materials.

Learning Objectives

1. Learn what makes some plants useful for baskets and cordage
2. Gain an appreciation of the history of baskets and cordage used by Native Americans
3. Understand the role of management when utilizing fiber plants
4. Sample hands-on techniques using plant materials to make cordage and basketry
5. Gain appreciation for the decorative designs used to personalize baskets (dyes, colored plant materials, motifs) as well as the techniques that create them
6. Understand that ecosystems influence available plant fiber materials

Vocabulary

fiber cell

lignin

cordage

coiling

twining

weft

warp

burden basket

tumpline

open weave

overlay

storage basket

Background

For millennia, people have used plant fibers to meet the needs of daily life, from making simple twine to bind things to building entire houses. Traditionally, plant fiber has played a large role in many cultures, but with the proliferation of manmade materials like plastics, this need has diminished, as have the skills that go with it. At one time plants provided the materials for food storage containers, clothing, utensils, tools, and adornments. A woman who needed water from a stream would use a basket made from tree bark and waterproofed with plant waxes or tree resin. Today, we just reach for the nearest bucket. Although modern society still depends on plants to supply fiber for paper, cloth, and lumber for building materials, much has changed in just the last couple centuries making our relationship with the plants around us very different than it once was.



*Student
Project*

Burden Basket: Plant Materials

What makes some plants useful as fiber plants? First, the plant must include **fiber cells**. These cells tend to be long, thin, and tapered on the ends. All plant cells have cell walls, making them tougher than animal cells, but fiber cells have extra thick cell walls that are reinforced with a substance called lignin. **Lignin** is a compound that makes fiber cell walls stronger, more waterproof, and more resistant to attack by fungi, bacteria and animals. Fiber cells are one of many plant structures that help support plants, letting them grow to reach sunlight, supporting their vascular tissue (water and sugar transporting cells), and providing them with protection from other organisms. Fiber cells are often present in the wood or bark of hardwoods, including oak, ash, and maple. The leaves and stems of some plants such as flax and jute also have fiber cells, which make these plants useful for fabrics like linen and weaving items like floor mats and bags. Fiber cells are also present in the leaves of many grass or grass-like plants, such as cattail, agave, and yucca which is used for twine and rope.

Traditionally, Native American tribes living throughout the Southwest used fiber from native plants, as well as other natural materials, to meet their needs for baskets, rope, fishing traps and nets, cooking containers, water jugs, garments, and houses! Nature supplied everything they needed. Although many of these traditional plant uses have declined, people, Native Americans and otherwise, still find time to gather materials and produce objects made from plants. In our busy modern times, creating a useful beautiful object with your own hands from materials collected yourself can be very fulfilling. What are some of the things you would need to know about fiber plants, design, and construction techniques to be able to make your own containers?

To begin, you might analyze the form and function of each container's design. A **storage basket** was used to preserve and to protect plants, often food or ritual objects. Storage baskets usually stayed in one secure and environmentally safe place such as a storage room, pit, or cave. Another common container design is called a **burden basket**. Sturdy burden baskets were frequently worn on the back much like today's backpacks. Burden

baskets were made for carrying heavy items such as firewood or for when the wearer needed their hands free such as while harvesting. Such baskets were often cone shaped and outfitted with a **tumpline**, a strap over the forehead or shoulders, and used for hands free transporting. The cone shape fits comfortably, while distributing the weight on the wearer's back. The large opening at the top allowed for easy filling by tossing items over the shoulder, and the cone shape discouraged thrown items from bouncing out. Tumplines were a tightly woven strap made of soft pliable materials for the wearer's comfort. The baskets were often made of an **open weave** to hold bulky items while contributing a minimum of weight in basket material to carry. At times, baskets were quickly woven on site to transport materials back to camp. Tightly woven burden baskets were used to harvest small seeds and berries. The burden basket is just one of many designs perfectly suited for its jobs.¹



In New Mexico, baskets were commonly used for storing food and constructed of many different native plant materials. Some species stand out for their superior fiber or weaving attributes. Yucca leaves, split lengthwise into long strips were the preferred fiber for woven vessels. Young branches of willow, mesquite, and skunkbush sumac and the stems or leaves of sotol and sacahuista were all prized materials. Branches from willow or skunkbush sumac were employed in constructing coarser baskets or trays, especially the coiled type.² Traditionally, baskets were used in all aspects of life; some were plain and quickly made for immediate use. Other baskets show painstaking attention to detail and were intricately decorated. Some baskets show geometric patterns that are woven in or overlaid in contrasting colors. An **overlay** is a technique used to add color designs on twined baskets. The colored weaving fiber is woven on the inside of the basket and brought to the front with a half



Burden Basket: Plant Materials

twist to replace the standard weaving fibers. Plant materials supplied the colors for these designs. For example, mountain-mahogany roots and alder bark were used for red dye. Yellow came from rabbitbrush blossoms. Pueblo people mixed the twigs and leaves of skunkbush sumac mixed with piñon pine gum to produce black.² Navajo used skunkbush sumac leaves to make a black dye. Highly decorated baskets are cherished, culturally important, used

in ceremonies, and passed down from generation to generation.



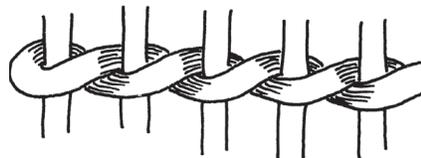
Cordage

Cordage is another essential tool of native people that uses plant fiber. Cordage was used as ties or a binder of household articles, rope ladders, fishnets, headstraps, thongs for sandals, snowshoes, belts, headdresses, and baskets. The most common plant source for cordage of Southwest Native Americans was yucca. Many species of yucca were used for tying material, cords, ropes, string. Yucca leaves were boiled, then beaten or chewed,

and finally soaked to extract their fibrous strands which were then twisted together to form twine or rope. Other examples of plants used by Southwest peoples include lechuguilla and Sacahuista in Southern New Mexico. Also, the Jemez split the epidermis of western purple cranesbill and used the fiber to sew moccasins.² Native Americans used plants, especially vines such as bindweed, clematis, and Virginia creeper as ready ties.

Plant fibers can be used as cordage, bundled, or in their natural form as weaving material. There are many techniques for making baskets, with two common methods being **twining** and **coiling**.

The twining method uses two pliable "weft" strands that are twisted around a more rigid "warp" or foundation structure. This method was used to make some of the specialized baskets like water jugs, cooking containers, and soft hats. In the second technique, coiling, the base foundation is a spiral of



twining

materials that are sewn together with a pliable fiber thread.

Different plant species have different optimum times for harvest. Tree and shrubs are often harvested early in the year when new growth is lush and supple. Reeds and grasses are typically harvested later in the season when their growth becomes more fibrous. Preparation for use can include softening fibers, stripping bark, or splitting larger canes.



coiling

Continuous harvesting and the use of fire, pruning, mowing often had the result of changing the phenotype

of the plant source. For example, repeated harvesting new growth of willow plants changes the plants general appearance, giving it a thicker base.

Traditionally, fire was used by many New Mexican tribes as a management technique to promote long, straight plant re-growth for harvest. This traditional management method has become more difficult to use with changing times although it is still employed in natural areas around the state. Lack of regular burning has left high levels of woody materials and underbrush that could now fuel large wildfires. As populations have changed, so have land management techniques. It is now more common to use pruning or mowing than fire to manage plant growth.

Gathering native plant materials requires ethical collecting practices to ensure access for future generations as well as to protect significant natural ecosystems and species. Ethical collecting includes preventing over-collection to minimize population damage. When gathering plant material, one should minimize damage to the parent plant by cutting and removing only a small section of plant, not disturbing the roots, and never taking whole plants. Collect only from large plant populations and allow plants to reproduce between collections. Using thoughtful practices can allow you to harvest plants fibers without hurting plant populations. Think also about actions you can take to protect or enhance native plant populations for the future. Imagine the connection you would have to your environment if you used plants to supply all your needs, from containers to clothes!



Burden Basket: Plant Materials

Student Directions

1. Think of all the containers that you come into contact in a day; food storage, cooking, eating, backpacks, purses, boxes, water bottles to egg cartons, we are surrounded by containers of all uses, shapes, and sizes. Make a list of 10 containers that you commonly use in a day. Take 5 from your list and brainstorm ways that you could construct an adequate replacement container using materials found in nature. Share your best ideas with the class.
2. Challenge yourself to learn some of the traditional art of using native plants to make utilitarian as well as decorative objects. Choose one of the project sheets from this lesson and learn a new skill.
3. Go on a gathering walk to collect materials needed for your project (cordage and/or baskets). Work with a partner or in a small team. Each team will need pruners/clippers, a plastic bag, and gloves.
4. Spring is a good time to collect flexible young twigs from willows. Grasses are best collected in summer once they have gone to seed and just as they begin to lose their green color. Cattail is best collected in fall, when the leaves have dried and are less fleshy.
5. Review responsible gathering guidelines and how to identify plants to be avoided (i.e. stinging nettle, poison ivy, and poison oak). Collect in an area where you have permission (your teacher will guide you), and take precautions to avoid damaging the plants; cut rather than pull out or tear your materials, don't over collect or gather more than you need. Use gloves to protect your hands while collecting.
6. Traditionally most fiber materials are collected when they are green and are dried before use. This helps to keep the basket weaving tight, because green materials will shrink as they dry, and may disrupt the weave. This might not be important factor in a large gathering basket, but it is critical in baskets used to hold water. We will be using green, un-dried materials for this project because of time limitations, and because green materials are easier to work with.
7. Once you return to the classroom, organize your collected materials. Separate similar materials into piles so that all of the grasses are in one pile, the willow in another, and so on. Prepare your materials by removing leaves, cutting off seed heads, etc. Store your materials in a folded damp towel to keep them moist and pliable until you are ready to use them.
8. If you are working with dried materials, soak them in water for several hours to make them more flexible before working with them.
9. Consult the project sheets for directions to make your specific project.

CLASS DISCUSSION

How often did baskets come up as a container in the brainstorming session? What are the pros and cons of using traditional vs. present day container materials? Be sure to address such things as: individual vs. mass production, knowledge of materials, cost, time, and skills. Don't forget to include issues concerning sustainability and environmental integrity.



Burden Basket: Plant Materials

EARLY FINISHERS

Add to the "Who Walked Here Before Me" activity by adding fiber plants to the seasonal round calendar created in that lesson. Include where they were collected, at what time of year, special handling or preparations, and what they were used for. Appendix IV is a great resource for this assignment.

-or-

Fiber plant materials are valued for many attributes, including strength, durability, availability, and beauty. Fiber was used for cordage to make rope, snares, fishing line, and nets, where strength was critical. Design a way to test the strength of cordage materials. Make cordage from several different fiber sources and compare their strength. Write up a simple analysis of your trials. Explain how you control for different variables in your testing. Consider testing for other qualities such as strength when wet, durability, and ease of working with.

Reflection

Cultures throughout time have used their skills and talents to decorate their homes and belongings. How would you decorate a basket to express what is important to you? Design a basket that you would call beautiful. Share it either through making it, drawing it, or writing a detailed description. If you feel artistically challenged in this activity, try using small square graph paper and color in the squares to make your display your pattern. Geometric patterns lend themselves well to this technique.



Self Assessment

- 1 Describe what makes some plant materials more useful as fiber plants.
- 2 List two native plant materials that are valued to use for their fiber.
- 3 Define cordage, explain how it is constructed, and list some of its uses.
- 4 Name several traditional uses for basketry.



Resources

- The Language of Native American Baskets from the weavers view. <http://www.nmai.si.edu/exhibitions/baskets/subpage.cfm?subpage=intro>
- Ethnobotany documents: <http://unesdoc.unesco.org/images/0014/001458/145847e.pdf>
- National Museum of the American Indian, Smithsonian Institute. American Indian collections research: <http://www.americanindian.si.edu/searchcollections/home.aspx>
- Native American Ethnobotany Database: <http://herb.umd.umich.edu/>
- New Mexico Arts article: <http://nmarks.org/native-american-baskets.html>
- Plants used by American Indians for food, medicine, shelter tools, and other applications: Moerman, Daniel E. *Native American Ethnobotany*.
- Otis Tufton Mason: *American Indian Basketry*



Burden Basket: Plant Materials

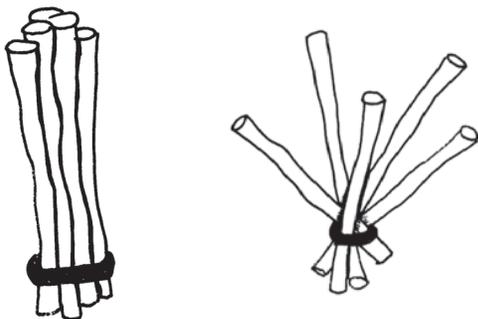
Make a Simple Burden Basket

Gather, prepare plant materials, and make a simple cone shaped burden basket using the twining technique.

Materials Needed

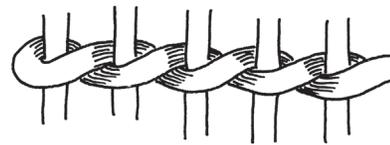
- plant fibers for weaving
- thin, flexible, straight twigs (5 or more per student)
- rubber bands
- pruners
- optional: colored raffia or yarns for design work

1. Make a rigid form for your basket out of straight, supple twigs of uniform size. Use a minimum of 5 twigs, approximately the diameter of a pencil and 10 – 12 inches in length. Using additional sticks or longer sticks will make a larger basket. Bundle the twigs together with a rubber band approximately 1 1/2 inches up from the bottom. Fan out the longer end of the twigs to make a cone shaped form for your weaving.

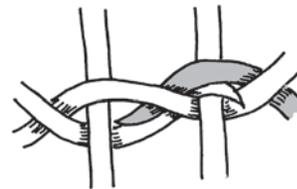


2. Prepare your plant weaving materials. If you are using green, supple materials, little preparation is necessary. The drawback is these materials will shrink as they dry and can leave your weaving loose. If you have dry materials presoak them before using to make them flexible and less prone to breaking. Wrap the fibers in a warm wet towel, and leave for 30 – 60 minutes before using. Raffia must also be presoaked.

3. Prepare your weaving strands. In the twining technique you will use two strands of the material; each one passing on either side of the twig form and then twisting between the sticks, alternating as you work around the basket.



4. Start by taking an 18 to 24 inch strand of fiber and folding it loosely about one third from one end. Place the fold at this point you will stagger the ends and making it easier to add new weaving material smoothly. Place the fold around one of the twigs at the bottom of the basket form (near the rubber band) and start. Don't forget that to make the twining weave the double strands need to cross between each twig.



5. Continue weaving your strands around the twig form, twisting your fiber to alternate back to front at each twig.
6. When you start to run out of weaving material, add a new strand by laying the new strand overlapping the old one 3-4 inches. This is called splicing them together. Then continue weaving as before.
7. After each course around your twig form be sure to push the weaving materials down to fill in empty spaces.
8. Hints: To keep your cone shape basket form, start weaving with thinner materials (e.g. grasses). As you work up the cone use weaving material of thicker diameter or double-up the fiber strands. Additionally, if you are right-handed, hold your left hand (switch if you are



Burden Basket: Plant Materials

Make a Simple Burden Basket (continued)

left-handed) in a fist in the center of your basket to maintain the spread shape as you weave. This will keep your basket spread and keep you from pulling in the twigs in by weaving too tightly.

9. To finish the edge of your basket, make a loop knot around the last twig and tuck the ends into the weaving below. An experienced weaver can finish their basket so you cannot even find the ends of the strand. Don't expect this for your first attempts. You have just finished a very simple twining weave basket. Don't expect your first weaving attempts to be uniform or tight. If you find this interesting try a more detailed how to book or take a basketry class.



Add a Design (for ambitious basket weavers)

10. Design by texture: Use different textured fibers or weaving materials. Experiment with leaving the leaves or seed heads on your plant fibers or using different diameter strands for twining.
11. Design by color: Traditionally designs were created from naturally colored fiber (e.g. black from maidenhair fern, white from bear grass) or dyed materials (e.g. red from the inner bark of alder). You can also add color with yarn or raffia fiber worked into your design.



Resources

- Jensen, Elizabeth. *Baskets from Nature's Bounty*. Interweave Press, Loveland, Colorado USA 1991. ISBN 0-9340226-69-9
- *Native American Basketry* by Tara Prindle, 1994; website of Native American Technology & Art: <http://www.nativetech.org>



Burden Basket: Plant Materials

Making Fiber Cordage

Materials Needed

- one foot section of two-ply twisted natural twine (jute, sisal, or hemp)
- plant fibers-- cattail is one of the easiest to identify and find, other traditional plant fiber can be found in the ethnobotany appendices.



1. Get a feel for cordage by investigating a piece of ready-made twine. Observe the twisting pattern that you see. Unravel it slowly and note how the cord twists as you pull it apart. Look for the direction of the twist. If you stop pulling the twine and give it slack, it will most likely re-twist slightly. The twisting motion is what holds the twine together and makes it strong. Most twine is made by machines. Your early cordage attempts will not be as uniform, but with practice your skills will improve.



2. Prepare your plant fibers. Remove extra leaves, seed heads, or outer bark. Plant fibers will need to free from chafe and pithy interior materials. Roll or rub the fiber by hand, or lightly pound it with a rock to divide the fibers. Divide larger leaves such as cattails by standing on the leaf tip and pulling the ends apart making several smaller strands out of one leaf. Prepare fibers of uniform size to produce a higher quality product. Green fibers can be used soon after collecting but may shrink when dried. If working with dry fibers wrap them in a damp towel to make them pliable. For dry cattails, soak them about 15 minutes before working; other types of fibers may need longer soaking times.



3. Take 2 strands of different lengths and tie them together with a knot in one end. This makes it easier to add new materials as you add to your cord.

4. Have a partner hold the knot or clip it to a stationary object to hold while you are twisting. Take a fiber strand in each hand about 6" from the knot. Twist both strands tightly to the right.

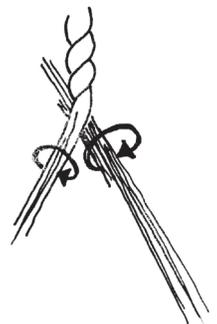


5. Once you have the two strands twisted, pass your right hand over your left and switch the bundles in your hands. This will produce the double twist.

6. Continue twisting the individual strands to the right for another 6" and cross your hands again, right over left and switch bundles. Continue in this pattern to make your cord as long as needed. Make sure you are always twisting and crossing your hands in the same direction.

7. When you come to the last 3-4 inches of your fiber strand, you will need to splice in a new fiber piece to continue. Overlap the thinnest end of the new fiber with the old, and just twist the two together as you work.

8. You may end up with some fiber "hairs" sticking out but these can be trimmed off when you are completed. If you staggered the ends of your initial fiber these spliced joints will come at different spots on your cord.



9. When your cord reaches your desired length, end by tying an overhand knot including both ends.

10. Use your cordage to tie things together, make a handle for a basket, or add beads and turn it into a bracelet.

Resources: Native American Cordage by Tara Prindle, 1994; website of Native American Technology & Art: <http://www.nativetech.org>

Jensen, Elizabeth. Baskets from Nature's Bounty. Interweave Press, Loveland, Colorado USA 1991. ISBN 0-9340226-69-9



Plants as Medicine: Make Your Own Herbal Salve

"Take the breath of the new dawn and make it part of you.
It will give you strength." - *Hopi Tribe*



Preparation

For an alternative lesson format: combine class discussions and collecting cottonwood buds into one session, assign the remainder of the lesson as homework, and use a second session for students to make their salve. Infuse the herbal oil one day ahead (this should only take a few minutes to start). Oil can be re-warmed in a double boiler before adding the beeswax.

Assessments

- 1 Define phytochemical and explain one or two environmental processes that prompt plants to produce secondary chemicals.
- 2 Explain the importance of biodiversity to the medical and pharmaceutical fields.
- 3 Link phytochemical properties of the plant to the medicinal value of the plant.
- 4 Give two examples of plants used historically by native New Mexicans.

Overview

Students learn about the rich history of plants being used as medicine throughout the ages. Students will learn about the importance of conserving the biodiversity of plants as it relates to potential discoveries of medicine. Students will study the medicinal properties of species in the genus *Populus*, which includes poplars, cottonwoods, and aspen. Students put their knowledge to work by making their own healing salve from poplar buds.

Teacher hints

- For Part I of the activity your study of medicinal ethnobotany could be expanded by having each student group research a different native plant with medicinal uses.
- For the salve activity in Part 2: Different *Populus* species are found in different regions. Use field guides or the help of a local botanist to help you find them if you are unsure. Note: introduced poplars used for wood and pulp production are less valuable medicinally, as their buds contain less resin. Some suggestions for common native, New Mexican *Populus* species to collect are: Fremont (*Populus fremontii* spp. *Fremontii*), Rio Grande (*Populus deltoids* ssp. *wislizeni*), and narrow-leaved (*Populus angustifolia*) cottonwoods and quaking aspen (*Populus tremuloides*).
- Look in late winter or early spring for *Populus* buds. Collect before the buds open but are resinous to the touch. *Populus* species commonly grow in wet areas; along waterways, drainage ditches, streams, rivers, lakes, and wetlands. Finding fallen branches from storms is the easiest way to access the buds.
- If *Populus* trees are not accessible in your area, substitute the leaves of self-heal (*Prunella vulgaris*), sage (*Artemisia* sp.), or yarrow (*Achillea millefolium*).
- Additional information about *phytochemicals* can be found in the Ecology of Native Plants section in the "Plant Wars" lesson.



Plants as Medicine: Make Your Own Herbal Salve

"Take the breath of the new dawn and make it part of you.
It will give you strength." - *Hopi Tribe*

Materials Needed

Classroom session

- online computer access for ethnobotany and phytochemical research
- plant field guides with ethnobotany information
- Appendix IV New Mexico Ethnobotany Plants and Their Uses

Salve making supplies

- glass jar with lid
- olive oil
- crockpot (for quick method)
- old pan and spoon to mix salve
- latex gloves
- candy thermometer
- glass measuring cup
- strainer
- beeswax (2-3 oz. for each pint of infused oil)
- cheese grater
- small salve containers (i.e. lip gloss containers, very small jars, baby food jars) enough for all the students
- labels for salve
- vitamin E capsules or oil (optional)

Overview

In this lesson you will learn about the rich history of plants being used as medicine throughout the ages. You will learn about the importance of conserving the biodiversity of plants as it relates to potential discoveries of medicine. You will study the medicinal properties of species in the genus *Populus*, which includes poplars, cottonwoods, and aspen. Then, put your knowledge to work by making your own healing salve from poplar buds.

Learning Objectives

1. Gain a basic understanding of native plants used as medicine, highlighting Native American uses
2. Define phytochemical, understand the purpose of secondary biochemicals in response to the environment, and learn how humans harness phytochemicals for their medicinal properties
3. Examine the connections between plant biodiversity, potential future of discoveries in plant medicine, and untested plant compounds
4. Study the historic uses of a native tree, including its biochemical properties
5. Participate in collecting and producing a plant medicine (*Populus* bud healing salve)

Vocabulary

phytochemical

biochemical

analgesic

herbalist

pheromones

antibacterial

ubiquitous

medicinal



Plants as Medicine: Make Your Own Herbal Salve

Background

Plants are one of the oldest sources of medicine. The history of humans using plants as medicine begins long ago before writing and language even existed to record it. Much of what we know about the early history of ethnobotany (the human use of plants) is patched together from early rock pictographs. It is generally thought that the first depictions of plants used for **medicinal** purposes are from the cave paintings of Lascaux in France, which are radiocarbon dated to be from 13,000-25,000 BC.¹ Early written records of the use of herbs for medicine come from Sumerian tablets (3500 BC), ancient Egyptian writings (1000 BC), and the Old Testament of the Bible. Herb use has also been documented in the early cultures of India (1900 BC) and China (2700 BC). Many ethnobotanists suspect that the use of plants as medicine extends much farther back in human history, but there are no records to prove this. Plants have been such an important part of medicine that botany was considered a branch of medicine until about 150 years ago, at which time the use of chemical treatments and synthetic medicines began to gain popularity. This was at the expense of homeopathic medicine, which once was taught in most medical schools. However, many of the medicines that are used in conventional medicine today are still derived from phytochemicals that originated in plants and now can be synthesized in today's laboratories. A notable example is the Pacific yew (*Taxus brevifolia*), which has produced the potent anticancer drug Taxol. Taxol, derived the bark of trees native to the Pacific Northwest has become one of the most widely used drugs used in treatments for several cancers. **Phytochemicals**, which are various chemical compounds that are produced naturally in plants, continue to be studied by pharmaceutical companies in the search for new, effective medicines. In recent years there has been a growing resurgence of interest in the use of herbs to prevent and treat illness. This has led to a renewed interest in looking at the world's plants as a storehouse of medical wealth.

Indigenous people have a long history of using plants, fungi, and other natural resources for healing. In earlier times, people had a general knowledge of which plants

were used for treating common illnesses and as well as rare or serious conditions. This information was passed down orally from generation to generation through the wisdom of the tribal elders through stories. Many cultures also had (and many still have) designated healers with specialized training in plant medicine and who can also invoke ceremonies or intervention of the spirits to help with healing. Generations of observations, trial and error testing, and plant knowledge has been passed on in this way for millennia. The wealth of indigenous people's plant knowledge locally and worldwide is immense, but with changing societies and cultures much of the information is being lost. Still, worldwide it is estimated that 80% of indigenous people continue to use plant remedies.² Worldwide, there are many efforts to record these indigenous healers' knowledge of medicinal plants so that it is not lost.



Despite the extensive history of medicinal plants, estimates are that only 10% of plants have been investigated for possible medicinal use. Modern science has yet to explore the phytochemical properties of countless plant species, and many of those species that have not been studied are being lost to extinction. The loss of any one species may be a lost opportunity for a future medical breakthrough



Plants as Medicine: Make Your Own Herbal Salve

that could cure or alleviate the symptoms of human diseases.³ The significance of this becomes apparent when you consider that twenty-five percent of all prescription drugs in this country contain at least one ingredient that was extracted or derived from plants.²

So what makes plants so useful as sources of medicine? All plants produce chemical compounds to help them absorb nutrients, photosynthesize, and produce color pigments. Plants also produce secondary chemicals in response to their environment. These secondary chemicals have a wide variety of functions. They can act as toxins to help the plant defend itself from herbivores, disease, fungi, and even competition from other plants. In addition, plants can produce chemicals that act as **pheromones** or pigments to attract specific pollinators such as bees, birds, butterflies, and flies. Because of the great variety of environmental conditions and organisms to which the great diversity of plants must respond, there are a wealth of secondary chemicals found in nature. These diverse secondary chemicals often can be harnessed to serve our medicinal needs. Many of these secondary chemicals have supplied the human pharmacy for millennia. Even today, that pharmacy continues to grow as our knowledge of botany and chemistry expands. However, as we lose biodiversity from the Earth through extinction, many undiscovered medicines are lost forever.



Common medicines used today are linked to native plants that were once used medicinally by Native American tribes in New Mexico. One example is willow (*Salix*). The Comanche used willow stem ashes for sore eyes and the Zuni took an infusion of bark for coughs and sore throat. The Navajo used a decoction of leaves to cause vomiting and the Isleta used a decoction of leaves for a skin bath.

The bark of willow contains salicin, a naturally occurring compound with anti-inflammatory properties. Studies of the chemical activity of salicin led to the discovery and invention of aspirin, which is now among the more common pain relievers on the market. Pain relievers are considered **analgesic**.

Native plant species such as yucca, buckwheat, puccoon, sumac, and willow were used to treat stomachache by New Mexican native people. Nearly all these plants contain chemicals such as saponin which has properties that induce vomiting. Saponin irritates mucous membranes and can cause vomiting when digested. Today, natural saponins have largely been replaced by a synthetic preparation.

Populus, the genus of cottonwood, poplar, and aspen, is well known for exhibiting medicinal properties and has been used as a fever-reducer and pain-reliever and is anti-inflammatory. Historically, there are countless accounts of this genus being used medicinally by Native American tribes throughout the United States. For example, the Klallam tribe in Washington used an infusion of cottonwood buds as an eyewash. The Ojibwa in Minnesota, Nez Perce in Montana, and Iroquois used an infusion of pounded plants for rheumatism and an infusion of bark and roots for internal blood diseases. In the Southeast the Cherokee used buds for rheumatism, pain, sores, and stomach problems. The Ojibwa and Chippewa used a decoction of buds as a salve for frost bite, sores, strained muscles, and inflamed wounds. Tribes in Alaska used buds in a salve for rashes and sores and a decoction of buds was taken for colds and coughs. Southwest tribes and pueblos of New Mexico used Rio Grande cottonwood and aspen extensively as food rather than medicine. The Zuni, Apache, Chiricahua, Navajo, and Mescalero used buds for food and chewing gum. In times of famine, they also scraped off and baked cakes from the inner bark or ate the inner bark raw. The inner bark (cambium layer and phloem) was a logical source because *Populus* bark is photosynthetic and produces plant proteins and sugar with nutritional value. The fibrous bark filled the stomach and relieved hunger. The following activity provides an opportunity to make a healing salve from the buds of *Populus* trees.



Plants as Medicine: Make Your Own Herbal Salve

Student Directions, Part 1 – Research medicinal plant uses

1. Work in small groups to investigate local native species used historically for their medicinal properties. Appendix IV provides many examples of native plants used medicinally by Native American tribes in New Mexico. Choose a few plants that you are able to find information on their chemical properties. Specific plants are best, but if information is only provided on the genus, this information is valuable as well. Two great sources for this activity are the Natural Herbs website: (<http://www.naturalmedicinalherbs.net>) and the Medicinal Plants of the Southwest website (<http://medplant.nmsu.edu/newplants.shtm>).
2. Use the data sheet to record the phytochemicals of your plant and the biological activity of the chemical (example: antibacterial, fungicide, pesticide), what part of the plant is used (example: resin, bark, leaves), and the type of preparation (example: tea, salve, poultice). More information also can be found in field guides that contain ethnobotany information, or use online sources (see resource section).
3. Continue to fill out the data sheet, providing the historical medicinal uses of the plants from Appendix IV.
4. When your team has completed the data sheet, discuss your findings within your group. Write a conclusion to your research. Can you connect the historical medicinal uses with the phytochemical analysis? Why or why not?

CLASS DISCUSSION

What makes a substance “medicine?”

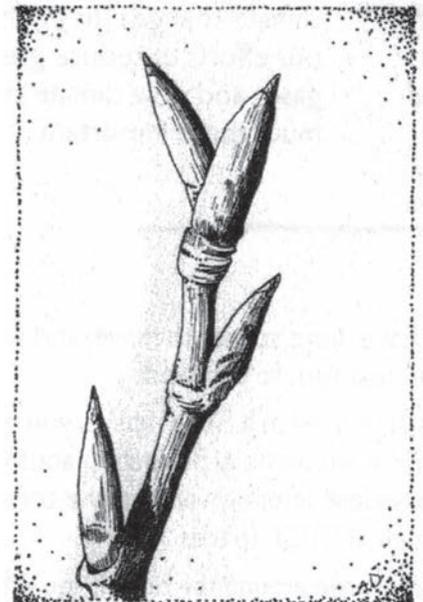
How do you make personal judgments on what medicines you use?

If you don't need a prescription for a particular medication, who should be responsible for ensuring correct usage and dosage?

When you buy unregulated herbal medicines, how do you know you are getting the real thing?

Much of our medicinal plant knowledge comes from indigenous people. Who owns the rights to the knowledge of and the use of these plant medicines?

If more people use plant medicines by collecting plant materials in the wild, how will we protect the populations of those species from overharvesting?





Plants as Medicine: Make Your Own Herbal Salve

Part 2 - Make a healing salve for minor skin irritations such as cuts, scrapes, and chapped skin from resinous cottonwood buds

1. See the "In the Field" section for directions to collect *Populus* buds, or use buds that your teacher has already collected. If cottonwood buds are not readily available, consider substituting fresh or dry leaves of self-heal (*Prunella vulgaris*), sage (*Artemisia*), or yarrow (*Achillea millefolium*).
2. Smell the buds. Does the scent remind you of anything?
3. Lay the cottonwood buds out to dry for a day before proceeding. Water on the buds does not mix well with the oil and can lead to mold in your finished product.
4. Use clean sterilized containers for all the steps of the process. Wear latex gloves to maintain the purity of your finished product.
5. Make an herb-infused oil by one of the two following methods:
 - a. Traditional method:** Fill a sterile pint jar with the cottonwood buds. Fill the remainder of the jar with olive oil, leaving no head room or air space, and cap. Place the jar in a bowl or container to collect any overflow. Leave in a warm place for 4-6 weeks. Periodically check and add more oil as needed; the twigs will absorb some oil. Heat can also cause expansion and overflow.
 - b. Quick method:** Spread the cottonwood buds in the bottom of a Crockpot and just cover with olive oil (this will likely require at least a pint of oil). Heat the mixture, trying to maintain temperatures near 100°F for 4-5 hours. Let the mixture reach 120°F, then turn off the pot and let it cool to 100°F before turning on the pot again. Repeat this procedure for 4-5 hours.
6. When the infused oil mixture is finished (from either method), strain the oil into a clean double boiler pan.
7. To make a salve, take the warm infused oil and gradually stir in shredded beeswax. Use the large holes of a cheese grater to shred the wax. Warm the oil slightly in a double boiler and heat just enough to cause the wax to melt. A general guide is to use 1 1/2 ounce of beeswax to a pint of infused oil. To test consistency, remove a spoonful of the mixture and put in the refrigerator to cool to room temperature. If it is too soft, add small amounts of beeswax to thicken. If it is too hard add a small amount of infused oil.
8. Vitamin E can be added to the salve at this point to act as a natural preservative. Empty 2-6 capsules into the salve and stir.
9. When the salve is finished, pour into sterile small containers and leave to cool. Cap the containers when the mixture has cooled to room temperature. Label with the name of the salve, the ingredients, and the date.



Self Assessment

- 1 Define phytochemical and explain one or two environmental processes that prompt plants to produce secondary chemicals.
- 2 Explain the importance of biodiversity to the medical and pharmaceutical fields.
- 3 Link phytochemical properties of the plant to the medicinal value of the plant.
- 4 Give two examples of plants used historically by native New Mexicans.

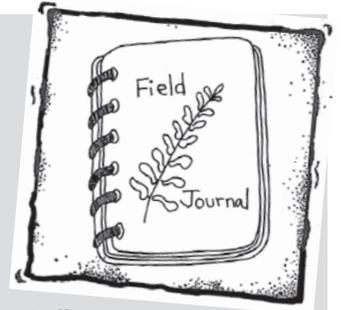


Plants as Medicine: Make Your Own Herbal Salve

In the Field

Collect your own *Populus* buds to make salve. *Populus* species generally grow in areas with plenty of moisture in the soil, often near rivers and streams, wetlands, lake edges, and wet ditches. A regional field guide or local botanist can help you decide what species of *Populus* you will find in your area. The timing of collection will also depend on where you live, with buds maturing from late winter through spring. You can ask a local botanist or naturalist for guidance on both location and timing for collection. Collect buds when they are large or swollen in appearance. Some of the buds may be dripping resin. At this point they will be easy to break from branches. Trees will often lose branches in windy conditions, so try collecting soon after blustery weather in order to find many branches

knocked to the ground. Take a field guide on your trip to help you with tree identification if needed. For winter tree identification concentrate on looking for the shape of the tree (tall somewhat columnar), the bark of mature trees (dark gray, and deeply furrowed), the location of the leaf buds on the branches (alternate), a distinctive sweet and spicy odor, and sticky resinous buds. Also check underneath the tree for old fallen leaves to help confirm your identification. Always remember to check with land owners before harvesting, and tread lightly. You will need to collect enough buds to fill a pint size jar (one jar for the entire class).



Reflection

Write about the ethnobotanical knowledge in your family. Record it in paragraph form, charts, or stories. Include what you use and how you use it. Search your memory or, better yet, interview your parents or grandparents to record your family's ethnobotanical history. Think of foods you might eat to stay healthy, such as eat your carrots for good eyesight (why?). What does your family do for a sore throat, coughs, or stomach ache? The plants you list could be ones you eat, drink as teas, or use in other ways. Don't forget to check your medicine cabinet for such things as aspirin, menthol, or herbal throat lozenges. Be mindful of the plants that you use in your day-to-day life.



Resources

- University of Michigan, Native American Ethnobotany: <http://herb.umd.umich.edu/>
- Medicinal Plants of the Southwest; this site provides phytochemicals and medicinal uses for the following genus: *Agave, Anemopsis, Artemisia, Brickellia, Ephedra, Juniperus, Pinus, Populus, Prosopis, Rhus, Yucca*: <http://medplant.nmsu.edu/newplants.shtm>
- Natural Herbs website: <http://naturalmedicinalherbs.net/herbs>
- Moerman, Daniel E. 2000. *Native American Ethnobotany*. Timber Press, Portland. ISBN 0-88192-453-9. A comprehensive collection of many plants with descriptions of their uses.
- S. Foster and C. Hobbs. 2002. *The Peterson Field Guide Series A Field Guide to Western Medicinal Plants and Herbs*. Houghton Mifflin Co, New York. ISBN 0-395-83807-X. A field guide with photographs of each plant and descriptions of their uses.
- Green Pharmacy, Dr. Jim Duke's Botanical Desk Reference. <http://www.greenpharmacy.com/> March 25, 2010.
- Appendix IV New Mexico Ethnobotany Plants and Their Uses



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Plants as Medicine: Make Your Own Herbal Salve

Data/Handout Sheet

Name(s) _____

Plant name (common and scientific) _____

Ethnobotany Information Source Used (column A & B) _____

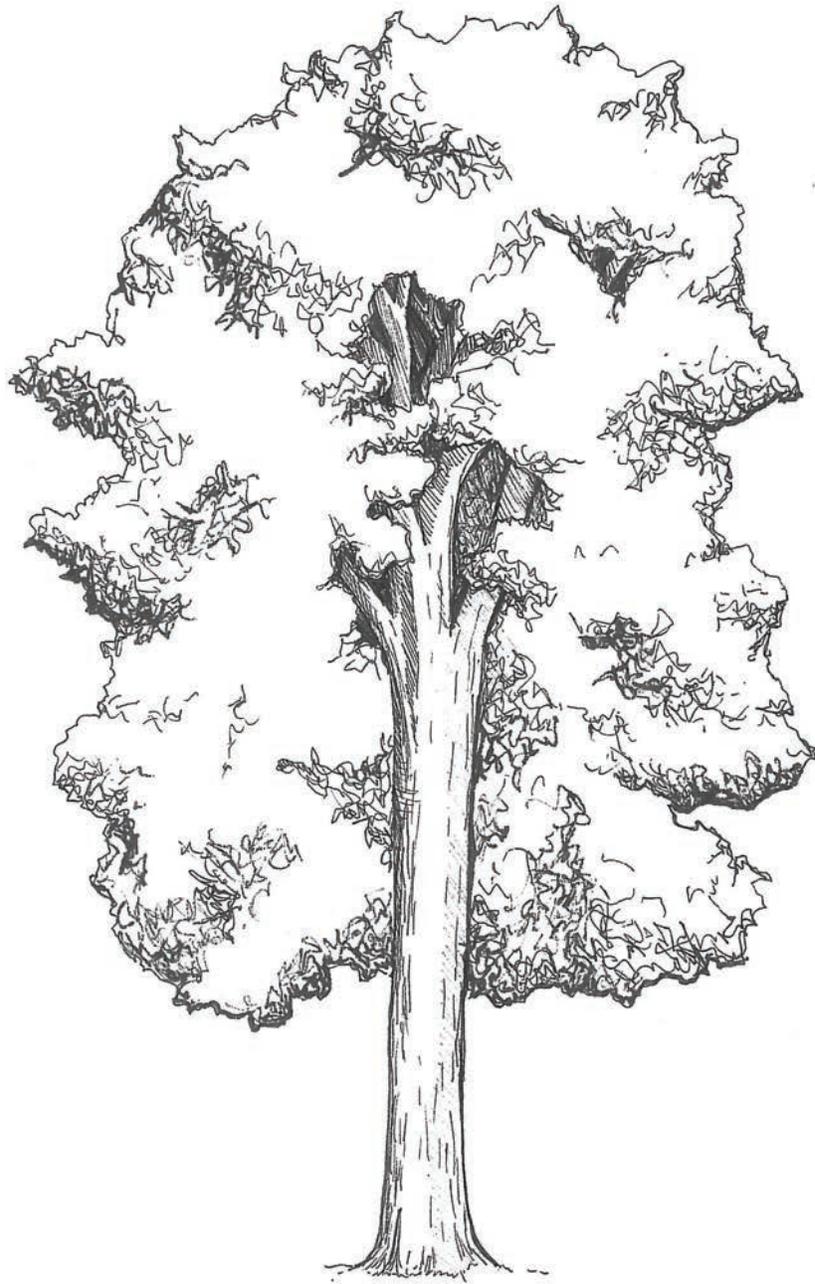
A	B	C	D
Historical Use	Plant Part Used	Phytochemicals in Plant Part	Phytochemical Biological Activity
		1. 2. 3.	1. 2. 3.
Historical Use	Plant Part Used	Phytochemicals in Plant Part	Phytochemical Biological Activity
		1. 2. 3.	1. 2. 3.
Historical Use	Plant Part Used	Phytochemicals in Plant Part	Phytochemical Biological Activity
		1. 2. 3.	1. 2. 3.
Historical Use	Plant Part Used	Phytochemicals in Plant Part	Phytochemical Biological Activity
		1. 2. 3.	1. 2. 3.

Use the following web links for column C & D:

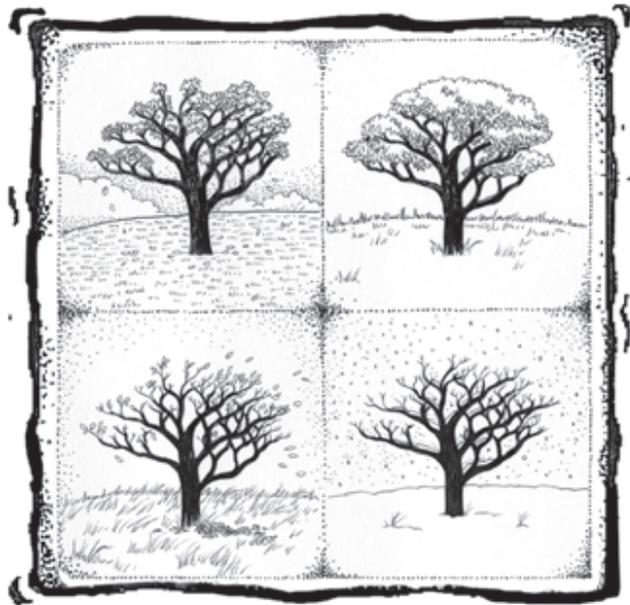
Natural Herbs website: <http://www.naturalmedicinalherbs.net>

Medicinal Plants of the Southwest website: <http://medplant.nmsu.edu/newplants.shtm>

Dr. Duke's Phytochemical and Ethnobotanical Databases: <http://www.ars-grin.gov/duke/>



Section 6:
**Climate Change
and Phenology**





Phenology: Tracking the Seasons in Your World

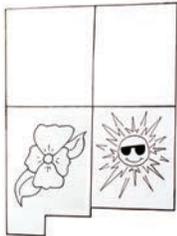
"If you want an adventure, take the same walk that you took yesterday, and do so again tomorrow." – *John Burroughs*

Time Estimate

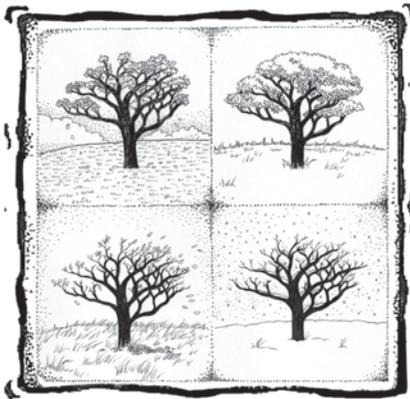
60 minutes with additional regular short observation periods covering several weeks of seasonal change

additional time required for In the Field!

Best Season



Spring
Summer
(after monsoon season begins)



Overview

Introduce the science of phenology, which is simply the study of biological changes as the seasons unfold. Students will use observational skills to track seasonal changes, collect data, and learn real world applications. They will relate nature observations to climate and examine how global change is affecting species, habitats, and ecosystems. Students will learn about the connections between phenology observations and the study of climate change and have the opportunity to participate in a citizen science program to contribute to a national database of climate change information.

Teacher hints

- Streamline the plant selection process by creating a list of Project BudBurst plants that occur near your school grounds, then let students choose from your list. This activity is most meaningful as a long term project, tracking the events of the seasons for an entire year or multiple years in their field journal.
- Students can make Regular Reports with Project BudBurst both for their own understanding of natural cycles and to provide the most beneficial data for climate change scientists.
- Have students practice their prediction skills by holding a contest to predict the date of the first spring flower on the school grounds. Have each student record their predictions by writing their name on their chosen date on a calendar. The winning prediction should have an incentive (a prize, extra credit, whatever will motivate your students). Remind students weekly to be watching for the first flower. Now the hunt is on. Set up ground rules; the plant must be found on the school grounds, the flower be left in place, the teacher must verify the find, and determine how to handle a tie. Extend this to predict other significant events such as the return of the first sighting of a particular migratory bird or the date a schoolyard tree will leaf out.
- You can also connect with another teacher or classroom in another region in New Mexico, especially one at a different elevation, and do the activity in the same season and compare your data.

(Teacher guide continued on next page)



Phenology: Tracking the Seasons in Your World

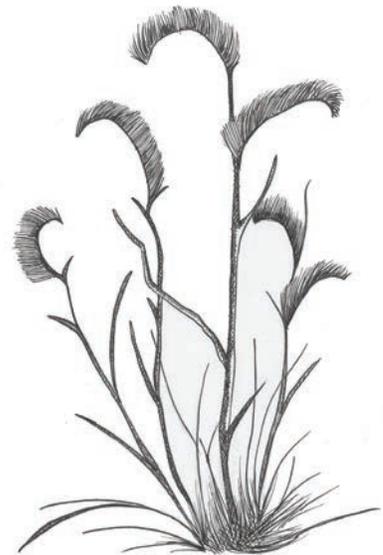
Preparation

1. Introduce the activity by leading a discussion to enable students to explore and review what they know about the seasons: what causes them, how plants (and other organisms) react to seasonal changes, what triggers those changes in living organisms to happen (daylight hours, temperatures, calendar dates, weather), and what do those seasonal changes tell us. Use this discussion for the students to throw out ideas or make statements of what they already know or believe. Facilitate the students' exploration of the answers to these questions and more throughout the activity.
2. Go through the Observing Plants tutorial on the Project BudBurst website (budburst.org) to become familiar with the project and how it works. Consider walking through the different parts of the tutorial with your students so they gain a better understanding of plants, plant groups, and the two ways to make observations.
3. Read the Registration Guide for Middle/High School Teachers found under the Educator tab on the Project BudBurst website to learn how to create Teacher and Student reporting accounts. Then create reporting accounts for your students. If you want your students to make Regular Reports of plants, follow the instructions in the Registration Guide for adding sites and plants to your students' accounts.
4. Download and print Regular Report or Single Report forms for your students from the Project BudBurst website or have the students do this as part of the activity once they have decided on a plant to monitor.

Project BudBurst™

Assessments

- 1 Describe how plants and animals respond to seasonal changes in your region of New Mexico based on first hand observations.
- 2 Show basic understanding of natural cycles and how they are affected by temperature and day-length.
- 3 Explain how the study of phenology can be applied to climate change research.





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Phenology: Tracking the Seasons in Your World

"If you want an adventure, take the same walk that you took yesterday, and do so again tomorrow." – *John Burroughs*

Materials Needed

- Phenology journal (including Project BudBurst Report Forms)
- Drawing material such as markers, colored pencils, and pens)
- Plant field guides for your area
- Optional: camera, binoculars, hand lens
- Optional: Project BudBurst Identification Guide for your plant

Vocabulary

Phenology

Phenophase

Equinox

Solstice

Monsoon



Overview

Discover more about nature and the place you live by exploring phenology, the science that measures the timing of life cycle events throughout the changing seasons. Use your observational skills and your senses to track the seasonal changes of species and habitats and create a phenology journal. Participate in a citizen science program and contribute to a national database of phenology information for researchers studying climate change.

Learning Objectives

- Be able to make observations and record data on the timing of leafing, flowering and fruiting of plants being studied
- Understand nature's seasonal cycles and what influences those changes
- Explain how knowledge of phenology has been used by humans in the past
- Understand how phenology observations can be used in scientific research
- Successfully participate in a plant phenology based, citizen science program

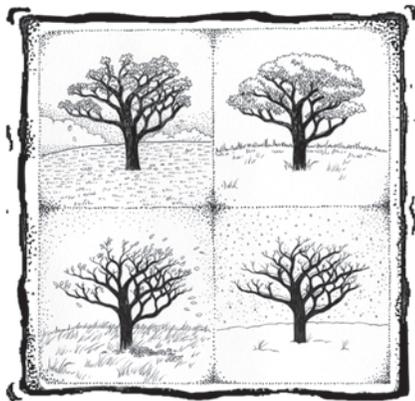
Background

Phenology is the study of natural events that recur periodically in relation to climate and seasonal changes. Examples include bird migration and changing of leaf color in autumn, the blooming of flowers, the onset of fruit, the emergence of insects, and so much more. The word phenology comes from the Greek words "phaino" (to show or appear) and "logos" (to study). Life on earth has long been intimately tied to our connection with (or instinctual or innate reactions to) phenological cycles. Before weather stations and written calendars, humans needed to keep track of natural cycles to predict when to hunt, gather edible fruits and nuts, migrate, and plant crops. Many native peoples linked natural events with cycles of the moon, the re-appearance of a migrating bird species, or the timing of many other natural events. Today, people observe and record natural events to stay in tune with the seasons, keep time with the natural order, and to gain a better understanding of the life histories of different species. Animals are cued in to phenological cycles as well, albeit on a more instinctual level.



Phenology: Tracking the Seasons in Your World

The annual discovery of the first bloom of a plant was an event treasured and recorded by conservationist and naturalist Aldo Leopold. In *A Sand County Almanac*, he wrote, "Every week from April to September there are on average ten wild plants coming into first bloom. In June, as many as a dozen plants may burst their buds on a single day".¹ Leopold kept daily journals of observations whenever he happened to be in the natural world. These journals held the keys to understanding patterns among plants, animals, weather, water, soil, and land. By regularly recording natural events, particularly those events occurring on family walks, Leopold and his children would compare changes from year to year, as they learned about the natural world.



Author and naturalist Henry

David Thoreau was one of the first to record extensive phenology data in the United States. He kept detailed journals that recorded bloom time data for over 500 wildflowers that grew in the area he lived near Concord, Massachusetts between 1852 and 1858. His work was continued by botanist Alfred Hosmer in 1878 and 1888-1902. Recently, scientists have collected data on the same wildflowers in the same location to make comparisons that might be related to climate change. Their comparative studies show that plants are blooming an average of one week earlier than in Thoreau's time.²

The timing of life history events, or **phenophases**, is crucial to the interactions between different organisms. The ebb and flow of resources that results from seasonal changes affects the entire food web. For example, as spring arrives in a deciduous forest, an event called "bud burst" marks the beginning of the growing season. The emergence of these first new leaves represents the end of a famine season for herbivores like caterpillars. Generations and generations have taught these little grazers not to hatch out until just before the new leaves appear, so their hatch

date corresponds directly to the sudden availability of high quality food. In turn, many insectivorous birds carefully time their reproduction so their young fledge just in time to take advantage of the influx of nutrient-rich young caterpillars. Can you think of ways that organisms higher up in the food chain may in turn time their life events to correspond with those of the songbirds?

In this way, seemingly small or insignificant seasonal changes or events can ripple up through a food web and have very profound effects. Spend some time thinking about the changes that occur during spring where you live. Perhaps the water level in rivers rises as a result of snowmelt or rain, or April brings a flush of new green grass. In New Mexico the **monsoon** season typically begins in early July delivering dramatic weather such as intense rain, large hail, powerful winds, whirling dust, and a startlingly high number of lightning strikes. Hot summer temperatures are suppressed and vegetation is resuscitated.³ How might some of these events affect different levels of the food chain? Also, note when the Fall/Spring equinox and Winter/Summer solstice occur. The **equinox** is the time or date (twice each year) at which the sun crosses the celestial equator, when day and night are of equal length and plants may be especially active (leafing, flowering, fruiting) in your area. The **solstice** is either of the two times in the year, the summer solstice and the winter solstice, when the sun reaches its highest or lowest point in the sky at noon, marked by the longest and shortest days. How might these changes in day-length affect plant growth?

The study of phenology is particularly pertinent in the context of climate change. Changes in weather, such as temperature and precipitation, signal many organisms to enter new phases of their lives. For example, warmer, earlier springs have led to earlier budburst for many tree species. Other organisms must therefore change the timing of their reproductive events in order to maintain the link with their food source. Some organisms rely on a variety of cues to tell them when it is time to act and not all organisms rely on the same cues. Birds, for example, use day length as a cue for some of their phenophases, a cue that doesn't change as the climate warms. Some plants, however, use a combination of temperature, precipitation, and day length for their cues. Temperature and precipitation are influenced by



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Phenology: Tracking the Seasons in Your World

climate change. Imagine, too, the challenge for migratory birds, which winter in places such as South America, and are informed by environmental cues there. They have little access to information about conditions in their northern breeding grounds. For these and other reasons, organisms at different levels of the food chain are exhibiting something called “phenological mismatch,” where shifts in the life cycles for predator and prey don’t correspond with one another. The full impacts of this trend are not fully understood, and are the subject of much research.⁴ Experts have not seen any clear-cut trends in monsoon activity over the last 100 years, but are concerned about the effect of climate change on the monsoon.

A collaboration between the US Fish and Wildlife Service and the National Phenology Network connects various organizations together to monitor and record phenological patterns. Organizations can log into the Phenology’s Network’s “Nature’s Notebook” to track the ecological condition of plants and animals and their response to environmental and climatic change. Valle de Oro National Wildlife Refuge (located a few miles south of Albuquerque, New Mexico) has been selected as a pilot for phenology monitoring using Nature’s Notebook. Nature’s Notebook can easily be used throughout New Mexico to engage a variety of groups.

Valle de Oro National Wildlife Refuge established The Rio Grande Phenology Trail to connect like-minded organizations through a shared community project. It

encourages citizens to engage in outdoor education and investigate phenological patterns.

Valle de Oro National Wildlife Refuge has partnered with Santa Fe Botanical Garden, Whitefield Wildlife Conservation Area, and the Albuquerque BioPark Botanical Garden to participate in monitoring the phenology of a suite of focal species using “Nature’s Notebook”. By tracking this information across, years, decades, and hopefully, centuries, ecologists will get a better understanding of how species and ecosystems are changing through time, especially in the face of climate change.

What do the seasons look like where you live? Select a place around your home, schoolyard, or a favorite place you like to visit. Walk the same route in spring, summer, fall, and winter and tune your senses into what is occurring around you. You do not need to travel a great distance to study phenology; it is happening all around you. You just need to tune into what is happening wherever you are. This activity focuses on the phenology of plants, but others are tracking phenology as it applies to wildlife, insects, fungi and nearly every type of life on Earth.



Student Directions

In this activity you will take part in a nationwide citizen science project. Project BudBurst is a nationwide program that engages the public in gathering important phenological data about plants. This data is used by scientists to understand the impacts of climate change on plants locally, regionally, and nationally. Thousands of participants submitting individual observations around the country in a consistent manner provide a uniquely valuable set of data for climate scientists. For instance, at the Rio Grande Nature Center State Park in Albuquerque, volunteers maintain a Budburst accountant and provide phenological data on plants in their area. In this activity, you will learn about two different ways to observe plants with Project BudBurst, through Regular Reports and Single Reports. You will then contribute to the Project BudBurst data set by making either a Single Report or repeated Regular Reports on a plant you observe near your school. During the growing season, plants often move through their phases quickly, sometimes going from one phase to another in just a day, so you will need to watch your plant carefully and be on the lookout for changes!



Phenology: Tracking the Seasons in Your World

Student Directions, Option 1: Regular Reports

1. Observing a plant regularly throughout the growing season and over many growing seasons provides detailed information about the phenology of a plant. With Regular Reports, you will observe your plant regularly and record the date at which it reaches certain events in its life cycle (i.e. budburst, first flower, full fruit, and more). This is also called event-based monitoring. You will record the date of occurrence for as many of your plant's "**phenophases**" as possible. Your data collection will be part of a phenology journal. A phenology journal is a place to record the changes that you observe in the natural world.
2. Ask your teacher to provide you with login and password information for your Project BudBurst account. Your teacher should have added a plant to your account for you to monitor.
3. Your teacher will provide you with a Regular Report form for your plant. Include the Regular Report form with your field journal. Be sure to record all of the information requested on the form, paying close attention to detail. You will keep this Regular Report form in your journal as you continue to make observations about your plant over the coming weeks. The specific data you collect depends on whether you are monitoring a deciduous tree or shrub, a wildflower, an evergreen tree or shrub, a grass, or a conifer, so be sure you have the correct report form for your chosen plant.
4. For your first journal entry, write a thorough description of your plant's location and habitat. Next, draw a map of your location and describe what plants you find there. Describe the plant you are going to observe in detail. What do the leaves look like (size, amount, color)? Does your plant have buds, flowers, or seeds? How does your plant interact with its environment? Do you observe any activity around your plant (insect, birds, squirrels, other)? Look closely!
5. Visit your plant regularly—a few times a week during its active growing season. You will be watching for certain events that are listed on your Project BudBurst Regular Report form—bud burst, emergence of the first leaf, first fruit, and others. When one of these events occurs, be sure to note the date the event occurred in your field journal, as well as the weather, and other observations about your plant and its habitat. Note changes that occur around your plant as time passes.
6. After you observe an event, such as first leaf, submit your observation data to the Project Budburst website. Be sure to remember this step! This will provide important information for climate scientists to use. Once you are logged in to your account, be sure to select "Submit a Regular Report" from the list of options.
7. Make additional observations about your plant. How does the overall appearance of your plant change with time? Does it get taller or bushier? Do the leaves change color or appearance? What color are the flowers? Who pollinates the flowers? Look for when ripe fruits appear on the plants. What happens to the fruits? What happens to the seeds? Do they fall on the ground, are they eaten by birds, or do they catch on your socks? What other changes do you notice about your plant as the days pass?
8. Note what is happening in the environment around your plant. Is the ground wet or dry? What is the weather like? What other plants are near your plant? What animal signs are at your location? Spend at least 10 minutes closely observing your plant (time yourself!), and then spend an additional 5-10 minutes recording your observations in your journal. Add to your journal entries with sketches and photographs.



Phenology: Tracking the Seasons in Your World

9. Track the growth of a new leaf. Flag a new leaf with a piece of yarn and take regular measurements (use metric scale) of length and width. Each time you make an entry in your journal, update the measurements of your leaf. How long did it take for the leaf to reach its maximum size? Compare these numbers with your classmates studying a different species. Is your plant a fast grower or does it grow more slowly?
10. Always note the date and time of each journal entry and add weather information including wind direction, cloud cover, and temperature. Visit the websites in the resource section to add day-length and climate data for your observation days.
11. Things to think about: If you kept a phenology journal from year to year, how accurate do you think your predictions could become? What do you think it would show? Can you think of ways the information could be useful for you? What ways could the information be useful to others?

Reflection

What seasonal changes do you go through? Think about how you react to temperature, light and dark. What signs in your body and your outside environment tell you that fall is approaching? How do your senses help you detect these changes? What new sounds, smells, and colors occur? What signs tell you that winter, spring, and summer are approaching? What is your favorite season and why?



Option 2: Single Report

1. Ask your teacher to provide you with your login and password information for your Project BudBurst account.
2. With a group of three or four other students, decide which plant you will monitor. You can choose from of Project BudBurst's New Mexico species list, and explore the plants in the Project BudBurst database from the "Plants to Observe" page.
3. Once you have chosen a plant, it's time to go observe it. Your teacher will provide you with a Single Report form for your plant. You will be collecting specific data depending on whether you have chosen to monitor a deciduous tree or shrub, a wildflower, an evergreen tree or shrub, a grass, or a conifer.
4. Out in the field, observe your plant. Fill out your Single Report form thoroughly and carefully, paying close attention to your plant. If you do not know your latitude and longitude, you can find it using Project BudBurst's map feature when you enter your data on the website later.
5. In the comments section of your Single Report form, make notes about the habitat, the weather, and other observations about your site.
6. Now submit your data online at the Project Budburst website so scientists can use your data in their research. Once you are logged in to your account, be sure to select "Submit a Single Report" from the list of options. You are now part of a nationwide effort to better understand the effects of climate change on plants in your area and around the world!

Self Assessment

- 1 Describe how plants can respond to seasonal changes using your observations.
- 2 Explain how nature's cycles are affected by temperature and day-length.
- 3 Explain how the study of phenology has been used in the past and its implications for the future.





*Student
Project*

Phenology: Tracking the Seasons in Your World

In the Field

Team up with an elementary school to mentor younger students or a school in another region of New Mexico and teach them about phenology. Together, choose a special, prominent tree in their school yard to monitor and report your findings to Project BudBurst. Read about the BudBurst Buddies program (budburstbuddies.org) for elementary students and use resources from the BudBurst Buddies website with the students. Have the students share their observations about the tree and record them in one place. Take a photo

of the class gathered around the tree. Return regularly with the class to make new observations and take a photo. At the end of the school year you can look back at how the tree and the students have changed. Take a copy of Aldo Leopold's book *A Sand County Almanac*, and pick out some fun passages to read aloud to classmates outside beneath the tree, or read a BudBurst Buddies story.



EARLY FINISHERS

Class Phenology Log-- Make a permanent phenology log for the classroom by setting up a notebook with index dividers for each month and a sheet of notebook paper for each day of the month. Record the date but not the year itself (i.e. January 1, not January 1, 2016) at the top of each page, add the year to the left margin, and then make notes about what occurs each day. Everyone in the class can share their observations in the same book. The log can be added to each year; just add the current year in the left margin and place the new observations

underneath. Add additional pages when needed. Look for the same events to occur (for example, first flower on a certain species in your native garden) year after year. Note whether those same events occurred on the same day, earlier, or later in the year and think about why those changes may have occurred. This document will become more valuable with added years and may indicate possible relationships between climate change and biological cycles in your schoolyard and town.

Resources

- Sunset and Sunrise times for your town: http://aa.usno.navy.mil/data/docs/RS_OneDay.php
- National Climate Data Center: <http://www.ncdc.noaa.gov/oa/ncdc.html>
- Leopold, Aldo. *A Sand County Almanac*. 1949. Oxford University Press, New York.
- Project BudBurst: a National Ecological Observatory Network citizen science project that engages individuals from all walks of life in making observations of the timing of leafing, flowering, and fruiting of plants. Observations from participants across the country contribute to a better understanding of how plants respond to climate change at a local, regional, and continental scale: <http://budburst.org/>; Educators go to <http://budburst.org/educators>
- National Phenology Network USA: Participate in citizen science monitoring projects and additional education resources. Source to download: Haggerty, Brian P. and Susan J. Mazer. *The Phenology Handbook: A Guide to Phenological Monitoring by Students, Teachers, Families and Nature Enthusiasts*. 2008 University of California, Santa Barbara for the UCSB Phenology Stewardship Program: <http://www.usanpn.org/>.
- Windows to the Universe; Phenology and climate change Modified from *The Phenology Handbook* by Brian Haggerty and Susan J. Mazer, University of California, Santa Barbara: http://www.windows2universe.org/life/phenology_climate_change.html



*Student
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Phenology: Tracking the Seasons in Your World

Phenology Journal Page

Name _____

Date _____ Season _____ Location _____ Weather _____

Sunrise Time _____ Sunset Time _____ Day Length _____

Minimum temperature _____ Maximum temperature _____

Last precipitation date _____ Form (rain/snow) _____ How much _____

Soil moisture: Dry _____ Moist _____ Saturated _____

Plant life cycle stage (check all that apply)

dormant in bud leaf opening flower buds in bloom full leaf leaf drying leaf drop

Special Spot Observations

(e.g. plant, wildlife, bird, insect, and fungi observations)

Special Spot Sketch

I wonder?

(questions that your observations generate)



Teacher
Page

Plant Migration Game

"Climate is what we expect, weather is what we get. — *Mark Twain* (1835-1910)"



Overview

Students are bombarded daily with news of climate change and the impacts of their "global footprint" on the environment, but little information is out there about how climate change is affecting plants, especially native plants. In the field of restoration ecology, predicting plant responses will help us direct our restoration plans to be the most adaptable and successful given the uncertainty of our climate future. In this lesson, students will play a game to explore some of the potential impacts and challenges of climate change on plant life in the Southwest region.

Teacher hints

- Students should have a general background in climate change science to fully appreciate this lesson and explore the potential impacts on plants. See the "Resources" section provided in this lesson.

Preparation

1. The game will be played in groups of 4-5 students. Photocopy and enlarge enough game boards and gather additional materials for the entire class in advance. Bowls of dry beans or other small objects can act as the seed bank or currency. Two handfuls of seeds per group should be sufficient.
2. Photocopy and cut out plant cards. Plant cards are drawn at the end of the game to assess the final fate of your plant.
3. Gather or make pieces to move around the board (one for each player). Pieces can be objects (paper clips, rocks) or as simple as colored paper squares.
4. Consider having students color and laminate the boards for long term use.
5. Definitions for vocabulary words can be found in the glossary if not explained in the text.

Assessments

- 1 Discuss the impacts that affected success or decline of his or her species during the game.
- 2 Name three potential negative impacts of a changing climate on plants.
- 3 Identify one or more positive impacts of a warmer climate on plants.
- 4 Describe why certain types of plants may be more adaptable than others to changing climatic conditions.



Plant Migration Game

“Climate is what we expect, weather is what we get. — *Mark Twain* (1835-1910)”



Materials Needed

- Game of A Plant's Life board
- one die
- dry beans or other “currency”
- container for seeds
- player pieces
- plant cards

Vocabulary

climate

weather

greenhouse gas

microclimate

seed dispersal

assisted migration

carbon sink

Overview

Almost daily we hear about climate change and its likely impacts for humans, but how will climate change affect plants, especially native plants? Changes in our native flora as a result of climate change will have lasting impacts on wildlife, water nutrient cycling, and on humans as well. In this lesson you will play a board game to explore some of the potential impacts and challenges of climate change on plant life in the Southwest region.

Learning Objectives

1. Explore potential impacts of climate change on plants
2. Gain insight into predicted climate shifts
3. Speculate how different species will adapt to climate change based on their life history strategies
4. Learn how climate change can affect plant conservation and invasive species issues

Background

Shifts in climate have altered the earth’s ecosystems throughout geologic time. There is clear evidence that the earth’s climate is changing at an accelerated rate due to human-caused accumulation of greenhouse gases in our atmosphere. Scientists can sample air bubbles in ancient polar ice to investigate the characteristics of the atmosphere from thousands of years ago. While there have been periodic climate shifts throughout the history of the earth, scientists have noticed a distinct warming trend that is strongly correlated with our increased dependence on wood and fossil fuels. When populations increased and society industrialized, we began to combust large amounts of fossil fuels and wood for energy, releasing carbon dioxide (CO₂) into the earth’s atmosphere. Carbon dioxide is considered a **greenhouse gas** because it traps solar radiation in the lower atmosphere, effectively heating the earth. While this greenhouse effect is critical to maintain warmth to support life on earth, the massive amounts of greenhouse gases generated by humans enhance the effect.

Scientists have developed very complex models to predict how the earth’s systems may react to further increases in CO₂ concentrations. Modeling is useful on a global scale and to some extent on a regional scale, but local **microclimates** are so varied that it is impossible to accurately predict the effects of climate change on a precise local level. Modeling uncertainty





*Student
Project*

Plant Migration Game

increases in regions with a highly variable climate, fewer weather stations, and complex topography. The effects from climate change will not be consistent across the globe. Models indicate that the United States as a whole will face increased average annual temperatures, but the resulting changes in factors such as the extent of temperature change, precipitation, the timing of precipitation, climate variability, and extreme weather events will vary widely from place to place. Due to the great variability across the landscape, conditions may improve for certain plants in some areas and decline in others. It is important to differentiate between climate and weather to understand the concept of climate change. **Weather** is what we experience on a short time scale, whereas **climate** refers to long-term average weather patterns.¹

The US Global Change Research Program has made projections for the Southwest region of the US. Snowpack and streamflow amounts are projected to decline in parts of the Southwest, decreasing surface water supply reliability for cities, agriculture, and ecosystems. The Southwest region produces high value crops such as vegetables, grains, fruits, and nuts, which are irrigation-dependent and particularly vulnerable to extremes of moisture, cold, and heat. Reduced yields from increasing temperatures and increasing competition for scarce water supplies will likely displace jobs in some rural communities. Increased warming, drought, and insect outbreaks, all caused by or linked to climate change, have increased wildfires and impacts to people and ecosystems in the Southwest. Fire models project larger and more intense wildfire and increased risks to communities across extensive areas.

According to a 2005 study by the State of New Mexico, climate models project substantial changes in New Mexico's climate over the next fifty to one hundred years if no measures are taken to reduce global greenhouse gas emissions. Projected climate changes by mid-to late-21st century include: air temperatures warmer by 6-12°F on average, but more in the winter, at night, and at high elevations; more episodes of extreme heat and fewer episodes of extreme cold with a longer frost-free season; more intense storm events and flash floods; and winter precipitation falling more often as rain, less often as snow. Some climate models project that average precipitation

will increase, while others predict a decrease. Higher evaporation rates because of warmer temperatures will exacerbate effects of drought, and will at least partially offset the effect of any increase in precipitation that might occur due to climate change.

Climate change will have a pronounced effect on native plants, especially in the arid Southwest. While animals and humans have the option of relocating in response to climatic shifts, individual plants cannot move to find more suitable conditions. When we think about the effect of climate change on plants, we must realize that factors such as rising temperatures are acting on individual plants, and the collective responses of those individuals result in changes in the entire population.

We can begin by looking at how individual plants may react to the stresses inflicted by a changing climate. Shifts in temperature and precipitation patterns will be the main drivers of potential impacts on vegetation. Plants exist in a continual state of competition with neighboring plants. Subtle changes in environmental conditions or the availability of resources affect their ability to effectively compete and therefore to survive and reproduce successfully. Just as they do for animals like yourself, adverse conditions cause physiological stress to plants. As plants respond to stress, they may shift their energy allocation to focus on growth or reproduction. While under stress, plant metabolic processes are overtaxed, which reduces their ability to resist diseases or insect infestations. The stresses each individual faces will affect its ability to survive and reproduce.

Increased temperatures cause some phenological events, such as spring bud burst, to happen earlier in the year than usual. Why does this matter? Such alterations in timing may cause disruptions in a plant's intricate relationships with co-evolved insect pollinators. If the pollinators emerge at the normal time, they may miss the earlier flowering of their target species. In another example, many species of insect pests are currently controlled by cold winter temperatures that kill most of their larvae. As winters become warmer, more of the pest larvae survive to adulthood, and some pest species may even complete two life cycles in one season, causing twice the damage to plants.



*Student
Project*

Plant Migration Game

The effects of climate change on the fitness of individual plants will vary over their range, and this affects the state of the population as a whole. Though the effects on individual plants may seem small, the collective responses of these individuals result in profound changes at the population level. Many species are already experiencing range shifts as certain areas become climatically uninhabitable for them and other new locations become suitable.

Which variables should be taken into account when predicting a species' success in the face of climate change?



Species that are generalists and can thrive in a wide variety of conditions will tend to be the most successful in a rapidly changing environment. Species that are rare and especially those that specialize in a unique environment are less likely to adapt well to climate change. These species already tend to have very low population numbers, low diversity, often use less successful seed dispersal strategies, and as a result will be less competitive. **Seed dispersal** is key for survival in an unstable climate.

Which species will benefit from climate change? Species that can disperse large quantities of seeds over great

distances have a higher potential of reaching sites with more favorable conditions. These will likely be more successful than long-lived perennial plants that only produce a few seeds. Because invasive plants are often generalists and have strong seed dispersal ability that allows them to rapidly colonize new areas, they may be better suited than many native plants to shift or expand their range to cope with climate change. It is important to remember that native and invasive species are competing for the same water supply.

Climate shifts will likely have an impact on lands already set aside for conservation. Current habitat preserves may see new species move in, while the original target conservation species may shift to new regions. Land managers and preserve designers are beginning to consider these potential shifts in habitat and species compositions as they manage existing preserves and plan new ones. It is important to predict where species of concern may be able to find suitable habitat in order to identify and conserve potential refuges in a changing climate. Restoration ecologists are also considering the impacts of climate change on their projects. As they try to restore degraded habitats to their natural state, ecologists should consider how future climate shifts may affect the habitat. **Assisted migration** is a new and controversial conversation topic among restoration ecologists--should restoration ecologists relocate species to new habitats that will be suitable in the face of climate change, assisting them in survival? These and other questions make native plant conservation more challenging and will require conservation biologists to work creatively, hedge bets by conserving more plants than would be necessary without climate change, and make our efforts to reduce greenhouse gases and slow climate change that much more important.

Forest conservation plays an important role in climate change discussions. Trees assimilate atmospheric carbon dioxide during photosynthesis, and as trees grow, they act as **carbon sinks**. Planting trees and protecting existing stands may help sequester excess carbon that has already entered the atmosphere. While climate change presents many challenges for plant life, there are still steps we can take to slow the rate of greenhouse gas emissions and mitigate the effects of climate change on native species.



Plant Migration Game

Student Directions

Read over the background information to get a working understanding of climate change and its potential impacts on plant life before playing the game.

1. Set up your **Game of a Plant's Life** board. Shuffle the Plant Cards, place them face down in the center, and select your game piece. Get out a sheet of paper to keep track of the climate events your plant encounters with each roll of the dice throughout the game. This will be reviewed at the end of the game to evaluate how climate change affected your species.
2. Rules for the game:
 - To begin, draw a Plant Card and get to know your species
 - Each player starts with 3 seeds from the Seed Bank
 - Roll a single die on your turn to move forward
 - At the start of the game, you may select one of the two paths for germination
 - Once the two paths merge, you have germinated and become a representative of the entire population of your species
 - You must stop at the STOP spaces, even if you still have more spaces to move, and wait for your next turn to proceed
 - When you reach a STOP space, you get one seed for successfully navigating another year – pay close attention to how the conditions change at STOP spaces
 - As you move around the board, you will pick up or return seeds to the bowl as your space instructs
 - The object of the game is to accumulate as many seeds as possible
 - If you run out of seeds during the game, your species has gone extinct and you are out
 - Your Plant Card explains how many seeds you need to survive – if you do not have enough seeds, your plant doesn't survive
 - To win, a player must have enough seeds to fulfill their Plant Card requirement AND have the most seeds overall

CLASS DISCUSSION

How will different species in different habitats and life strategies will be affected by climate change?

Do you think humans should move plants to expand their range, or into new types of habitats, in an attempt to help plants cope with climate shifts? If so, how far would you be comfortable with moving them? Or is there a measure other than distance you would use to determine where to move plants?

What about moving endangered plants? How might moving plants affect ecosystems?

Do you have any new ideas on how restoration ecologists might help native plants survive climate change?

What issues are most important for New Mexico as we face a changing climate?



Plant Migration Game



Reflection

Choose a native species from your area. It can be your favorite, or just one you would like to learn more about. Write a paragraph that describes how you think it might respond to climate change. Through observation or research find out how your plant is pollinated, how it disperses seeds, and what conditions it lives in. All of these factors can be used to support your idea. Write how you feel about climate change and the fact that nature as we know it is changing during your lifetime because of human impacts. Does it motivate you to live in a certain way? For ideas on ways to reduce climate change, get connected with others, and speak up about climate change, go to the Alliance for Climate Change's website: <https://acespace.org>.

EARLY FINISHERS

Climate change data is being recorded daily by citizen scientists throughout the world in one of several phenology observation programs (see Phenology: Tracking the Seasons in Your World lesson). The records kept by Henry David Thoreau at Walden Pond in the mid 1800's have proven to be invaluable for climate change scientists who have used them to discover that not all species in a given area respond the same way to climate change. Research the results that have been found from Thoreau's observations and use them to inspire you to collect your own data that may become very relevant to scientists and decision makers someday. Consider adopting your favorite native plant or natural area and observing and recording its phenology data over a long period of time. Keep your data in a special field journal devoted to this plant. Try to observe the start and end date of bud break, bloom, seed set, and leaf fall or dormancy. It will be extremely important to keep record of the location where you collected your data, and to continue to collect data every year for as long as possible. Though your sample size will be very small (only one plant!), in future years your data could help track plant species range changes, as well as climate related phenology changes. If you are able to collect data over a long period of years or decades, watch for trends in your data and share them with others. Submit your data to Project Budburst to help add to our knowledge about climate change.

Self Assessment

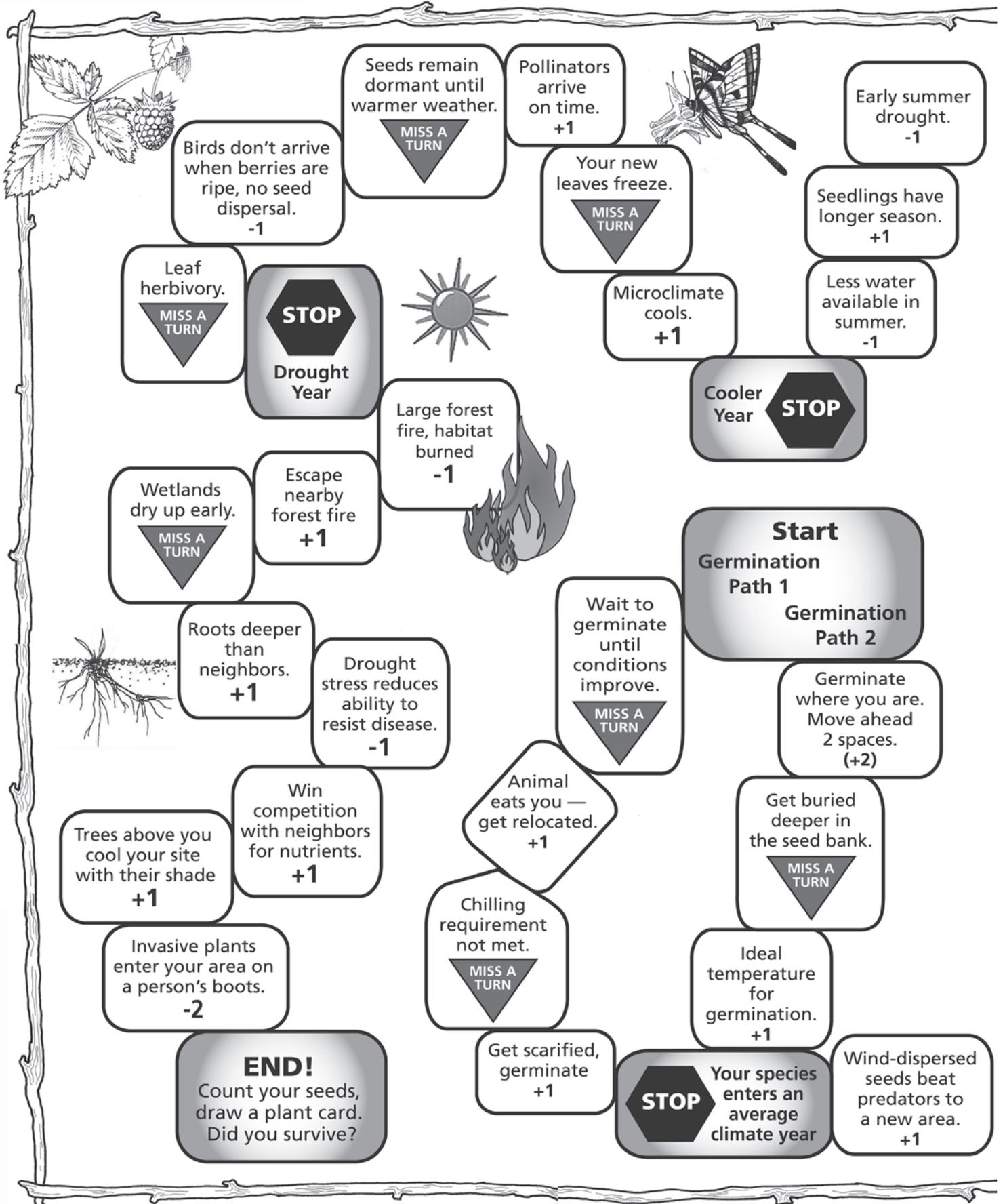
- 1 Discuss the impacts that affected the success of your species during the game.
- 2 Name three potential impacts of a warmer climate on plants.
- 3 Identify one or more positive impacts of a warmer climate on plants.
- 4 Describe why certain types of plants may adapt more rapidly than others to changing conditions.



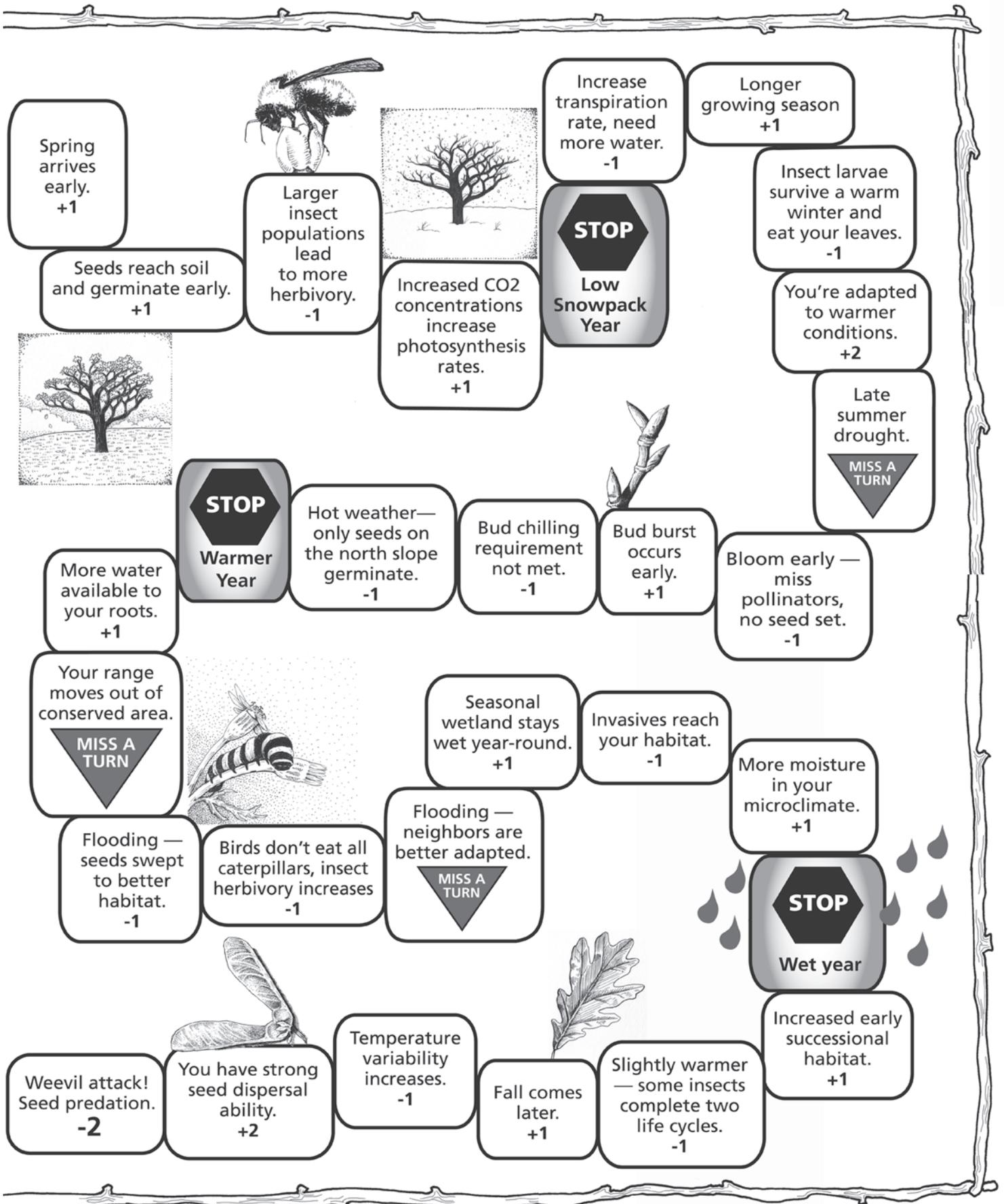
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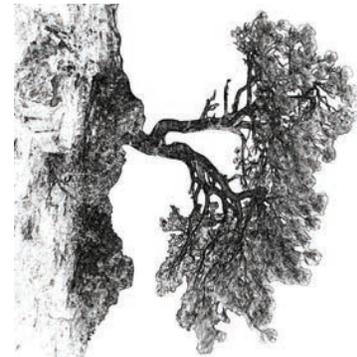
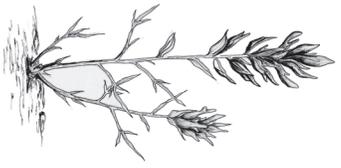
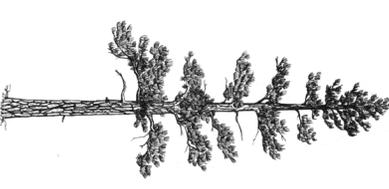
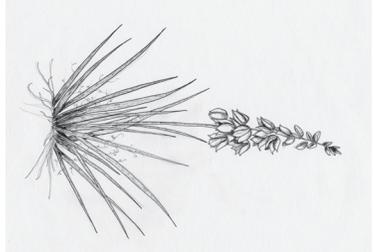
- U.S. Global Change Research Program, general and regional climate information: <http://globalchange.gov>
- *Climate Literacy: The Essential Principles of Climate Sciences*: <http://globalchange.gov/resources/educators/climate-literacy>
- NOAA Office of Education - climate change information and curricula for educators: http://www.education.noaa.gov/Climate/Climate_Change_Impacts.html
- State of New Mexico; Agency Technical Work Group. Potential Effects of Climate Change on New Mexico. December 30, 2005: https://www.env.nm.gov/aqb/cc/Potential_Effects_Climate_Change_NM.pdf
- Dr. Healy Hamilton on Climate, Change and Biodiversity: <https://vimeo.com/8986311>
- US Department of Agriculture website: Southwest Regional Climate Hub: swclimatehub.info

Game of a Plant's Life:



A Survival Quest Game



<p>Bracks hardwall Cactus <i>Sclerocactus cloverae</i> ssp. <i>brackii</i></p>  <p>Status: rare Habitat: desert Seeds needed to survive and reproduce - 13</p>	<p>Blue grama grass <i>Bouteloua gracilis</i></p>  <p>Status: common Habitat: grassland Seeds needed to survive and reproduce - 8</p>	<p>Piñon pine <i>Pinus edulis</i></p>  <p>Status: common Habitat: foothills Seeds needed to survive and reproduce - 11</p>	<p>Skunkbush sumac <i>Rhus trilobata</i></p>  <p>Status: common Habitat: shrubland Seeds needed to survive and reproduce - 6</p>
<p>Desert paintbrush <i>Castilleja chromosa</i></p>  <p>Status: locally common Habitat: moist areas Seeds needed to survive and reproduce - 5</p>	<p>Bull thistle <i>Cirsium vulgare</i></p>  <p>Status: invasive Habitat: open areas Seeds needed to survive and reproduce - 1</p>	<p>Ponderosa pine <i>Pinus ponderosa</i></p>  <p>Status: common Habitat: moist forest Seeds needed to survive and reproduce - 11</p>	<p>Soapweed yucca <i>Yucca glauca</i></p>  <p>Status: common Habitat: desert Seeds needed to survive and reproduce - 7</p>

Section 7:
**The Future of
Native Plants**





Teacher
Page

Biodiversity and Ecosystem Services: Can't Live Without 'Em

"Uniformity is not nature's way; diversity is nature's way." - *Vandana Shiva*
(1952-present)

Time Estimate
2+ hours; additional session required for In the Field!

Best Season

		Fall
		Spring



Overview

In this lesson students will explore biodiversity, global endemic hotspots, and ecosystem services. Students will conduct a schoolyard plant diversity survey.

Teacher hints

- Have students work in teams of two (one spotter and one recorder) for conducting a plant diversity survey on the school grounds. Assign student teams to work in different areas to get a good representation of plant life on the school grounds.
- For step #5 of the student directions: follow the protocols from the Plant Press activity (Section 1) or use green leaves and adhere them to the butcher paper with contact paper.
- Vocabulary words not defined in the text can be found in the glossary.

Preparation

1. Use a map to help students visualize the entire schoolyard.
2. Decide on areas of the school grounds to use for the plant diversity survey. Mark particular sites or areas to use for the plant diversity survey. Spread the surveys over an assortment of vegetation types (landscaped, lawn, weedy, or others if you have them). Pre-mark these sites on a map or help the students to locate their site on the map when they finish.

Assessments

- 1 Define biodiversity and describe why it is important.
- 2 What is a biodiversity hotspot? What is a biodiversity hotspot near where you live?
- 3 Demonstrate or describe a method of measuring and calculating plant diversity.
- 4 Compare and analyze results of two or more plant diversity surveys.



Biodiversity and Ecosystem Services: Can't Live Without 'Em

"Uniformity is not nature's way; diversity is nature's way." - *Vandana Shiva* (1952-present)

Materials Needed

- schoolyard map
- 4-meter string loops (1 for each survey team)
- clipboard and data sheet
- butcher paper
- optional: toothpicks, field guides, plant press, adhesive contact paper

Overview

In this activity, you will explore biodiversity, global endemic hotspots and ecosystem services. You will conduct a schoolyard plant diversity survey.

Learning Objectives

1. Define the terms biodiversity and hotspot
2. Conduct a simple plant diversity inventory
3. Gather, analyze, and present data
4. Understand the concept of ecosystem services, name several, and discuss their biological and economic values

Vocabulary

- biodiversity
- endemic
- hotspot
- ecosystem
- services
- percent cover

Background

Have you ever considered that the food you eat for breakfast is brought to you each morning by the wind that pollinated the grasses that produced the grains that make up your cereal, or that the clear, cold, clean water you drink everyday was likely purified for you by a wetland or perhaps the root system of an entire forest? Trees in your schoolyard capture dust, dirt, and harmful gases from the air you breathe. The bright fire of oak or pine logs you light to keep warm on cold nights and the medicine you take to quell the pain of a headache come to you from nature's warehouse of services. Through the intricate processes in ecosystems, biodiversity provides clean air, water, food, medicine, shelter and a wealth of interactions between species that keep an ecosystem functioning and healthy. In addition, biodiversity provides us with recreational opportunities, aesthetic beauty, and cultural and spiritual connections for the human soul. Natural ecosystems perform fundamental life-support services upon which human civilization depends. Unless human activities are carefully planned and managed, valuable ecosystems will continue to be impaired or destroyed.

The term **biodiversity** encompasses the variety of all living things and includes the diversity of species, the genetic diversity within species, and the diversity of ecosystems that these species call home. Scientists estimate that the Earth is home to 10-30 million species, but have named and cataloged only a fraction of that number so far. Advances in DNA sequencing and knowledge of the genetic code continue to open up new worlds of organisms that have yet to be identified.





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Biodiversity and Ecosystem Services: Can't Live Without 'Em

With eight ecoregions converging in New Mexico, our state is enormously rich in biodiversity. Across plants and vertebrate animals, New Mexico has the fourth highest native species richness in the US. However, the level of **endemism** (species found only in a specific geographic area) is relatively low. New Mexico ranks eleventh in endemism.¹

How do scientists measure biodiversity? To do this, they evaluate the two primary components of diversity in the field, which are species richness and species evenness. Species richness refers to the total number of different species an area supports, but does not take into account the number of individuals of each species. In this measure, a single individual carries as much weight as a species with many individuals. Species evenness refers to the relative abundance of each species present. Consider a meadow with 30 species present. It has a species richness of 30. Its species evenness would be assessed by how many individuals of each of the 30 species were present. If there were 1,000 of one species, and only one of each of the other 29 species, the meadow would have low species evenness. A community with one or two species dominating is considered less diverse than a community in which all 30 species have a similar abundance. As species richness and evenness increase, so does species diversity.

How do biodiversity and healthy ecosystems provide ecosystem services? Let's use the example of plants; they provide the oxygen that we need to breathe and take up and store carbon from the atmosphere. We depend on plants to provide our food either directly (such as fruits, vegetables, and grains) or indirectly as food for animals that provide meat and dairy products. Plants can work to mitigate the impacts of drought by helping to hold moisture within the soil, and moderate floods through plant roots stabilizing soil to prevent erosion and landslides. Plants also filter our water by taking up pollutants and trapping them in their biomass. These services, as well as pollination, climate modification, nutrient cycling, and many more are collectively called ecosystem services and are provided by rich biodiversity, the interactions between species, and the healthy ecosystems it supports.

Essential Ecosystem Services Provided by Plants

- soil fertility
- water filtration
- carbon sequestration
- flood control
- drought mitigation
- air purification
- nutrient cycling
- pollination of crops and native species
- recreation
- moderation of weather extremes
- moderation of climate
- medicine sources
- maintain genetic diversity
- disperse seeds
- prevent erosion
- decompose wastes
- protection from harmful ultraviolet rays
- control of agricultural pests
- regulate disease carrying organisms
- capturing energy through photosynthesis



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Biodiversity and Ecosystem Services: Can't Live Without 'Em

Assigning monetary values to ecosystem services can be challenging. For example, what if acid rain or another disaster sterilized the soil over a large area of farmland or forestland, eliminating soil fungi and microorganisms essential for decomposition and nutrient cycling? Soil fertility would no longer be naturally renewed. If farming or timber production in the area were necessary, what would it cost to remove materials that would not be broken down and to continuously apply fertilizer? Alternatively, if pollinators declined dramatically, what would it cost cherry farmers that are dependent on having their trees pollinated to produce a crop? You could think of ecosystem services as being like the infrastructure of a city: you may not think about or notice the water supply, sewer lines, electric grid, road systems and emergency response teams that keep your town functioning on a daily basis, but they are always there. The study of ecosystem services reminds us of the enormous complexity of life forms that are behind the scenes, playing critical and essential roles in supporting our own lives and activities.

Studying the fossil record, paleontologists have noted continual extinctions of species over the history of the earth, but recently the extinction rate appears to be rapidly increasing. In fact, the evidence shows that we are currently in the midst of a mass extinction event. This loss of biodiversity could have huge impacts on the ecosystem services on which humans rely. What factors lead to biodiversity loss? Habitat loss, in which humans change natural ecosystems through development, farming, filling wetlands, changing water courses, and generally expanding the human footprint, is a primary cause. Habitat loss can also occur naturally through volcanic activity, wildfire, and individual species loss to disease or competition. Additional factors that diminish biodiversity include climate change, the proliferation of invasive species, the overuse of resources, and pollution.²

In the discussion of worldwide biodiversity loss, you may come across the term “biodiversity hotspot”. To be designated a biodiversity **hotspot**, an area must be home to a high level of biodiversity, including more than 1500 **endemic** plant species, and it must be under significant

threat from human activities. The global non-profit organization Conservation International lists 34 hotspots worldwide. The California Floristic Province is a biodiversity hotspot in North America. This hotspot extends from Baja California into southern Oregon, in the Klamath Mountain ecoregion, also called the Siskiyou Mountains.³ In addition, the World Wildlife Fund named the Siskiyou Bioregion as one of 200 global hotspots on Earth. The Klamath-Siskiyou area alone is home to 131 native plants found nowhere else. The region is likely so diverse because it is a mixing pot between 5 major biotic regions: the Great Basin, Coast Range, Cascades, Sierra Nevada and Central Valley of California.⁴

Although the concept of a biodiversity hotspot may sound grim, there is much that can be done to protect biodiversity beginning at home. You can contribute to preserving biodiversity by choosing to live a more sustainable lifestyle, decreasing use of fossil fuels, conserving water, recycling, and gardening. Become an informed citizen and use your voice and vote to educate and lead. On a community-wide level, protect wild areas, work to restore degraded habitats, support ecological education and sustainable development.





Biodiversity and Ecosystem Services: Can't Live Without 'Em

Student Directions: Biodiversity Activity

1. For this activity, you will measure plant diversity in your schoolyard. Work in teams of two to measure the diversity of plants using a meter square (or a 4-meter string tied into a loop and staked into a square). Each team will measure a different area of the schoolyard that will yield different results.
2. Spread the square-meter plot on the ground and estimate the percent cover of different species of plants or plant-like organisms that are living within the square. For this it might be easiest to have one person estimate cover and the other record the results. It is not essential to know the name of the plants (although this is helpful). To record the species, take a digital photo or draw a sketch to ensure you only measure percent cover for each species once. Alternately, you can use a marker like a toothpick stuck in the ground or yarn tied to the plant to designate the species that you have already measured. Include mosses and lichens.
3. Calculate the Simpson's diversity index (D) for your plot. Use the following equation for Simpson's index of diversity:

$$\text{Diversity (D)} = 1 - \{\text{sum } (p(i)^2)\}$$

where $p(i)$ = the proportional abundance of species i

You can use either decimal or percentage values; both will come out the same. If species i has cover of 78% and the total cover is 140%, then $p(i)$ is $78/140 = 0.55$ or $0.78/1.40 = 0.55$

Square each $p(i)$ value, add up all the $p(i)^2$'s, subtract the total from 1, and you have your diversity index.

In this index of species diversity, D ranges from 1 to 0, with 1 representing infinite diversity and 0 representing no diversity. In the example in the table below, you may have the following species composition in your plot, where you found one grass, two things that looked like daisies but were clearly two different species, and one shrub:

Species	Percent cover	$p(i)$	$p(i)^2$
grass #1	40 %	$(40/130)=0.307$	$(0.307)^2=0.094$
daisy #1	15 %	$(15/130)=0.115$	$(0.115)^2=0.013$
daisy #2	40 %	$(40/130)=0.307$	$(0.307)^2=0.094$
shrub #1	35 %	$(35/130)=0.269$	$(0.269)^2=0.072$
Sum	130%	-	0.273

$$1.00 - 0.273 = 0.727$$

$$\text{Diversity (D)} = 0.727$$



Biodiversity and Ecosystem Services: Can't Live Without 'Em

Student Directions (*continued*)

4. The final number may seem abstract but remember this is a relative measure. It lets you know how diverse your plot is between no diversity (0) to infinite diversity. In our example, our diversity index is 0.727. This may seem high since we only had four species, but remember that species evenness plays a role as well. Note that our species composition was relatively even, with no one species dominating completely. For comparison, use the same four species but change it so one species is at 91% and the other three are at 3% and see how your diversity index changes.
5. You may also collect plant specimen samples in a plant press. Use butcher paper to make a large chart of your findings. Hang all the plot sample charts for the class to compare results. A simple way to classify your findings is to divide the plants by category and press a leaf specimen from each. Record the results by grouping types of plants together: tree, shrub, grasses, broadleaf herbaceous, mosses, and so on, with the sample of the leaves. **Extra Credit:** Identify the plants at your site. Label with scientific and common name. Are they native or non-native?
6. Return to the classroom and add your site location to the schoolyard map. Record the species richness and species diversity of your plot on the map. When all the teams have added their data to the map, discuss the results. Do the most diverse plots also have the greatest species richness? Discuss the difference between diversity and richness.
7. Make a graph of the class results (plot number, species diversity, and species richness). Which teams have the highest diversity? Which the lowest? Do the numbers correlate to any patterns that you observed on the school grounds (landscaped areas vs. native areas)? Do humans influence the abundance or diversity of plant life? Explain your reasoning. Do you think native plant diversity and exotic plant diversity show the same patterns? Explain why or why not.

CLASS DISCUSSION

What does "biodiversity" mean? (Hint: Break the word into parts to help formulate a definition).

Why do you think biodiversity is important in an ecosystem?

How is biodiversity an indicator of the health of the environment? Explain your reasoning.

How does the reduction of biodiversity harm the environment? How is it bad for humans?

Can you think of any positive things that come from the reduction of biodiversity?

Think about your own habitat. Would you consider it biodiverse; why or why not?

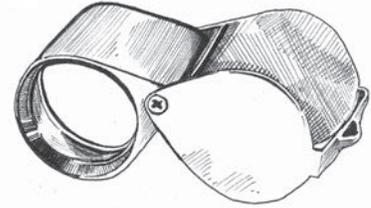


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Biodiversity and Ecosystem Services: Can't Live Without 'Em

Self Assessment

- 1** Define biodiversity and describe why it is important.
- 2** What is a biodiversity hotspot? What is the nearest biodiversity hotspot to where you live?
- 3** Demonstrate or describe a method of measuring and calculating plant diversity.
- 4** Compare and analyze the results of two or more plant diversity surveys.



Resources

- Information biodiversity hotspots: <http://www.cepf.net/resources/hotspots/North-and-Central-America/Pages/default.aspx> and <http://www.conservation.org/How/Pages/Hotspots.aspx>
- "Estimating Percent Cover" worksheet from the Measuring and Monitoring Plant Populations lesson in this guide.
- *Ecosystem Services: A Primer*. Links to ecosystem services background articles and lessons appropriate for high school students: <http://www.actionbioscience.org/environment/esa.html>
- New Mexico Biodiversity Collections Consortium: <http://nmbiodiversity.org/nmbiodiversity.php>



Saving Botanical Treasures

“What we plant in the soil of contemplation, we shall reap in the harvest of action” –
Meister Eckhart (1260-1328)

Time Estimate
1-2 hours

Best Season

		Winter
		Fall
		Spring
		Summer

Overview

Do any threatened or endangered (T & E) species live in your backyard? This lesson introduces the Endangered Species Act (ESA) through the threatened, endangered, and rare plants of New Mexico. Students learn how to influence government decisions and voice opinions on local rare species issues.

Teacher hints

- See <http://www.jigsaw.org/> for tips on implementing the jigsaw model. It is designed to reduce conflict, improve motivation, and increase enjoyment of the learning experience.
- In Part 2, use the field guide template sheet from the “Create-A-Plant” lesson (Section 1).

Assessments

- 1 Demonstrate a basic knowledge of the Endangered Species Act (ESA) and understand how citizens can be involved in shaping regulation of endangered species.
- 2 Write a supported opinion of the ESA.
- 3 Students will name one (or more) threatened or endangered plant species from their ecoregion.

Preparation

1. Jigsaw activity set up: assign students to core groups of four students. Groups need to include a mix of abilities, gender, and backgrounds. Have the members of the group count off by fours and these will become the secondary expert working groups.
2. Each expert working group will be a research team. Give them class time to work together, making sure all members of the group participate.
3. Conduct a pre-activity class discussion to assess prior knowledge and opinions of endangered species conservation. Discussion ideas: Explore personal opinions on the conservation of rare species. Ask if students can name any rare species that occur in New Mexico. Do they know of any species that have gone extinct and no longer exists in the last 100-200 years? What, if anything, happens in an ecosystem when an animal or plant species becomes extinct? Should we do anything to protect and recover endangered species? How much effort and money should we spend to keep species from going extinct? Explore possible reasons to protect rare species (e.g., aesthetics, moral reasons, ecosystem services, future medical discoveries).





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Saving Botanical Treasures

"What we plant in the soil of contemplation, we shall reap in the harvest of action." –

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Materials Needed

- computer with internet access for research
- copies of the ESA readings for jigsaw group activity
- jigsaw question sheets

Overview

Do any threatened or endangered (T & E) species live in your backyard? How would you feel if they did? This lesson introduces you to endangered, threatened and rare plants of New Mexico. You will collaborate with your classmates to become familiar with the basics of the Endangered Species Act (ESA). You will learn how you can influence government decisions and voice your opinions on local rare species issues.

Vocabulary

extinct

endangered species

threatened species

candidate species

rare

extirpated

species of concern

endemic

de-listing

down-listing

Learning Objectives

1. Explore the federal Endangered Species Act (ESA)
2. Learn how the public input process works in government actions (ESA process of listing a species)
3. Find out about state laws and conservation organizations that work to preserve rare species
4. Learn about rare plant species in your state
5. Increase your technology based research skills

Background

We often hear in the news of high profile near-extinction wildlife species: the polar bear, California condor, and gray wolf to name a few. Take some time to look up the definition of all the vocabulary words in the glossary to familiarize yourself with the terms to describe the status of listed species. Did you know that there are threatened, endangered and at-risk species in New Mexico, too? People living near rare species are frequently unaware that these species exist, and are often uninformed as to what has put the species in jeopardy. Species rarity is often linked to habitat loss, among other issues, and shares the same causes that fuel the biodiversity decline.



Federal and state laws protect species that are listed as endangered or threatened. The primary protection comes under the federal Endangered Species Act (ESA), which is administered by the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS). The USFWS has the primary responsibility for terrestrial and freshwater organisms, while the NMFS takes the lead on critical marine species such as whales and anadromous fish such as salmon. As with most



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laws, the ESA can be challenging to parties on all sides of the issue. For example, private landowners with rare species on their property are often concerned about losing the right to use their land as they like and fear that their property values will decline if endangered species are present on their land. Conservation organizations are working to save rare species and their habitats and private lands provide critical habitat for many species. Is there a middle ground where private landowners can feel safe from regulations and species can still be saved?

Investigating how the ESA works, how public input can affect species listings, and your role in shaping public policy is a way to learn about where policy and science meet to work to recover endangered species. During the first part of this activity you will gain a basic understanding of the history of the ESA, its components, and how it works to protect species. You will also have an opportunity to design a better law that may be more effective at saving species than the ESA.

Student Directions

Part I: ESA Jigsaw Activity

1. You will be divided into groups of 4 students- your core group for the jigsaw activity. Each person in the core group will be responsible for learning one section of the information needed for the group as a whole. The success of the group depends on each person doing their part.
2. In your core group count off 1, 2, 3, and 4. All the number ones in the class will form an expert group on the ESA Basics and History, twos will be the ESA Species Listing Process, threes will be ESA Critical Habitats and Habitat Conservation Plans, and fours will be ESA Recovery and De-listing.
3. Each expert group will work together in class to research its topic and answer a set of questions provided at the end of this lesson. Use the USFWS endangered species page <http://www.fws.gov/endangered/index.html> as a starting point. Each expert group may work on the questions together or divide them up. Keep your answers brief and concise. Come up with a creative way to share what you learned (draw a diagram, create a game, etc.) when you return to your core group.
4. Return to your core group and take turns teaching each other the key points you learned in your expert group. Encourage your core group to ask questions during the presentations so everyone benefits from your research!
5. Be prepared to have your teacher test your knowledge on the basics of the ESA.
6. Corps Group Discussion Extension– Discuss the merits and pitfalls of the ESA and any changes you think would improve it. Common arguments about the ESA include: the law values endangered species over humans; the law does not do enough to protect endangered species; the ESA listing process is too slow, allowing species to lose critical numbers during the wait, and the program is too costly. What do you think and why? Should money be spent saving individual endangered species or should it be spent to preserve and enhance entire ecosystems in peril?



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Student Directions (*continued*)

Part II: Apply your ESA knowledge to New Mexico:

1. There are rare plants all around the United States. Some are listed under the federal ESA, and others are listed under state ESA laws, which have different implications and meanings. Do you know which rare plants grow in your state?
2. Create a list of rare plants in your state. Include the name of the plant (scientific and common) and its status under the federal and/or state ESAs. A good resource for creating this list is the United States Fish and Wildlife Service website, where you can find endangered species listed by state: <http://www.fws.gov/endangered>. Research which threatened and endangered plants occur near your area. The New Mexico Rare Plant Technical Council's rare plants of New Mexico website also provides detailed information on listed plants: <http://nmrareplants.unm.edu>.
3. Create a field guide page for one rare plant from your state (use the template from Create-a-Plant). Have everyone in the class cover at least one species so the class will end up with a field guide to rare plants of your state.
 - As with any research project, be sure that you cite your sources both for written content and photos. Write the citation information directly on your field guide page. Keep track of the sources of your information as you conduct your research.
4. Search by scientific name on the internet. Many rare plants that are federally listed or are in the listing process will have extensive records of research, public hearings, etc. associated with them. Use this information to fill in the missing parts of your field guide. Include the reasons why the plant is rare and a summary of the steps to down-listing or de-listing if a recovery plan has been completed.
5. Use easy to understand language and define unfamiliar terms in your field guide so it will be easy for the general public to use.
6. Complete your field guide page with a high-quality picture (with proper copyright credits) or a color drawing and references.
7. Assemble everyone's pages to create a rare plant field guide for your ecoregion.





Saving Botanical Treasures

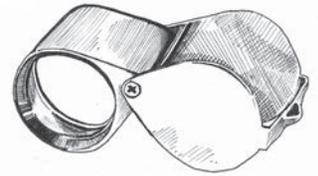


Reflection

Should we protect endangered species? What can you do to influence endangered species protections? What are some of the most common reasons that species become endangered? What role does human activity play? What kinds of people, groups, or institutions do you know of that are helping to protect endangered species today? How do you think these efforts are funded? Do you think that protecting endangered species is worthwhile? Why or why not, and to what extent? What have you done or are you doing to help protect your local ecosystems? Can you do one additional thing to help? What have you learned about critical habitat, the importance of biodiversity, and ecosystem conservation? How has this activity changed your views on endangered species protections? Why?

Self Assessment

- 1 Demonstrate a basic knowledge of the Endangered Species Act (ESA) and understand how citizens can be involved in shaping regulation of endangered species.
- 2 Write a paragraph expressing your opinion on an aspect of the Endangered Species Act. Support your opinion with evidence or examples.
- 3 Name one (or more) threatened or endangered plant species from your ecoregion.



Resources

- US Fish & Wildlife Service. Find species listed under Federal ESA as well as species of concern. <http://www.fws.gov/endangered/>
- The Citizen's Guide to the Endangered Species Act: https://www.givengain.com/unique/esc/upload/citizens_guide_esa.pdf
- New Mexico Rare Plant Technical Council's database of rare plants of New Mexico: <http://nmrareplants.unm.edu/>

Expert Group 1

Endangered Species Act (ESA) – Basics and History

Questions:

1. What is the purpose of the ESA?
 2. Who administers the ESA?
 3. What species are eligible for protection under the ESA?
 4. The ESA protects species by prohibiting “take.” Define “take” as it applies to wildlife in the ESA.
 5. Do the same “take” prohibitions apply to plants, and if not, how are they different?
 6. Describe how the federal government works with state governments in regards to the ESA.
 7. In what year did Congress pass the Endangered Species Act into law as we know it?
 8. Has the ESA been changed since it first became law?
 9. From its start, Congress authorized funding the ESA through 1992. How has the ESA been funded since 1992?
-

Expert Group 2

Endangered Species Act (ESA) – Species Listing Process

Questions:

1. What are candidate species?
 2. What are the two ways that species can become listed under the ESA? Give a short explanation of both.
 3. What are the five basic factors that influence whether a species is listed?
 4. When enough scientific information has been submitted to consider a species for listing under the ESA, biologists at the USFWS draft a proposed listing rule; what is included in the listing proposal?
 5. The ESA requires a final determination on the listing of a species to be completed within what time period?
 6. Outline the process for public input into an ESA listing proposal.
 7. ESA listing decisions are required to be based on best scientific principles. In this process they solicit peer review, explain this process.
 8. If all the steps are completed and the species listing is approved, what happens next?
-

Expert Group 3

Endangered Species Act (ESA) – Critical Habitat and Habitat Conservation Plans

Questions:

1. What is critical habitat?
 2. What is the purpose of designating critical habitat?
 3. How is critical habitat determined?
 4. What are habitat conservation plans (HCPs)?
 5. What do HCPs do?
 6. Many HCPs require mitigation to offset take of endangered animal species authorized by incidental take permits; mitigation is completed through specific conservation strategies that are manageable and enforceable. List several examples of mitigation practices.
-

Expert Group 4

Endangered Species Act (ESA) – Species Recovery and De-listing

Questions:

1. The USFWS uses many techniques to recover endangered species; list 3-5 such techniques.
2. What does recovery mean?
3. Give an example of a partnership that the USFWS has made to help recover endangered plant species.
4. Define the terms de-listing and down-listing, as used in the ESA.
5. What happens after a species has been de-listed?

Answer Key

Expert Group 1 Answer Key – ESA – Basics and History

1. What is the purpose of the ESA? -- The ESA protects and recovers imperiled species and their habitats.
 2. Who administers the ESA? -- It is administered by the Interior Department's U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service (NMFS).
 3. What species are eligible for protection under the ESA? -- All species of plants and animals, except pest insects, are eligible for listing as endangered or threatened.
 4. The ESA protects species by prohibiting "take." Define "take" as it applies to wildlife in the ESA. -- Take is "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." Take may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering.
 5. Do the same "take" prohibitions apply to plants, and if not, how are they different? -- Listed plants are not protected from take under the federal ESA, although it is illegal to collect or maliciously harm them on *federal* land. Protection from commercial trade and the effects of federal actions do apply for plants. State Endangered Species Acts may provide additional protection for plants on some land ownerships.
 6. Describe how the Federal government works with State governments in regards to the ESA? -- The federal government encourages states to develop and maintain conservation programs for threatened and endangered species. Federal funding is available to promote state participation. Some state laws and regulations are even more restrictive than the federal ESA in granting exceptions or permits.
 7. In what year did Congress pass the Endangered Species Act into law as we know it? -- 1973.
 8. Has the ESA been changed since it first became law? -- Significant changes to the law have been added in the form of amendments but the basic structure of the 1973 Act has been preserved.
 9. From its start, Congress authorized funding the ESA through 1992. How has the ESA been funded since 1992? -- Congress has annually appropriated funds.
-

Expert Group 2 Answer Key – ESA – Species Listing Process

1. What are candidate species? -- Species for which the USFWS has sufficient information on their biological status and threats to propose them as endangered or threatened under the Endangered Species Act (ESA), but for which development of a proposed listing regulation is precluded by other higher priority listing activities.
2. What are the two ways that species can become listed under the ESA? Give a short explanation of both. -- 1. The petition process – any interested person may petition the Secretary of the Interior to add a species, or 2. Through the candidate assessment process – USFWS biologists identify species as candidates for listing.
3. What are the five basic factors that influence whether a species is listed? -- 1. The present or threatened destruction, modification, or curtailment of the species' habitat or range; 2. Overutilization for commercial, recreational, scientific, or educational purposes; 3. Disease or predation; 4. The inadequacy of existing regulatory mechanisms; and 5. Other natural or manmade factors affecting the species' continued existence.
4. When enough scientific information has been submitted to consider a species for listing under the ESA, biologists at the USFWS draft a proposed listing rule; what is included in the listing proposal? -- Background information on the species (taxonomy, historic and current range, population information, habitat requirements, etc.), a summary of the threats faced by the species, a determination and/or designation of critical habitat if appropriate, examples of available conservation measures, and a preview of actions that would be prohibited (as well as actions that would *not* be prohibited) if the species were to be listed.
5. The ESA requires a final determination on the listing of a species to be completed within what time period? -- A decision on whether to make the proposed listing final must be completed within 12 months from when the proposal is published.
6. Outline the process for public input into an ESA listing proposal. -- 1. Press release announcing the proposal is published in area newspapers, and personal contacts are made by Field Office, Regional Office, and Washington, D.C. Office personnel. 2. Direct notification of cities and counties, state agencies, federal agencies, Congressional offices, local organizations, and others. 3. A 60-day public comment period begins once a listing proposal is published in the *Federal Register*. 4. A public hearing must be held if one is requested within 45 days of publication of the proposed rule. 5. Public meetings also may be held in areas where the species occurs to provide the public with information about the species and the proposed listing. 6. The public comment period may be extended or reopened at any time; however, extensions must be within reason.
7. ESA listing decisions are required to be based on best scientific principles. In this process they solicit peer review, explain this process. -- The USFWS contacts several peer reviewers during the open comment period, provides them with the listing proposal, and asks them to review the document for scientific accuracy. Current USFWS policy requires at least three independent reviewers to be contacted. The reviewers are free to comment on any aspect of the proposal, but they may also be asked to consider specific questions regarding the species' taxonomy or biology.
8. If all the steps are completed and the species listing is approved, what happens next? -- The rule becomes effective 30 days after publication (to allow Congress to review the listing) and the species is officially added to the federal endangered and threatened species list.

Answer Key

Expert Group 3 Answer Key – ESA – Critical Habitat and Habitat Conservation Plans

1. What is critical habitat? -- Specific geographic area(s) that contain(s) features essential for the conservation of a threatened or endangered animal species and that may require special management and protection. Critical habitat may include an area that is not currently occupied by the species but that will be needed for its recovery.
2. What is the purpose of designating critical habitat? -- Federal agencies are required to consult with the FWS on actions they carry out, fund, or authorize to ensure that their actions will not destroy or adversely modify critical habitat. In this way, a critical habitat designation protects areas that are necessary for the conservation of the species.
3. How is critical habitat determined? -- Biologists consider physical and biological features needed for life processes and successful reproduction of the species, including: 1. Space for individual and population growth and for normal behavior; 2. Cover or shelter; 3. Food, water, air, light, minerals, or other nutritional or physiological requirements; 4. Sites for breeding and rearing offspring; and 5. Habitats that are protected from disturbances or are representative of the historic geographical and ecological distributions of a species.
4. What are habitat conservation plans? -- HCPs are planning documents required as part of an application for an incidental take permit for a threatened or endangered animal species. They describe the anticipated effects of the proposed taking; how those impacts will be minimized, or mitigated; and how the HCP is to be funded.
5. What do HCPs do?-- In developing habitat conservation plans, people applying for incidental take permits describe measures designed to minimize and mitigate the effects of their actions— to ensure that animal species will not be jeopardized.
6. Many HCPs require mitigation to offset take of endangered animal species authorized by incidental take permits; mitigation is completed through specific conservation strategies that are manageable and enforceable. List several examples of mitigation practices.-- Mitigation practices include, but are not limited to, payment into an established conservation fund or bank; preservation (via acquisition or conservation easement) of existing habitat; enhancement or restoration of degraded or former habitat; establishment of buffer areas around existing habitats; modifications of land use practices, and restrictions on access.

Expert Group 4 Answer Key – ESA – Species Recovery and De-listing

1. The USFWS uses many techniques to recover endangered species; list 3-5 such techniques. --Techniques include restoring and acquiring habitat, removing introduced animal predators or invasive plant species, conducting surveys, monitoring individual populations, and breeding species in captivity and releasing them into their historic range.
2. What does recovery mean? -- Recovery is the process by which the decline of an endangered or threatened species is arrested and threats are removed or reduced, ensuring the long-term survival of the species in the wild. At that point the species is recovered, and protection from the ESA is no longer necessary.
3. Give an example of a partnership that the USFWS has made to help recover endangered plant species. -- A national partnership with the Center for Plant Conservation, which has expertise in conserving plants. Founded in 1984, the Center is supported by a nationwide consortium of 29 botanical gardens and arboreta. With about one of every 10 plant species in the United States facing potential extinction, the Center is the only national organization dedicated exclusively to conserving rare native plants.
4. Define the terms de-listing and down-listing as used in the ESA. -- To de-list species, the USFWS is required to determine that threats have been eliminated or controlled, based on several factors, including population sizes and trends and the stability of habitat quality and quantity. When the USFWS reclassifies species from endangered to threatened, a less dire status, they down-list them. If some of the threats have been controlled and the population has met recovery objectives for down-listing, the USFWS may consider changing the status of an endangered species to threatened.
5. What happens after a species has been de-listed? -- The Endangered Species Act requires the USFWS, in cooperation with the states, to monitor species for at least five years in order to assess their ability to sustain themselves without the protective measures of the Act. If, within the designated monitoring period, threats to the species change or unforeseen events change the stability of the population, the USFWS may extend the monitoring period or re-list the species.



Teacher
Page

Nobody Right, Nobody Wrong: A Role-Playing Game

"Begin challenging your own assumptions. Your assumptions are your windows on the world. Scrub them off every once in awhile, or the light won't come in." - *Alan Alda*, *Scientific American Frontiers* (1936- present)



Discussion Scenarios included in this lesson:

- **Land Use Planning and Endangered Species:** See description for Scenario 1.
- **Grazing in Riparian Areas:** See description for Scenario 2.
- **Forest Management:** See description for Scenario 3.

Assessments

- 1 Students participate in role-playing discussion in a positive and productive way.
- 2 Students state their opinion on a controversial environmental subject and give one or more reasons based in fact to back up their opinion.
- 3 Students demonstrate empathy by listening to differing viewpoints and demonstrate respectful disagreement.

Overview

In this lesson, students will play a role-playing game based on issues in local ecosystem management and conservation. Included in this exercise are three fully developed example scenarios to explore different issues that pertain to various ecoregions, as well as additional ideas for scenarios that may be more applicable to your area. Ideally, develop a locally applicable issue if possible for your area. Students will develop roles, form an opinion that reflects their position, and defend their position during the game. This lesson will help students understand and cultivate empathy for differing viewpoints on controversial issues, and prepare them for future stewardship decisions.

Teacher hints

- These scenarios are intended to be applicable to the area where you live. The example scenarios are best matched to location as follows: urban and developed area -- *Land Use Planning and Endangered Species*; non-forested rangeland -- *Grazing in Riparian Areas*; and forested regions -- *Forest Management*. See the "Preparation" section for hints on designing more locally applicable scenarios.
- Try to frame this as a discussion that emphasizes listening rather than a debate, which focuses students on winning. To make role-playing productive, keep discussion focused and make objectives clear to the students. Students need productive feedback from the teacher and/or peers and the freedom to explore alternate roles. Students need to listen to other viewpoints, weigh all sides of the issue, and form an opinion. The goal is that students will gain knowledge of the issues and develop empathy for stakeholders on all sides of each issue, regardless of their position.
- Establish clear guidelines of acceptable behavior in role-playing games. Controversial issues can and often do lead to strong feelings and arguments; it is important that no one feels intimidated. As part of the debriefing, at the end of the game, consider adding discussion about handling such issues in real life situations.
- For larger groups, assign multiple copies of roles or create additional roles of your own. For smaller groups leave out some roles, but be sure to balance both sides of the issue. Students reluctant to participate in oral projects could pair up as teams.



Nobody Right, Nobody Wrong: A Role-Playing Game

Preparation

Make it Place-based:

You don't have to limit your choice of discussion to the three scenarios included in this lesson. There are endless possibilities for discussion of controversial ecosystem issues. It is likely that you and your students are aware of local issues that can be addressed. Try looking to the local newspaper for ideas, or look at some additional ideas listed below. Pick an issue that is applicable and timely in your local area.

Once you have selected an issue for your students to address, use the three scenarios that are included in this lesson as templates for guidance in designing your own discussion.

1. Decide on a scenario for your class to play out and then create a sheet that explains the background story and the various roles that students will play. You will need to provide enough detail for a constructive and informed conversation.
2. Determine a specific decision that needs to be made. This gives the conversation a clear goal.
3. Identify specific roles for each student or group of students. Give them time to think about and research the viewpoints and concerns of the demographic that they are representing.
4. Provide background information or time for research and practice so that students are comfortable and able to back up their ideas and arguments.

Optional Scenarios to consider for Further Development:

Planting of invasive exotic plants in urban areas:

Invasive exotic plants used for landscaping and ornamental purposes in urban area have the tendency to spread to a degree believed to cause damage to the environment, human economy or human health. The same characteristics that make many exotic plants attractive in urban landscapes – colorful berries, pest-resistance, and tolerance of harsh conditions – can make them difficult to contain. Exotic plants that are attractive to birds and other wildlife are often the most invasive because animals serve as great dispersers of fruits and seeds, often moving the seeds great distances away from where the fruits were eaten. Exotic fruits, while attractive to wildlife, may not provide the best nutrition for native wildlife. Areas covered with only a few invasive, exotic plant species provide poor habitat for wildlife. Invasive species often exploit disturbances to an ecosystem (wildfires, roads, foot trails) to colonize an area. The cost of controlling these invasive species is quite high. One example of an invasive exotic common in New Mexico is Siberian elm. Many homeowners greatly appreciate the shade and aesthetic value it provides and would not consider removing it from their property. Meanwhile, these trees spread many seedlings each year, growing within city infrastructure such as sidewalks, powerlines, and right-of-ways and entering riparian areas. Much like the example of salt cedar given in the “Plant Wars” section, these exotic trees can compromise the function of our riparian areas. Should invasive exotics plants be banned from urban areas?

Agricultural Runoff: Agricultural runoff has led to massive algal blooms in water bodies, threatening the native plants and wildlife that depend on these habitats. The food and jobs produced by the agricultural industry are essential to the economy of the New Mexico. However, healthy lakes, riparian areas, and oceans are economically important too, and are of great intrinsic value to people and living systems. Should your state government place more strict regulations on agricultural runoff?

Hydraulic Fracturing: Hydraulic fracturing, often called “fracking”, is a process used to extract natural gas from deposits in shale rock. The process requires drilling and injecting fluid into the ground at extremely high pressures. The impacts of this process are many: millions of gallons of water are required, often in locations where water is scarce; large volumes of chemicals are mixed with water in the fracturing fluid, which can contaminate both groundwater and surface water; and natural gas is a fossil fuel which contributes to the carbon dioxide load in our atmosphere. However, natural gas is a more efficient and cleaner fuel than petroleum and coal. Natural gas extraction is also an important economic industry, and is a source of energy that doesn't need to be imported from outside the United States. Should your city council grant permission to companies to utilize hydraulic fracturing around your town?



Student
Project

Nobody Right, Nobody Wrong: A Role-Playing Game

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Materials Needed

- scenario descriptions

Overview

In this lesson you will explore a local issue surrounding ecosystem management and conservation topics through a non-judgmental role-playing game. Develop and play your role at a mock planning meeting and, in the end, weigh all sides and form your own opinion. Types of scenarios include: *Land Use Planning and Endangered Species*, *Grazing in Riparian Areas*, and *Forest Management*, and more.

Vocabulary

stewardship

Learning Objectives

1. Examine values and beliefs in controversial environmental issues
2. Explore diverse opinions in a safe environment through role-playing
3. Gain insight into problem solving skills, using defined steps to analyze the process
4. Exercise the process of being an informed citizen and making personal stewardship decisions
5. Learn ways to become involved in local policy issues

Background

If you read, listen or watch the news you can't help but hear stories of conflict over environmental issues (i.e., the Endangered Species Act, water and air quality issues, or climate change) which are frequently out in front of the public. In your community, there may be conflict over the management of native ecosystems that have people with very strong opinions pitted against one another in what seems like a feud of monumental proportions. How do these issues become such conflicts? Conflicts can arise when the livelihood or safety of people feels threatened by the conservation of natural resources and vice versa.

There are no right or wrong answers to the issues in this activity. The main purpose of this role-playing game is to provide an opportunity to explore viewpoints on controversial environmental issues in a non-judgmental atmosphere. Begin by considering what environmental **stewardship** means. It is generally defined as the concept of responsible caretaking, or management of the environment for future generations. Under this definition of stewardship we are all responsible for natural resource management and each decision we make can consider all

kinds of future impacts, including economic, social, cultural, and environmental. It is said that native peoples took into consideration the impact of all decisions on the next seven generations. How do we form our opinions when making stewardship decisions? Often we fall back on our values—an individual's standard of right and wrong, or those of our families. Factors such as economics, education, politics, spiritual beliefs, and culture all go into forming our values. As you can imagine, this complex stew of values can make reaching an agreement on environmental issues difficult, and often requires diplomacy and compromise between all the parties involved. Practice listening to the viewpoints of others; understand that they bring different values to the table, and that most people generally want to do what they feel is the "right" thing.

How does role-playing help you to work through controversial subjects? This role-playing exercise will give you time to organize your thoughts, listen to different sides of the issue, and weigh all the information before forming your own opinion on a controversial environmental subject.



*Student
Project*

Nobody Right, Nobody Wrong: A Role-Playing Game

Student Directions

1. This activity is designed to help you evaluate your own feelings, and form your own personal viewpoint while listening to and weighing the differing viewpoints of others. You will gain the most by participating fully, but relax and view the role-playing as a learning experience. Ask questions as needed to clarify your understanding, but respect the opinions of others. The purpose of this activity is to get everyone involved and thinking about the friction that can arise over environmental concerns between different segments of our society and how you will address and resolve these issues in your future.
2. Student roles:
 - 3-5 students will act as the planning board (decision makers), with one appointed or elected chairperson for the group
 - remaining students will be the audience participants
3. Read over the scenario chosen by your teacher or the class and ask questions before starting. You will be assigned a role to play. Take time to develop your character's background and values, using both your imagination and research about the topic that you are assigned. You can work individually or discuss this with others, but the viewpoints and concerns you will discuss should reflect your character and not your personal viewpoint. Play your role as accurately as possible; realize that it may not mirror your own viewpoint, but do your best to empathize (walk in your character's shoes).
4. Start the game: The setting is a planning board or task force meeting (the board will sit together as a panel). Audience participants sit facing the panel. The chairperson will call the meeting to order, read the scenario, and explain rules of the meeting. Audience members will give a brief (3-4 minutes) presentation representing their character's opinion on the issue and how they feel it should be resolved. Commissioners can ask questions and take notes to help them make a final decision at the end of the meeting.
5. At the conclusion of the meeting, call a brief recess. At this time the board will meet privately to reach their joint decision. During the board recess, conduct two polls of audience members. First, vote as your character would vote in this scenario. Then, vote as you would personally vote, (not your character), after weighing all the presentations you heard during the meeting.
6. Have the board announce their final decision and reasons. Tally the audience vote; does it agree or disagree with the board decision?



Nobody Right, Nobody Wrong: A Role-Playing Game

CLASS DISCUSSION

Is there any part of this conflict that both sides of the issue can agree on?

What values do both sides share?

How might people's values influence their viewpoint?

How do you recognize bias?

How would you weigh information to determine bias?

Do you recognize how your values have influenced your decisions?

What have you learned through participating in this meeting?

Do you think it has improved your listening skills, why or why not?

Values and prior knowledge will shape your first impressions; did any of the presentations cause you to change your first impression?

How successful do you think a solution will be if it requires people to change or compromise their values?

Look at the issue; what do you think would happen if no decision is made?

Do you see any parallels between this local issue and larger global issues?

Reflection



Reflect on the definition of stewardship: what does it mean to you personally? Do you feel that you have a responsibility as a citizen to help make decisions on land management issues? How can an individual's actions make a difference to their community, to the world? Identify a stewardship decision you make that could affect someone in another part of the world. Do you think the role-playing activity will change the way that you make decisions in the future? Explain your reasoning.

Self Assessment

- 1 Participate in the role-playing activity in a positive and productive way; researching, presenting, and discussing material within your character's role.
- 2 Listen and weigh others' opinions and demonstrate respectful disagreement.
- 3 State your opinion on the subject and give at least one reason to back up the opinion.



EARLY FINISHERS

- Read a current article about a controversial environmental issue taking place in your community. Analyze the article for bias; is it a balanced portrayal of the issue or is it written from one perspective? Identify other positions that might not have been addressed?
- Become involved with a local issue. Participate in public hearings, planning commission meetings, or write a letter to your government representative or the local paper. Express your opinion, back your opinion with examples, propose a solution(s) to the problem – don't just complain.

Scenario 1

LAND USE PLANNING AND RARE PLANTS: EXTRACTION WITHOUT IMPACTION

Setting: Open period for public review of a proposed project

Background: The San Juan basin is a structural depression in the northwest corner of New Mexico and in southern Colorado that encompasses about 35,000 km² (13,500 mi²). Because this basin contains deposits of various natural resources such as natural gas, oil, coal, uranium, sand, gravel, limestone, humate, gypsum, road metal, building stone, and water, it has been of economic interest to industries for many decades. The San Juan River drains this arid region and along its length it is very often the only significant source of fresh water and boasts world renowned trout fishing in northwest New Mexico. The banks of the San Juan contain diverse animal and plant life and many interesting geological features. Rare and listed plant species such as Bracks hardwall cactus (*Sclerocactus cloverae* ssp. *brackii*), Aztec gilia (*Aliciella formosa*), Mancos milkvetch (*Astragalus humillimus*), Mesa Verde cactus (*Sclerocactus mesae-verdae*), and Knowlton's cactus (*Pediocactus knowltonii*) occur in the San Juan Basin. The San Juan basin has great recreational opportunities such as whitewater rafting, fishing, hiking and camping, and photogenic landscapes of the surrounding desert hide vast expanses of incredible eroded rock formations of every color and form imaginable. Other resource of interest in the San Juan basin include archeological and paleontological features. For travelers and residents of the area, the San Juan River also provides an interesting look at Native American in the form of ruins and rock art.

Problem: The Frijoles Gas Company would like to install a natural gas drilling rig south of Blanco and south of the San Juan River. A rare plant, the Bracks hardwall cactus, was found in the vicinity of the footprint of the project area. Aztec gilia is generally known to occur in this area as well. In order to comply with the federal Endangered Species Act (ESA), the gas company must consult with the US. Fish and Wildlife regarding the impact on these rare plant species. This could result in restrictions on development, or complications, and added cost to the project.

Differing Viewpoints: The Frijoles Gas Company wants to continue with their plan to install the drilling rig. They have already spent thousands of dollars to work on feasibility studies on choosing the best place to situate their equipment. To modify or change their plans at this point would require spending additional money. As gas companies cost rise, the price of gas for consumers rises. On the flip side, the agency botanists and conservation groups want to be sure the gas company minimizes impacts rare plants and other natural resources. Unlike animals, plants are rooted in place making it difficult to escape threats. This group clearly sees the intrinsic value of rare plants and wishes to preserve the biological diversity and the character of New Mexico landscapes. Rare plants have a role in supporting pollinators and other wildlife as well as an economic value related to horticulture and agricultural applications, fragrance, dyes, and building materials. These rare plants possess genetic traits with high economic value. They feel that the expenses would be minimal to protect endangered species and are prepared to advocate for this issue.

The Community: Everyone in this community is connected in one way or another to this issue, and decisions will have a ripple effect throughout the San Juan Basin. New Mexico is a leading producer of crude oil and natural gas in the United States. The energy industry plays a critical role in the New Mexico economy. Limiting resource development could discourage employers and the unemployed. Direct and indirect state revenues, increased fuel costs, and impacted social services are real concerns. Impacting rare plants or its habitat could irreparably damage the species' chances for recovery, permanently removing a key species from the local ecosystem. Other considerations are impacts to (1) visual landscape, (2) natural resources (air, soil, vegetation, and water) (3) archeological resources, (4) paleontological resources, and (5) recreation opportunities.

The Decision: What measures should the Frijoles Gas Company be required to take in order to minimize impacts to resources from their proposed project?

Stakeholders

Science and Government:

- BLM field office
- US Fish and Wildlife biologist

Business and Labor

- Frijoles Gas Company
- energy processing plants
- companies installing and maintaining pipelines
- solar panel manufacturer with a new business hoping promote alternative energy
- business owners struggling in a weak economy
- local resident looking for a job in the natural gas industry

Landowners/managers:

- farmer
- rancher
- tribal land manager from adjacent lands

Recreational Interest:

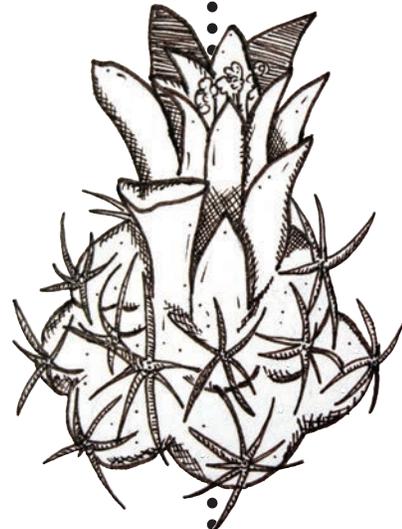
- naturalist, local birder, and hiker
- community parks advocate
- mountain biker
- OHV user

Conservation Groups:

- national wildlife organization representative
- land conservancy non-profit representative
- Native Plant Society

Other Interests:

- high school student
- attorney for the gas company
- wild card – make your own role



Resources:

- US Fish and Wildlife Endangered Species page: <http://www.fws.gov/Endangered/>
- Best Management Practices for Plants of Concern: <http://cpw.state.co.us/Documents/CNAP/Plant-OnG-BMPs.pdf>
- New Mexico Rare Plants website: <http://nmrareplants.unm.edu/>
- Oil and Gas Finance Facts: <http://www.nmlegis.gov/lcs/lfc/lfcdocs/finance%20facts%20oil%20and%20gas.pdf>
- Do an internet search to find current information on your chosen topic.
- Presidential Memorandum: Mitigating Impacts on Natural Resources from Development and Encouraging Related
- Private Investment: <https://www.whitehouse.gov/the-press-office/2015/11/03/mitigating-impacts-natural-resources-development-and-encouraging-related>

Scenario 2

GRAZING AND RIPARIAN AREAS: ON THE FENCE ABOUT FENCING

Setting: A community task force to discuss regulating livestock access to streams.

Background: Crispy City is a small town (population 5,000) in a rural, agricultural area that is home to a mix of people inside the city limits and the surrounding rural areas. Citizens include workers from a small tile manufacturing business that has attracted new families to the area, the farming and the ranching community, and needed service and support people. The city is served by a school district that draws both from the town and rural constituents. In recent years, Crispy City has attracted a growing retired population, which has relocated to enjoy numerous outdoor recreation opportunities.

Problem: Rattlesnake River and its tributaries drain this arid region, providing a source of water for Crispy City and the surrounding area. The riparian areas throughout much of the open rangeland in the vicinity of Crispy City lack suitable bank vegetation essential for stream bank stabilization, erosion prevention, filtering chemical pollutants, providing shade and maintaining low stream temperatures. These factors related to vegetation cover all strongly influence water quality and, therefore, fish and wildlife habitat. Past water quality improvement efforts have focused on controlling large source pollutants such as factory and sewage discharge and erosion and runoff from agriculture. This has improved overall water quality, but further improvements have stalled. More recent efforts have focused on non-point source pollution (run off from urban and rural locations). At present there are no state or federal laws regulating large ungulate (livestock and elk) damage to streams. Livestock grazing has been identified as a major non-point source pollutant for much of the area. Livestock tend to congregate around water sources, grazing and trampling the river bank's vegetation. Poorly managed grazing in uplands away from the river also has a major effect on water quality. This causes gullies at stream crossings, accelerates erosion, and increases water temperatures by reducing shade. Actions within in the Rattlesnake River drainage, have far reaching downstream implications as this river feeds into the Rio Grande. New Mexicans living within the confines of the Rio Grande River Valley are dependent on the Rio Grande as a freshwater source.

Differing Viewpoints: In recent years, a conservation organization has purchased a couple of ranches in the area, with plans to restore the native ecosystems which include 18 miles of riparian area along the Rattlesnake River and its tributaries. Its priority is to restore riparian areas and improve water quality in the streams that run through the properties. The restoration goal shall provide habitat for fish, wildlife and songbirds, and ultimately improve stream water quality and increase fish populations. The federally endangered fish species, the silvery minnow, along with other rare fish species are known to occur in this drainage. Farmers are nervous water rights may be restricted. The ranching community is in favor of improved stream quality, but has concerns with the methods the organization is proposing. By implicating their livestock as the cause of damage, they feel they are being unfairly blamed. Ranchers point to the fact that elk populations also damage riparian areas. Management efforts to keep livestock out of riparian areas could require fencing off riparian areas, and potentially developing new water sources for their livestock. This financial burden in addition to removing the most productive grazing land from their ranch land could force them out of business.

The Community: Water is a critical resource in Crispy City's arid region and each person living in the area has a stake and vested interest in water. Everyone in the community is connected in one way or another and decisions will have a ripple effect throughout. Agriculture consumes a large percentage of the surface water and groundwater withdrawals. Drought is a serious threat to the water supply, and climate change combined with population growth will stress the water supply even further. Retirees and other nature lovers are excited for future enhanced birding, fishing, hiking, and other recreational opportunities that come from improving watersheds. In addition, downstream communities as well as Texas and New Mexico equally have a vested interest.

The Decision: How can these riparian areas be managed better to benefit the most stakeholders? What type of incentive programs might work to encourage better grazing management?

Stakeholders-

Science and Government:

- Bureau of Land Management (BLM) rangeland manager
- State department of fish and wildlife biologist
- teacher with a spouse/partner that is rancher
- invasive species specialist
- Surface Water Quality Bureau
- New Mexico Department of Game and Fish

Business and Labor:

- local livestock feed store owner
- fishing and rafting guide
- small business grocery store owner
- large animal veterinarian
- Alfalfa farmer

Landowners/managers:

- tribal land manager – with interest in restoring fish populations
- cattle rancher/landowner
- farming community
- homeowner (in town) employed in manufacturing
- farmer living 100 miles south of Crispy City

Recreational Interest:

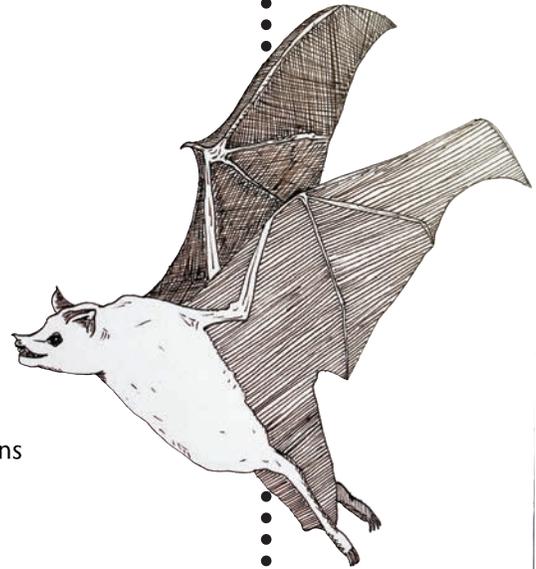
- outdoor recreationist (canoeing and camping)
- fisherman/hunter
- bird enthusiast

Conservation Groups:

- restoration ecologist from conservation organization
- member of conservation organization – retired school principal
- member of a group protesting land use limitations

Other Interests:

- high school student (graduating senior)
- boy scouts looking for service projects
- wild card – make your own role



Resources:

- Public Rangelands: Some Riparian Areas Restored But Widespread Improvement Will Be Slow: <http://archive.gao.gov/d16t6/136218.pdf>
- UNM School of Freshwater Sciences; Center for Water Policy; Climate Change Impacts on Agriculture in the Rio Grande River Basin: http://uwm.edu/centerforwaterpolicy/wp-content/uploads/sites/170/2013/10/Rio-Grande_Agriculture_Final.pdf
- US Fish and Wildlife Service: Rio Grande Water Quality Studies/Silvery Minnow: http://www.fws.gov/southwest/es/newmexico/EC_A_WQ_6.cfm
- Caring for the Green Zone – Riparian Areas and Grazing Management: <http://cowsandfish.org/>
- Local water quality regulations website: search websites for your local and state governments.

Scenario 3:

FOREST MANAGEMENT: SEEING THE FOREST THROUGH THE TREES

Choose a topic that best fits a current forest issues in your ecoregion.

Topic Ideas:

- Is Thinning Essential to Forest Health?
- Forest Wildfires: Suppression or Managed Fires?
- Protection of watersheds
- Forest Fragmentation
- Urbanization of Forest and Road Building

Setting: a town hall style debate

Background: Forests in New Mexico are key contributors to ecosystem services and are vital starting points for a healthy watershed, producing fresh water for the natural environment and our urban areas. New Mexico's forests range from large tribal and federal wildernesses to small, privately owned landscapes and are valued for multi-purpose resources. They are actively managed by private owners and organizations as well federal, state, and tribal land management agencies. These land managers and user groups have different and sometimes conflicting priorities and objectives. While forests provide tangible economic services such as raw resources for production and harvesting and areas for grazing, they also provide aesthetic, educational, cultural, and endless recreational opportunities (hiking, climbing, hunting, fishing, camping, solitude, wilderness, and cooler temperatures). Forests are home to a diversity of wildlife including rare species such as the Mexican spotted owl, Gila chub, and the Mexican gray wolf.

Problem: Resolve conflicting ideas in managing forests for multiple uses.

Differing Viewpoints: Historic fire suppression has contributed to unnaturally dense forests leading to larger and more intense wildfires. These fires can be devastating not only to the ecosystem but to downstream drinking water resources, and pose human safety and property risks. Climate change, drought, and forest urban fragmentation are increasing the complexity of forest management.

Prescribed fire and selective thinning are the two management approaches used.

- Prescribed fires are cost-effective, and mimic natural fires by reducing forest fuels, recycling nutrients and increasing habitat diversity for wildlife. Fire safety, smoke management, post-fire conditions, grazing and impacts to wildlife must all be carefully considered.
- Selective thinning is an alternative to prescribed fire and can promote local economic gain and resource utilization. However, it is significantly more expensive than prescribed burning. Because markets for wood products in New Mexico are limited, wood is often left on the ground and piles may need to be further managed.

All active forest management has the potential to introduce invasive plants and impact cultural, aesthetic, and tourist resources. How do we balance forest management with its use and the threat of catastrophic fire? What management approaches should be used? How do we prioritize areas for forest management in the face of limited financial resources?

The Community:

Decisions regarding forest management have far-reaching implications. These decisions affect jobs, the economy, forest health, air and water quality, and human enjoyment.

The Decision: What is the best way to manage our forests for current and future generations?

Stakeholders:

Science and Government

- U.S. Forest Service employee
- New Mexico State Forestry wildland fire manager
- restoration ecologist
- local town planning commission member
- local Fire Department chief
- New Mexico Environment Department employee
- University forestry and climate change researcher
- Bureau of Indian Affairs cultural officer
- New Mexico Department of Game and Fish

Business and Labor

- restaurant owner (tourism)
- ski area owner
- outdoor store employee
- rancher
- firewood or Christmas tree vendor

Other Interests:

- wild cards – make up your own role that represents your community

Landowner/manager

- homeowner on the forest/town interface
- tribal land manager of adjacent tribe-owned land
- small woodland owner

Recreational Interests

- hiker and camper
- avid fly fisher
- outdoor photographer
- deer/elk hunter

Conservation Groups

- Sierra club
- Native Plant Society
- Nature Conservancy
- Forest Guild
- Trout Unlimited
- Watershed Alliances



Resources:

- Use the internet to find current information on your chosen topic. Focus on government websites such as those for national forests in your area and state forestry webpages.
- Summer 2010 Publication of Forest Wisdom by the Forest Guild: http://www.forestguild.org/publications/forest_wisdom/Wisdom15.pdf
- USDA and Forest Service Press Release concerning a prescribed burn in the Santa Fe National Forest: <http://www.fs.usda.gov/detail/santafe/news-events/?cid=STELPRD3856294>
- New Mexico State Forestry Website; Forest Conservation Regulation: www.emnrd.state.nm.us/SFD/ForestMgt/ForestMgt.html
- All About Watersheds: New Mexico's Forest and Watershed Health Information Clearinghouse: <http://allaboutwatersheds.org/>
- Santa Fe Fireshed – an example of forest and watershed management http://www.forestguild.org/SantaFe_Fireshed
- San Juan – Chama Watershed Partnership: Protecting Drinking Water, Creating Local BioEnergy: <http://chamapeak.org/programs/san-juan-chama/>
- Lessons Learned from the Cerro Grande (Los Alamos) Fire: <http://www.gao.gov/new.items/rc00257t.pdf>

Role Development Sheet

Your Name _____ Scenario Title _____

Name of your character:	Age:	Gender:
-------------------------	------	---------

Briefly describe your fictional self (work, hobbies, home, family, values).	How does the issue affect your fictional life (economics, politics, ethics, etc.)? Does it conflict with any of your values?
Do you support or oppose the issue (in character)?	Give reasons to support your position (in character).

Role Development Sheet

Your Name _____ Scenario Title _____

Name of your character:	Age:	Gender:
-------------------------	------	---------

Briefly describe your fictional self (work, hobbies, home, family, values).	How does the issue affect your fictional life (economics, politics, ethics, etc.)? Does it conflict with any of your values?
Do you support or oppose the issue (in character)?	Give reasons to support your position (in character).



Designing a Habitat Restoration Plan

"Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it is the only thing that ever has."
- *Margaret Mead*, (1901-1978)



Overview

This lesson introduces the basics of habitat restoration through exploring restoration concepts, terminology, and methods. Learn about common restoration tools and weigh the trade-offs land managers juggle when planning a restoration project. Students will work as part of a team using design principles to plan, budget, and market a restoration plan to a land manager.

Teacher hints

- This lesson includes many aspects of the engineering design standards: defining a problem and stating a goal; brainstorming solutions; comparing solutions using the concept of trade-offs; then creating, analyzing, and refining a plan within set criteria; identifying strengths and weaknesses; and describing how it is more effective than alternative plans.
- Team projects can be run as a class competition. Invite local land management agency personnel (e.g., U.S. Forest Service, Bureau of Land Management, City, County, or State Parks/Natural Areas Departments), other teachers, or an ecologist, botanist, a member of a local watershed group or forester to act as judges.
- Use this lesson to introduce a service learning project. Partner with your local watershed council or other natural resource agencies on a nearby habitat restoration project. Ask to view their restoration plan, or to be involved in creating it.
- For advanced students, add an additional layer to the restoration plan. Have them research appropriate plant species for a local habitat restoration site. Find and price seed, plug, or plant material cost to include in their plan. Use figures to calculate total costs.

Preparation

1. Class discussion: Brainstorm what it means to "restore a native ecosystem". Have the class formulate a definition. Discussion questions: What part do humans play in restoration? Can restoration happen naturally? How and when? When is a restoration complete? Does the restoration process just treat a symptom or does it address the cause of degradation?

- Explore other associated words: reclamation, mitigation, reintroduction, conservation, degrade, disturbance, native, non-native, and invasive species.
2. Create a class word bank list to collect terms and definitions associated with habitat restoration.



Designing a Habitat Restoration Plan

"Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it is the only thing that ever has."
- Margaret Mead, (1901-1978)

Materials Needed

- budget worksheet
- site map
- tracing paper for overlays
- colored pencils

Overview

This lesson introduces the basics of habitat restoration through exploring restoration concepts, terminology, and methods. Learn about common restoration tools and weigh the trade-offs land managers juggle when planning a restoration project. You will work as part of a team using design principles to plan, budget, and market a restoration plan to a land manager.

Vocabulary

- restoration
- disturbance
- reference site
- rehabilitate
- reclamation
- mitigation

Learning Objectives

1. Increase understanding of habitat restoration terminology.
2. List several restoration tools.
3. Use engineering design process skills to create a habitat restoration plan.
4. Practice persuasive writing skills to market a habitat restoration proposal.

Background

Habitat restoration goes beyond protecting or preserving land and natural resources. Through the use of a wide variety of techniques and tools, restoration ecologists are learning to return degraded land to a condition that resembles its pre-disturbance state and in both community structure and function. If available, a reference site is used as a model for restoring another ecosystem. The reference site has more intact, ecological processes, higher functionality, more complex structure, and greater diversity than the system to be restored.

The Society for Ecological Restoration (SER) International defines habitat restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."¹ Many aspects of restoration are debated amongst scientists and on-the-ground practitioners in the habitat restoration community. Therefore, when planning restoration treatments, project managers must first know and understand what the "desired condition" is that they are trying to achieve. Can we really restore an ecosystem to a state that existed hundreds of years ago and do we even have the necessary data to do so? Since ecosystems are constantly changing through the process of succession, what stage of succession should a restoration project strive to reach?





*Student
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Designing a Habitat Restoration Plan

In North America, should ecological conditions be restored to mirror what is thought to have occurred before Euro-American settlements? What about ecosystems that have been heavily influenced by human cultures? For example, the indigenous people of our country manipulated ecosystems with fire for thousands of years; how should that be taken into account? Furthermore, what financial limitations or constraints need to be considered or how big does the project need to be to make an impact. These are some of the questions that land managers and restoration practitioners are challenged with and must address while planning a restoration project.

Humans are altering natural ecosystems at an accelerating rate due to population growth, resource extraction, and the need for urban development. In an attempt to counteract some of this habitat destruction, the process of **"mitigation"** enforcement has been introduced by government regulatory agencies. If a wetland, for example, is destroyed or heavily impacted while building a new shopping mall, the mall builders are liable to restore or create a new wetland in another location.

The theory behind mitigation is that there is no net loss of habitat. Do you think creating or enhancing an existing wetland in a different location can fully compensate for the loss of a naturally existing wetland?

In some cases, clean-up and restoration of an extremely polluted or degraded site is considered mitigation. At many mining sites the topography, hydrology, and soils of a site have been so altered that it is impossible to restore them to their desired condition. In this case, the goal may be simply to reduce pollution from the site and **rehabilitate** it to a new desired state. This type of mitigation is known as ecosystem **"reclamation."** In some forests where fire suppression is practiced, managers debate whether or not to thin or remove crowded trees and underbrush to mimic the ecosystem that might have existed with natural fire return intervals. Does this qualify as restoration? Can you think of other ways humans have altered natural ecosystems and are now trying to restore them?

Land management practices such as grazing, animal trampling within or across wetlands, logging, road or trail construction, and other stressors on the landscape can contribute to the degradation of resources. Evidence of degradation is often seen in deeply cut channels, steep eroded banks, and other areas where water has been channelized. Unless stabilized, these areas will continue to erode further which will reduce overall function within the watershed.²

Could restoration have a role in trying to react to climate change? Future restoration debates may center on how climate change may affect plant communities and species

ranges. Should we attempt to restore new habitats for species outside their current ranges to plan for the future? Should humans protect some species but not others?

Challenge yourself to define additional terms related to habitat restoration. Some words that you might see used in restoration project discussions are: re-establish, rehabilitate, and reintroduce. Can you think of or find others?



Habitat restoration is a complex process with many steps. All restoration projects include some similar components, including: defining current and desired future conditions; setting goals and objectives; planning; seeking public involvement and input; establishing work timelines; long term monitoring; and continued management. Good recordkeeping is essential and helps guide the project over the long term. Restoration projects are not completed in a season or even a year, but require many years. The end goal is a self-sustaining ecosystem with improved ecological function.

The chart below includes some restoration tools land managers use to accomplish restoration objectives. This is not an all-inclusive list, but it covers many commonly used restoration tools. Use the information in the chart to help you guide your own decisions as you work through your restoration plan.

Restoration Tool	Explanation	Benefit	Challenges
Part 1: Planning - Long term success of restoration			
Conduct baseline inventory	To describe current conditions, create list of plant and wildlife species present, note dominant species & rare species	Needed for long term comparison	Can be costly when inventorying a large site
Pick a model or reference ecosystem (What is the desired future condition?)	Study a nearby site with habitat to act as a model of what the restoration is attempting to achieve	Planning tool for species composition	Possibly no similar sites nearby to use as reference
Use historical data	Search original land surveyor records, explorer's journals to learn about the site's historical conditions	Information can give overview of the major species present prior to development changes	Records may be difficult to locate, hard to read, not complete
Create master plan	Written plan to guide each step of the restoration; Determine and address the cause of degradation	A document that all parties can use to guide activities	Plan needs to be kept current with modifications, timetable and monitoring data
Part 2: Restore historical topography and hydrology			
Earthmoving	Large machinery to restore historic topography	Restore natural hydrology	Disturbs soils, may interfere with native plants and wildlife
Culvert Assessment	Replace poorly placed or sized culverts	Restore natural hydrology	May affect neighboring property & local flooding
Stabilize Banks	Install log flow splitter, rock dams, and gabion techniques	Restore natural hydrology	Disturbs soils, may interfere with native plants and wildlife
Dam or water diversion removed	Take out earthen dams and swales that restrain or channel water	Restore natural hydrology	May affect neighboring property & local flooding
Part 3: Site Prep - Control unwanted vegetation (encroaching trees/shrubs, invasive species, other unwanted plants), open areas for planting, reduce competition for seedlings and transplants			
Hand pulling, digging, or cutting	Manually pull or dig out individual plants, cut larger shrubs and trees by chainsaw	Good control for small infestations, generally low impact to the environment	Labor intensive, may disturb the soil, not efficient for large sites
Herbicide	Chemical control through spot spraying (individual plants) or broadcast spraying (large infestations)	Good for large areas, fast, relatively inexpensive	Leaves chemical residues in soil and water, timing is crucial for application, need chemical applicators license, spray can drift off property, not suitable near water, can have negative effect on pollinators and wildlife
Mowing	Cutting vegetation close to ground level	Prevents plants from producing seed, good control of annuals	Weather or terrain may not be suitable, correct timing essential, repeat mowing will be necessary

Restoration Tool	Explanation	Benefit	Challenges
Prescribed burning	Low intensity, controlled burn of ground level vegetation	Mimics historic disturbance regime, encourages growth of grasses and flowering plants, discourages shrubs and trees	High cost, permits required, specialized equipment and trained staff needed, weather can be an issue
Soil nutrient removal	Growing, harvesting, and removing an annual crop to help remove excess nutrients from agricultural soils	Restores soils to nutrient levels more conducive to native plants	May take a few growing seasons,
Part 4: Restore Natural Vegetation - Seeding			
Local seed collection	Hand collect seed from plants at your site or nearby areas	Seed source is well adapted for your site	Labor intensive; plant identification & seed collecting knowledge needed, seed cleaning and storage may be required
Purchase regional seed collected from similar ecotype	Seed grown for regional restoration projects	Genetics similar to the plants native to the region of interest	Locating the needed seed may be difficult or impossible
Direct Seeding	Directly spread seed onto ground at the site, using broadcast seeding or a seed drill	Inexpensive, less labor-intensive, ideal for large areas	Some plants don't establish well from seed, inefficient use of seed, less able to compete with invasive plants than transplants
Plant propagation	Start and grow plants from seed, then transplant to restoration site	Gives more control over seed source and quality of material, plants available when needed	May require greenhouse, specialized seed starting knowledge, time to care for plants
Plant relocations	Move plants from local areas slated for development	Saves plants that might otherwise be destroyed, and ensures local plants are used at the new site	May be labor intensive, and can only occur at certain times of year
Purchase plant plugs from local native plant nurseries	Small plants in small cone-shaped pots	Relatively inexpensive, good availability, efficient to plant	More expensive than seeding, plants are small
Purchase bare root plant materials	Started plants with established roots for planting when dormant	Relatively inexpensive, easy to plant	Need to be planted when dormant, weather & accessibility issues
Purchase potted plant materials	Plants in pots of varying sizes	Established plants	Relatively expensive, will probably need watering for first year
Natural re-establishment of native plants and wildlife	Allow native plants and animals to recolonize on their own. Often native animals return after native plants and food sources have been reestablished.	Useful at sites with a minimum of destruction to be repaired, inexpensive, uses local seed source	Slow, leaves areas open for establishment of invasive plants

Restoration Tool	Explanation	Benefit	Challenges
Part 5: Monitoring—Evaluation			
Mapping	Create a data library. Maintain map of site plantings, locate invasive problems, can use GPS	Guides restoration, essential in communicating with partners	Need to keep updated with changes over time
Photo points	Photos taken from permanently marked fixed points (e.g., a fence post) on a regular basis for long term monitoring	Time saving, general view of restoration, easy to duplicate, inexpensive, gives good overview of changes to site	Gives only a general overview, no specific numerical data, limited use when following specific plant populations
On the ground data collection	Counting (sampling, percent cover, complete counts)	Can give more detailed information, good for tracking specific plant populations	Labor intensive, costly
Part 6: Long Term Maintenance - Simulating natural disturbance cycle and controlling problem species			
Prescribed burning	Low intensity, controlled burn of ground level vegetation, used in grassland and prairie restoration	Mimics historical disturbance regime, encourages growth of grasses and flowering plants, discourages shrubs and trees	Expensive, permits required, specialized equipment and trained staff needed, can only occur under correct weather conditions
Mowing	Uses large machinery to limit height of vegetation or prevent invasive plants from setting seed, used in grassland and prairie restoration	Replace disturbance regimen to control unwanted vegetation	Equipment can spread weed seeds from other sites, cut material (thatch) may accumulate over time and require removal (e.g., raking)
Livestock grazing	Manage timing, intensity and duration of grazing. Uplands rested for one entire growing season on a rotational basis (or longer in drought conditions)	Can control height of vegetation, browsers (goats) can target brush (goats) or grazers (cows) can target grasses	Animals may feed indiscriminately on all plant material, overgrazing can be harmful, trampling of sensitive species, uncontrolled access to water can denude stream banks, may spread exotic and invasive species

*These are restoration tools for restoring a plant community. There are other types of restoration which could focus on restoring other communities (animals, soil microbes, etc.) or hydrological conditions that may use a slightly different set of tools in the restoration toolbox.

Student Directions

Restoration Scenario

1. A local landowner recently left a ten acre rural property to a conservation group, Ecosystem Protection Services. The donation came with the stipulation that the land be restored back to grassland to enhance habitat for native plants and wildlife and increase local biodiversity. Previously the site was used for poorly managed livestock grazing, and it is currently a mixture of non-native grasses and invasive weeds. The site historically supported open grassland that was maintained by Native American tribes who routinely burned the area. The topography is a combination of upland and lowland that is bisected by a standing or slow moving water course during the wet season.
2. Work in teams of 2-4 students to create a restoration plan packet. Your plan will be submitted to the conservation group, Ecosystem Protection Services, as a bid proposal to do the actual restoration work. The plan needs to cover the first year of work including permitting, site preparations, restoring natural vegetation, and monitoring. You need to balance the restoration goals, current conditions at the site, environmental concerns you identify, and the costs of your project. There is no single right answer or approach to this project. Use your proposal letter to justify your team's decisions.
3. Identify your restoration goal from the scenario. Write it in your own words but use the appropriate restoration terminology. Be sure to extract all the useful information from the scenario for your plan.
4. Use the site map to help design your restoration plan. The map identifies topography, current vegetation, and other factors that you need to take into consideration (e.g. water, neighboring housing). Use one or more map overlays to diagram your restoration plan.
5. Write out a restoration plan to accompany your map. Use your student budget worksheet to guide you in the steps needed. Include the tools you will use in site prep, restoring vegetation, and monitoring. The site may dictate using more than one method or tool to reach your plan goals. If this was a real scenario, there would be a permitting component to your restoration plan. The team would need to check to see if all the archaeological compliance was completed and approved. In addition, if burning was prescribed, the team will research and comply with air quality regulations.
6. Make a budget using the budget rate sheet. Keep in mind the individual rate sheet units and the size of your site. Remember that the costs are generally per acre and you are working at a ten acre site. Give an itemized cost for each restoration tool used and calculate the grand total cost for the entire project.
7. Sell your proposal by writing a persuasive letter to accompany your bid. Your letter should include why you think your plan describes the best option. The letter should be signed by all the members of your team and addressed to the proper organization.
8. Your completed bid proposal packet will be used to assess your entire team's grade (see rubric at end of lesson).



*Student
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Designing a Habitat Restoration Plan

In the Field

Take a field trip to view a restoration project in progress. Ask the managers of the restoration project to talk to the class about what they are doing at the site, including their restoration goals, how the site was selected, what historical data they used, the steps of the project, and where they are in the restoration process. If available, visit restoration sites in various stages of completion (beginning, middle and finished). —Make observations in your field journal at each of the sites. Compare the sites- how do they differ, not only in ecosystem type but progress toward their desired future conditions.



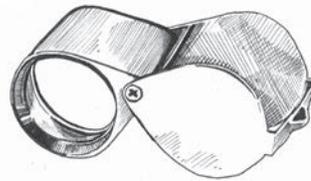
Reflection

This activity has touched on some of the philosophical difficulties associated with habitat restorations. Use what you know to evaluate the ways environmental ethics, public opinion, scientific work, and/or government policy impact your environment and society. Explore your own personal views on one of these topics.



Self Assessment

- 1** List the component parts of a successful restoration plan.
- 2** List and explain two tools used in each: planning, site prep, restoring vegetation, and monitoring in restoration projects.
- 3** Work as part of a team using engineering design principles to complete a restoration project proposal.



Resources:

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- The SER International Primer on Ecological Restoration: <http://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration>
- Native Seed Network: <http://www.nativeseednetwork.org/>



Designing a Habitat Restoration Plan

Restoration Rubric

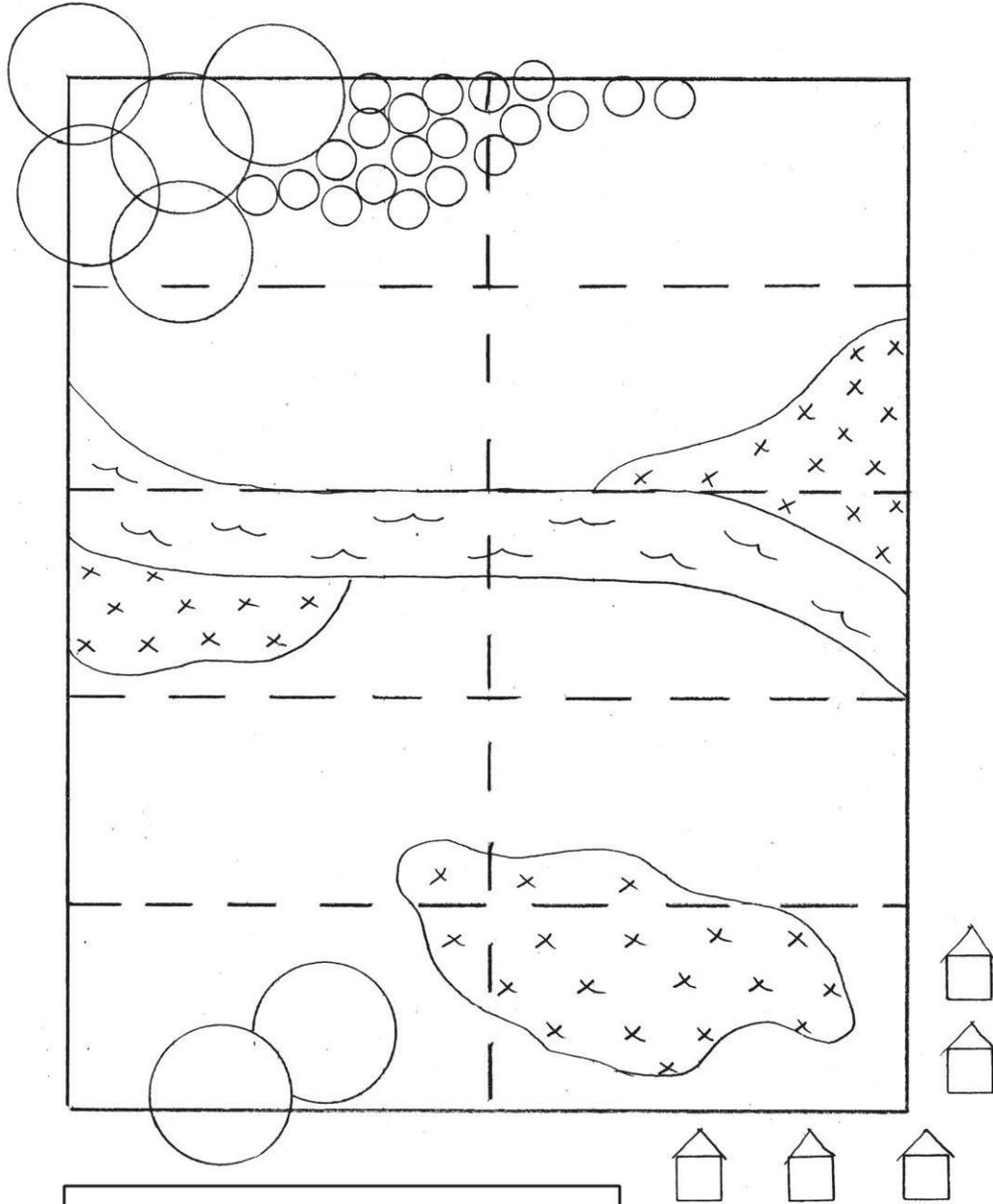
CATEGORY	Novice (1)	Apprentice (2)	Crew leader (3)	Professional (4)
Restoration Goal	Written in complete sentence, but copied from scenario. No attempt to use restoration terminology.	Written in complete sentences. Includes some factors from scenario, and uses at least one restoration terminology word.	Written using student's words, missing only one or two components, and uses one or more restoration terminology words.	Written in student's own words, encompasses all components from scenario, written in complete sentence form, and showing proper usage of restoration terminology.
Site Map With Overlay	Site map missing overlay. Incomplete key, or map and key do not match restoration tools from plan.	Site map with overlay. Missing one or two restoration tools from plan, or key is not complete or clear.	Site map with overlay. Missing one restoration tool from plan, or key is not complete or clear.	Site map with one or more overlays. Overlay shows all restoration tools used from plan, includes clear and complete key to match plan.
Restoration Plan	Plan is incomplete, missing one or more of the restoration tools needed, or plan does not include entire year.	Plan complete but does not include entire year in logical form, or is missing one of the required restoration tools needed.	Plan complete and addresses all restoration tools needed. Logical plan format could be improved.	Plan is logical to follow, written in paragraph or outline form. Includes one year timetable for site, and addresses all the restoration tools needed.
Budget Sheet	Budget sheet is not complete, missing tools from plan, mistakes in math, or does not include total project costs.	Budget sheet has one or more errors in matching plan, or errors in math, or total project costs.	Budget sheet matches plan, specifies tools used. Math has one or two errors in figuring tool costs.	Budget sheet matches plan and specifies tools used. Math is correct for individual tools and extended for entire job. Total cost of project figured correctly.
Bid Proposal in Persuasive Letter	Letter sloppy, not properly addressed, not signed, or not in proper letter format. Letter does not explain decisions made in plan.	Letter is neat and in proper format. Letter explains some but not all decisions made in plan.	Letter is neat and in proper format. Letter is persuasive in selling the proposal and explains most of the decisions made in the plan.	Letter neat, written in proper format, addressed to company name and signed by all team members. Demonstrates persuasive writing in selling proposal, and explaining all decisions made in plan.



Student Project

Designing a Habitat Restoration Plan

Map—10 acre site



KEY		Water drainage	
Tree		House	
Shrub		Invasive weeds	



*Student
Project*

Designing a Habitat Restoration Plan

Restoration Plan Budget Worksheet

Activity	Cost per acre	Hourly rate	Cost per pound	Cost per plug	Cost per site	Additional notes
Prescribed burn					\$3 – 5,000.00	Range for site includes complexity, location, fuels, & permits
Brush clearing (mechanical)		\$91.00				Figure 1 hour per acre for your site
Spot spray		\$61.00				Figure 1 hour per acre for your site
Broadcast spray	\$55.00					Need to be aware of drift issues close to water and housing
Hand pulling		\$25.00				Figure 4 hours per acre for your site
Tractor work (seeding, mowing)		\$75.00				
Plug planting (100 plugs per hour)		\$50.00				
Grass seed (rate of 5# per acre)			\$25.00			
Wildflower seed (forbs) (rate of 3-5# per acre)			\$100.00			
Grass & grass-likes plug cost (1210/per acre planted 6 ft. apart)				\$.45		
Wildflower plug (forbs) cost (1210/per acre planted 6 ft. apart)				\$1.40		
Monitoring		\$75.00				Range depending on complexity and size of site. 1 hr. for photo point, 8 hours for sampling, 24 hours for complete count



*Student
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Designing a Habitat Restoration Plan

Final Student Budget

	Tool Used	Cost Per Unit (Acre/Hour)	Total Cost for 10 Acre Site
Site prep			
Restoring Natural Vegetation			
Project Monitoring			
Total Project Costs			

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SECTION 1: PLANT IDENTIFICATION

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SECTION 6: CLIMATE CHANGE AND PHENOLOGY

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Glossary

- abiotic.....the non-living elements of an ecosystem. Example: rocks, water
- accessory fruit.....a succulent fruit developing from the receptacle instead of the pistil. A strawberry is an example, with the ripened ovaries' small achene on the fruit surface
- achenea simple, dry, indehiscent fruit with a single, small seed that attaches to the ovary wall at only one point
- adaptation.....a process over multiple generation in which an organism changes to better fit the habitat. Example: Natural selection would favor the deeper-rooted plants during climate shifts that cause drought conditions
- adventitious root.....a root structure developing in an unusual location, such as growing from a stem
- aggregate fruit.....a cluster of small fleshy fruit, as in the cluster of drupelets that make up a raspberry. Arising from several pistils in a single flower, each producing a single drupe that when connected, form a cluster
- allelopathy..... the process whereby one plant species produces biochemicals to inhibit the growth of other plant species
- alternatea leaf pattern where one leaf grows from each node on the stem, alternating sides of the stem
- analgesic.....a medicinal pain reliever
- angiosperma flowering plant that produces seeds in a fruit
- annual.....a plant that completes its entire life cycle in the same year; germinate, flower, set seed and die
- anther.....the enlarged, pollen-bearing part of the stamen; located at the tip of the filament
- antibacterial.....a medicinal that inhibits or destroys bacteria
- antioxidanta substance that slows oxidation. In the human body it counteracts the negative effects of oxidation on body tissues
- assisted migrationdeliberately moving members of a species from their present habitat to a new location with the intent of permanent establishment. Most commonly used in response to habitat loss and climate change
- axilthe angle point between the stem and the leaf growing from it
- azimuth.....a description of a location as it relates to North in degrees, minutes, and seconds
- basalleaves growing from the base of the plant stem
- berrya simple, fleshy, indehiscent fruit with many seeds, like a tomato or blueberry; commonly applied to any fruit that is fleshy throughout, though not botanically correct
- biennial.....a plant that takes two years to complete its life cycle; usually forming a rosette of leaves the first year, and producing flowers and fruit the second year
- binomial nomenclature
a two-part scientific system of naming organisms. Example: *Camassia quamash*
- biochemical.....a chemical process in living organisms
- biodiversity.....the variation of all life forms within an ecosystem; often used to measure the health of a given ecosystem
- biological controlthe control of a pest by the introduction of a natural enemy or predator
- biome.....the world's major ecological communities, defined by the predominant flora and climate, and covering large geographic areas. Examples: desert, forest, grassland, tundra
- bioticthe living elements that make up an ecosystem
- botany.....the scientific study of plants
- bract.....a small, leaf-like part at the base of a flower or along the flowering stem
- budundeveloped (or baby) stem or flower; covered with scales
- bulba short, vertical, thickened underground stem such as an onion; NOT a root
- burden basket.....a woven basket, usually conical-shaped with pointed or flattened bottom, made in an assortment of sizes and weaves to accommodate the load to be carried
- calyx.....the outermost whorl of flower parts
- candidate species.....plant and animal species that are proposed for addition to the Federal Endangered Species Act (ESA)
- capsule.....a dry, dehiscent fruit with more than one carpel
- carbon sinkplaces of carbon accumulation, such as

Glossary

- in large forests (organic compounds) or ocean sediments (calcium carbonate); carbon is thus removed from the carbon cycle for moderately long to very long periods of time ¹
- carpel.....one section of an ovary ²
- caryopsis.....a simple, dry, indehiscent fruit with a single seed that is firmly attached to the ovary wall on all sides and found in grasses; a grain
- chlorophyll.....a term used for several closely related green pigments found in cyanobacteria and the chloroplasts of algae and plants. Chlorophyll is an extremely important biomolecule, critical in photosynthesis, which allows plants to absorb energy from light
- circumscissile capsule . a capsule which separates into horizontal top and bottom sections
- classification.....In biological science, a method to group and categorize organisms
- clearcut.....a method of harvesting timber in which all the trees are removed, and then the entire plot is replanted
- climate.....the long term predictable weather; the average weather conditions of a particular place over a long period of time. Climate is what allows you to predict what the weather conditions will be next year
- climax community.....the final stage of succession, in which there is a relatively stable plant community with many complex interactions between organisms
- coevolution.....the process in which species exert selective pressure on each other and gradually evolve new features or behaviors as a result of those pressures¹
- coiling.....a basket-making technique in which coils of materials are stitched together in a spiraling pattern; designs are made by using different color stitching material
- common name.....a name by which a species is known to the general public, rather than its scientific or taxonomic name; can vary by region or country
- community.....all the organisms within a particular habitat, interacting in a complex food web
- competition.....an interaction between organisms or species for a limited supply of one or more resources (such as food, water, and territory) that are used by both
- composite head.....the clustering of numerous small flowers together on a single flower base (receptacle)
- compound.....a leaf divided into two or more separate leaflets
- conservation biology.....the scientific study of nature and biodiversity, with the focus on protecting species, their habitats, and ecosystems through stewardship of entire biological communities
- cordage.....several strands of fiber twisted together to make string or rope
- cordate.....heart-shaped
- corm.....a short, enlarged, vertical underground stem covered with papery leaves
- corolla.....all the petals of a flower
- cotyledon.....the first leaf of a plant embryo; sometimes called a seed leaf
- crustose.....a crust-like growth form that is closely attached to the substrate, like paint, generally adhering by all of the lower surface ³
- cultural landscape.....a landscape created by people and their culture; a product of nature and of human interaction with nature, that the associated people define as heritage resources ⁴
- culture.....a system of beliefs, values, and assumptions about life that guide behavior and are shared by a group of people. It includes customs, language, and material artifacts. These are transmitted from generation to generation, rarely with explicit instructions.⁵
- cuticle.....a waxy layer found on leaves or stems
- cutting.....a section of a plant originating from the stem, leaf or root that is capable of developing into a new plant.
- cypsela..... a dry (at maturity) indehiscent fruit derived from two inferior ovaries that are fused together. It looks very much like an achene, which is derived from only one ovary. This fruit type is found only in the Asteraceae (Sunflower Family)
- day-length.....duration of the period from sunrise to sunset ⁶
- dehiscent.....a type of fruit that opens or releases seed when mature
- delisting.....the process of removing an animal or plant species from the Federal Endangered Species Act (ESA) ⁷

Glossary

- dichotomousa splitting of a whole into exactly two non-overlapping parts; from "dichotomy"
- dichotomous keya tool to identify objects (such as plants) a succession of paired choices that progressively lead to a final identification
- dicota plant that sprouts two seed leaves or cotyledons; "di" meaning two, and "cot" referring to cotyledon
- disturbancea temporary pronounced change in an ecosystem. This can be a natural disturbance such as fire or flood, or a human-caused disturbance such as clearcutting
- dominant speciesthe most numerous and vigorous species. Ecological communities are described and defined by their dominant species.
- dormancy.....a temporary non-growing period in the life cycle of a plant or seed
- drupea simple, fleshy, indehiscent fruit with a single seed with a stony covering, such as a peach or cherry
- ecoregion.....Ecoregions denote areas within which ecosystems (and the type, quality, and quantity of environmental resources) are generally similar. Ecoregions classify patterns and the composition of biotic and abiotic phenomena using geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. Examples: Willamette Valley; Northern Basin and Range ⁸
- ecosystem.....an interacting system of biotic and abiotic elements
- ecosystem servicesthe life-sustaining services provided by healthy diverse ecosystems. Examples: flood control; water and air purification; pollination; nutrient cycling
- ectomycorrhizae.....mycorrhizal fungi that grow on the surface layers of the roots and are commonly associated with trees ⁹
- embryo.....the un-sprouted young (baby) plant contained within the seed
- endangered speciesan animal or plant species in danger of extinction within the foreseeable future throughout all or a significant portion of its range (see also ESA) ⁷
- Endangered Species Act (ESA)
The Endangered Species Act of 1973 is federal legislation, intended to provide a means to conserve the ecosystems upon which endangered and threatened species depend, and to provide programs for the conservation of those species, thus preventing extinction of plants and animals. The law is administered by the Department of Interior's Fish and Wildlife Service (FWS) and the Commerce Department's National Oceanic and Atmospheric Administration (NOAA) Fisheries, depending on the species protected. ⁷
- endemic.....found in a specific geographic area
- endocarpthe innermost layer of a fruit
- endomycorrhizaemycorrhizal fungi that grow within the root cells and are commonly associated with grasses, row crops, vegetables, and shrubs ⁹
- endosperm.....the food tissue contained with the embryo within the seed
- entire.....a margin of a leaf that is not toothed, notched or divided
- equinox.....the time or date (Spring/Fall twice each year) at which the sun crosses the celestial equator, when day and night are of equal length.
- eradicationelimination, complete destruction. ¹⁰
Example: The widespread eradication of a species can lead to extinction.
- ethnobotanythe study of the relationship between people and the plants in their environment
- exocarpthe outermost layer of a fruit
- exotic.....introduced, not native
- extincta species that no longer exists (see also ESA)
- extirpated.....a species that no longer survives in regions that were once part of its range, but that still exists elsewhere in the wild or in captivity (see also ESA)
- famine food.....a readily available food source strongly associated with hardship
- fauna.....the animal life of a given area or region
- fiber cella plant cell with a thickened wall that gives structure
- fiber plant.....a plant used or cultivated for its fibers; fibers used to make or manufacture products
- fibrous roota root system where the roots are all approximately the same thickness; a system of small, branching roots
- fibrous.....resembling fibers

Glossary

- field journal.....a place to record one's observations, interpretations, and data while working in or enjoying the outdoors, used by scientists and naturalists
- filament.....a thread-like stalk that supports the anther
- flora.....the plant life of a given area or region
- flower.....the reproductive part of some plants, used to help make seeds; often colored and showy
- foliose.....a lichen growth form with lobes, loosely or tightly attached to the substrate; leaf-like ³
- follicle.....a dry, dehiscent fruit with a single carpel opening on a single side
- forb.....a herbaceous flowering plant that is not a grass or grass-like.
- forest thinning.....a forest management practice of removing trees to allow more space between trees, to maximize growth, and/or to protect from fire and diseases
- Frankia bacteria.....a bacteria the converts atmospheric nitrogen gas into ammonia in a process known as nitrogen fixation. Frankia bacteria live in root nodules of some woody plants.¹¹
- frequency.....the number of occurrences within a given time period ¹⁰
- fruit.....ripened flower part that contains the seeds
- fruticose.....a three-dimensional growth form of a lichen, not differentiated into upper and lower surfaces, and including pendulous and stringy, upright, or bushy forms ³
- fuels reduction.....using management tools such as thinning, brush removal, and prescribed burns to reduce the amount of surface fuels, to prevent or lessen the severity of wildfires
- funiculus.....the stem-like stalk of a seed, connecting ovule to the placenta
- generalist species.....an organism able to thrive in a wide variety of environmental conditions and with varied resources
- genus/genera (plural).....a group of species with similar characteristics or relationship; within the taxonomic classification system following "family." It forms the first word of a scientific name; always Capitalized and italicized
- germination.....the process whereby seeds or spores sprout and begin to grow.¹⁰
- greenhouse gas.....gases that trap heat in the atmosphere. Some occur naturally and are emitted in natural processes; others are generated by human activity.¹²
- gymnosperm.....a plant that produces seeds in a cone-like structure, instead of contained in the ovary of a fruit
- habitat.....an area that provides a plant or animal with a suitable combination of nutrients, water, shelter, and living space
- harden off.....a process in which plants grown in a greenhouse are slowly exposed to natural conditions (temperatures, sunlight, water) before being planted outdoors
- herbaceous.....a plant with no woody stems; leaves and stems may die down to soil level at the end of the growing season or may persist year round Can be annual, biennial, or perennial
- herbalist.....someone that uses herbs for healing and medicinal purposes
- herbarium/herbaria (plural)
a collection or library of preserved plant specimens. Specimens are dried and mounted or preserved in alcohol for studying taxonomy or geographic distribution; they act as a historical record of change over time
- herbivory.....the consumption of plants by animals, including insects
- hesperidium.....a fleshy fruit with a tough outer skin or rind. Examples: oranges, lemons
- hip.....a berry-like fruit containing many achenes. Example: rose hip
- hotspot.....In reference to biodiversity, hotspot refers to a region that must meet two strict criteria: it must contain at least 1,500 species of vascular plants (>0.5 percent of the world's total) as endemics, and it has to have lost at least 70 percent of its original habitat. Twenty five biodiversity hotspots have been identified worldwide. ¹³
- hyphae.....microscopic fungi cells that usually grow as long threads or strands ⁹
- imperfect flower.....a single-sex flower; containing pistils or stamens but not both
- indehiscent.....not opening upon maturity
- inflorescence.....a cluster of flowers
- internode.....the part of the stem between nodes

Glossary

- introduced a species that is brought in to an ecosystem by humans (whether accidentally or on purpose) and becomes established there. If the presence of this species causes negative effects in its new location, it is considered "invasive"
- invasive a species, typically non-native, that causes harm to the environment, economy, or human health
- lanceolate..... a lance- (or sword-) shaped leaf, much longer than wide, with the widest part of the leaf towards the base or bottom
- landscape..... the visible expanse of an area of land, encompassing physical elements (landforms, water bodies), biotic elements (dominant flora and fauna), and human elements (buildings, roads, farms) ¹⁴
- latitude the angular distance north or south of the earth's equator, measured in degrees along a meridian, as on a map or globe
- leaf margin..... the edge of a leaf
- leaf flattened, above-ground piece of a plant attached to a stem, usually green during the growing season; uses sunlight to make food for the plant (photosynthesis)
- leaflet a division of a compound leaf that is similar to a leaf but is attached to a leaf vein instead of the stem
- legume..... a simple, dry, dehiscent fruit that opens along both long edges, as in the fruit of a member of the pea family
- lignin..... a natural polymer found in plant cells, that binds cellulose fibers to harden and strengthen cell walls of plants ¹⁰
- lobed..... with rounded segments on the margin, such as an Oregon white oak leaf
- locule..... the cavity, in the ovary that contains the seed or the anther that contains pollen
- loculicidal capsule.... a dehiscent fruit that dispenses seed through the locule cavity
- macro very large in scale, scope, or capability¹⁰
- margin..... used to describe the edge of a leaf
- mesocarp the middle layer of a fruit
- micro-abiotic a small-scale look at an ecosystem's abiotic elements. Example: Small-scale topography (such as cliff, boulder) can affect soils, wind, moisture and other factors that influence plant growth or plant selection in a given spot
- microclimate small local atmospheric zones in which the climate differs from the surrounding area. Example: a protected place that remains warmer than the surrounding temperatures
- microscopic..... so small as to be invisible without a microscope
- mitigation..... steps taken to avoid or minimize negative environmental impacts. Mitigation can include taking protective steps, repairing, restoring, or compensating by replacing ¹⁵
- monocot..... a plant that sprouts one seed leaf or cotyledon; "mono" meaning one, and "cot" referring to cotyledon
- monsoon a seasonal shift in the prevailing wind direction, that usually brings with it a different kind of weather. In the Southwest, the monsoon season is a showcase of dramatic weather. While the storms suppress sweltering temperatures and resuscitates vegetation, they also deliver intense rains, powerful winds, and a high number of lightning strikes
- mulch..... a protective coat put over soil to inhibit evaporation or weed growth, to control soil temperature, to enrich the soil, or to prevent the dispersal of pathogens
- multiple fruit..... a fruit formed from several separate flowers on a single axis, as in a pineapple
- mutualism..... a symbiotic relationship between two different species in which each gains benefits from the other; they are interdependent ¹⁰
- mycelium..... large mass of fungi hyphae ⁹
- mycorrhizal fungi..... a type of fungi that colonizes plant roots. They form a mutualistic relationship in which plants supply carbon for the fungi and fungi bring soil nutrients (phosphorus, nitrogen, micronutrients, and perhaps water) to the plant⁹
- native..... a plant that is naturally found in an area, as opposed to a plant that people introduce into an area; see "introduced"
- naturalized..... introduced species, now established in a natural landscape and integrated into the ecosystem

Glossary

- natural landscape.....a landscape unaffected by humans
- natural selection.....a process of evolution that acts on variation within a population. Organisms with traits favored within a given set of environmental circumstances have a selective advantage over individuals with different traits; favored traits are only advantageous within a particular situation and may not aid survival in other circumstances ¹⁶
- nectar.....a sweet liquid produced in flowers to attract pollinators. Pollinators benefit from the nutrient source and the plant benefits from their pollination services
- nitrogen fixing.....a process in which bacteria converts atmospheric nitrogen gas, which is unavailable for plant use, into ammonia, that can then be taken up by plants. This mutualistic interaction takes place underground in the roots of plants, in the legume family and in some woody plants
- node.....swelling or knob where new growth originates
- non-native.....a plant introduced, purposely or accidentally, by human activity
- nonvascular.....plants lacking a system of tubes to transport water and nutrients
- noxious.....plant classified as injurious, to public health, agriculture, recreation, wildlife, or any public or private property¹⁷
- nut.....indehiscent fruit; hard and dry, usually with one seed
- nutlet.....a small nut
- observation.....the act of noticing or paying attention, using one's senses. ¹⁰ In science, a basic method of collecting data or of developing an understanding of a system
- open weave.....a basket-weaving technique which leaves openings between the weaving; allows water to drain, or used for carrying large items such as firewood
- opposite.....a leaf pattern where two leaves grow across from each other at the same node on the stem
- organism.....an individual living thing that can react to stimuli, reproduce, grow, and maintain homeostasis. Can be a virus, bacterium, protist, fungus, plant, or animal¹⁵
- ovary.....the enlarged base of the pistil that contains the developing seed
- ovate.....oval or egg-shaped, widest at the base
- overlay.....a technique used to add color designs on twined baskets. The colored weaving fiber is woven on the inside of the basket and brought to the front with a half twist to replace the standard weaving fibers as the design calls for. The colored fiber will replace the standard fiber and the weaving will slant in the same direction as the rest of the twining
- ovule.....the immature seed
- palmate.....a shape and vein pattern that is divided from a central point into lobes; similar to a hand with spread fingers
- panicle.....a flower arrangement with a central stalk and branched side stalks, with multiple flowers that mature from the base to the tip
- parasite.....an organism that grows, feeds and is sheltered on or in a different organism while contributing nothing to the survival of its host ¹⁸
- parasitism.....a relationship between two different types of organisms in which one benefits (the parasite) at the expense of the other (host)
- parthenocarpy.....fruit developed without seed production or fertilization taking place
- pedicel.....the stalk of a single flower attached in an inflorescence or a grass
- peduncle.....the stalk of a single flower
- pepo.....an indehiscent fruit; fleshy with many seeds and a tough outer rind/skin or exocarp
- percent cover.....percent of measured area (for example: ground, sky) covered by a target species; a method of collecting data when monitoring plant populations
- perennial.....a plant that lives three or more years
- perfect flower.....a flower that has both male (stamen) and female (pistil) reproductive parts
- pericarp.....the outer wall of a fruit
- perspective.....the appearance of things relative to one another as determined by their distance from the viewer.
- petal.....the inside layer of modified flower leaves; usually the brightly-colored, showy part of the flower
- petiole.....a stalk that attaches the leaf to the stem

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- phenologythe study of the timing of life cycle events in plants and animals in relation to changes in season and climate¹⁹
- phenotypethe observable traits or characteristics of an organism
- pheromonesa chemical substance secreted externally by some animals (especially insects) that influences the physiology or behavior of other animals of the same species¹⁰
- photoperiod.....the duration of daily exposure to light, either naturally or artificially²⁰
- phytochemical.....a plant-derived chemical
- phytotoxina chemical produced by a plant that is toxic to other plants or animals
- pinnate.....leaves or veins emerging from a central stalk or vein
- pistil.....the female reproductive part of the flower, including the stigma, style, and ovary
- plant communityall the different plant populations existing within a certain area or habitat
- plant diversitythe number of plant species per unit of area²¹
- plant populationa group of individuals, usually of the same species, within a specific area and at a given time
- plota small area (frequently a meter square) used to give a representative sample within a larger study site
- pollinationthe process of transferring pollen between anther and stamen
- pome.....a simple, fleshy, indehiscent fruit with a leathery or papery core, such as an apple
- poricidal capsule.....a dehiscent fruit that opens at pores
- precipitation.....water falling from clouds in any form, such as rain, snow, or sleet
- predation.....a symbiotic relationship between two different species in which one, the predator, feeds on the other, the prey
- prescribed burna management tool used in forestry and ecosystem restoration to clear land of excess organic ground material, get rid of unwanted vegetation, prepare a site for planting, and/or encourage the growth of favorable species
- propagule.....a portion of a plant such as a cutting or a seed from which a plant may grow.
- quadrat.....a square frame used for sampling
- racemea flower arrangement with a central stalk and single, individually-stalked flowers that branch from the central stalk and generally mature from the base to the tip
- rare.....infrequent or uncommon within a sampling site; or scarce within a species' habitat range
- receptacle.....structure at the end of the flower stalk where the flower parts attach
- reclamationworking to bring disturbed land back to its natural state; reclamation of mining sites
- reference site.....used as a model for restoring another ecosystem. The reference site has more intact, ecological processes, higher functionality, more complex structure, and greater diversity than the system to be restored
- rehabilitationto make habitable or useful again; to return to original condition
- reintroduction.....to return members of a species to their historical range. This strategy is sometimes used when a species has become locally extinct or if its population is threatened²²
- restoration.....the act, process, or result of returning a degraded or former habitat to a healthy, self-sustaining condition that resembles as closely as possible its pre-disturbed state²³
- restoration ecology .the application of the principles of ecology to the restoration of derelict, degraded and fragmented ecosystems²⁴
- rhizobia bacteriathe nitrogen-fixing organism associated with root nodules on legumes¹⁵
- rhizoid.....a root-hair-like structure found on moss, liverworts, and some vascular plants²⁵
- rhizome.....an underground stem that travels between plants; differs from a root by the presence of nodes
- rhizospherethe microhabitat immediately surrounding plant roots¹⁵
- riparianthe transitional ecosystem between land and water; the land directly influenced by water along rivers, lakes, and streams¹⁵
- root.....part of a plant without leaves; usually found underground. Roots anchor the plant and take up nutrients (food) and water
- samara.....a simple, dry, indehiscent fruit with wings, as in the fruit of a maple

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- saprophyte.....an organism that lives on dead or decaying organic matter
- scarification.....process of cutting or softening of the seed coat to hasten germination²⁵
- schizocarp.....an indehiscent fruit; dry; at maturity, splits into one-seed segments
- scientific name.....the two-part Latin name assigned to a species under the system of binomial nomenclature established in the 1700s by Swedish botanist Carl Linnaeus²⁶
- seasonal round.....the annual pattern followed in the production or collection of food²⁷
- seed coat.....the outer covering on a seed
- seed dispersal.....methods by which plants spread their seeds. Examples: animal ingestion, wind, water²⁸
- seed.....a mature or ripened ovule
- seed-bank.....a place where seeds are stored for long term preservation; seeds that are present in or on the soil
- seed leaf.....the embryo's first leaf; cotyledon
- sepal.....the green, leaf-like parts of a flower that usually sit directly below the petals
- septa.....the tissue separating the locules
- septicidal capsule.....a fruit that disperses seed through the septa
- serrate.....a leaf margin with teeth like a saw
- sessile.....without a stalk, stem, or petiole
- silique.....a dehiscent fruit; dry, longer than wide, and separating into two halves
- simple leaf.....an undivided leaf that is not separated into individual leaflets, but may still be lobed
- simple fruit.....a fruit developing from a single ovary
- solitary flower.....occurring singly and not in a cluster
- solitary.....single
- solstice.....either of the two times in the year, the summer solstice and the winter solstice, when the sun reaches its highest or lowest point in the sky at noon, marked by the longest and shortest days
- specialist species.....an organism that can only thrive in a limited or narrow range of environmental conditions and resources
- species.....a group of organisms that share a unique set of common characteristics and that (usually) can reproduce among themselves but not with other such groups.¹⁵ A species is the basic unit in taxonomic classification, under genus
- species of concern....an informal term referring to a species that might be in need of conservation action. Such species receive no legal protection and use of the term does not necessarily imply that a species will eventually be proposed for listing under the Endangered Species Act (ESA)⁷
- spike.....a flower arrangement with an unbranched, central stalk and single, un-stalked flowers that mature from the base to the tip
- spore.....a walled reproductive cell body capable of giving rise to a new individual, either directly or indirectly
- stamen.....the male reproductive part of the flower, including the anther and filament
- staple food.....a food making up the dominant part of the diet, that supplies a major part of a person's nutritional needs for survival; readily available
- stem.....part of the plant that supports the leaves and buds; usually grows above ground
- stewardship.....the responsibility to care for our natural resources sustainably, that is, in a way that preserves them for future generations
- stigma.....the portion of the pistil that is receptive to pollen
- stomata.....the pores or openings which allow the exchange of gasses
- storyboard.....a graphic organizer; a series of panels, of rough sketches outlining a sequence of actions. Borrowed from the film-making industry
- stratification.....the process of exposing seeds to low temperatures to mimic nature and improve germination rates
- structure.....Structure is a fundamental and sometimes intangible notion covering the recognition, observation, nature, and stability of patterns and relationships of entities¹⁴
- style.....narrow part of the pistil that connects the stigma to the ovary
- substrate.....a surface on which an organism grows or is attached¹⁰
- succession.....in ecology, the gradual and orderly process of change in an ecosystem brought about by the progressive replacement of one community by another until a stable climax is established¹⁰
- symbiosis.....a long-standing relationship between

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- two different species. Usually understood to mean mutualism (beneficial to both); but can also take the form of commensalism (beneficial to one, neutral to the other) or parasitism (beneficial to one, costly or damaging to the other) ¹⁵
- taproota large central root from which smaller roots branch off, such as a carrot
- taxonomyin biology, the study of the general principles of scientific classification; a classification of organisms into groups based on similarities of structure, origin, or other characteristics ¹⁰
- tepalacommon term for sepals and petals when both look very much alike ²⁹
- threatened species...an animal or plant species likely to become endangered within the foreseeable future throughout all or a significant portion of its range (see also ESA) ⁷
- topographydetailed study of the earth surface features of a region ¹⁰
- traditional knowledgeknowledge gained through long-standing traditions and practices of regional indigenous communities
- transect.....a line on the ground along which sample plots or points are established for collecting data ³⁰
- transplant.....in plants, a technique of moving a plant from one location to another, as in planting a potted plant in the ground
- tubera fleshy, thickened, underground stem. A plant structure used to store nutrients for plant re-growth during the next growing season. Also a means of asexual reproduction
- tumpline.....a woven or leather strap, worn across the forehead or shoulders, attached to a burden basket for hands-free carrying
- twining.....a basketry weaving technique using two or more weft strands are passed around the warp structure and twisted. By using different color, size, or texture weft strands, this technique lends itself to intricate decorative design
- ubiquitousbeing present everywhere at once ¹⁰
- umbel.....a flat-top or convex umbrella-like inflorescence with multiple small flowers; individual flower stalks arise from approximately the same point
- urban growth boundary (UGB)...a management tool used to contain urban areas and limit their expansion. It divides land that is urban—to be used for housing, shops, factories—from land that is non-urban and to be used for purposes such as conservation, agriculture, mineral extraction, airports and the like. An urban growth boundary encourages urban consolidation and protects valued non-urban areas from urban development. ³¹
- vascular tissue.....tissue that conducts water and nutrients through the plant body in higher plants ¹⁰
- veintransports water, sugars, and minerals within the leaf blade; can be seen radiating throughout the leaf
- warpin reference to basketry, the vertical elements that the weft fibers weave around; commonly the elements that give a basket structure
- watershed.....a region of land that drains to a particular body of water such as a river or a lake. Rain or snow that falls anywhere in that watershed eventually flows to that water body. It may travel overland as surface water or flow underground as groundwater
- weather.....the atmospheric conditions at a given time, as in rain or sunshine
- weed.....any plant out of place, unwanted where it is growing, difficult to get rid of, with an ability to spread ³²
- weft.....the horizontal weaving fibers of a basket or mat
- whorleda leaf arrangement in which three or more leaves are growing from the same node on the stem
- wildfire.....a rapidly spreading fire, often occurring in wildland areas, that is out of control ²⁴
- wildflower.....wild or uncultivated flowering plant¹⁰
- woody.....made of, containing, or resembling wood; made hard like wood as the result of the deposition of lignin in the cell walls. Examples: woody plants; perennial herbs with woody stems ¹⁰

Glossary Endnotes

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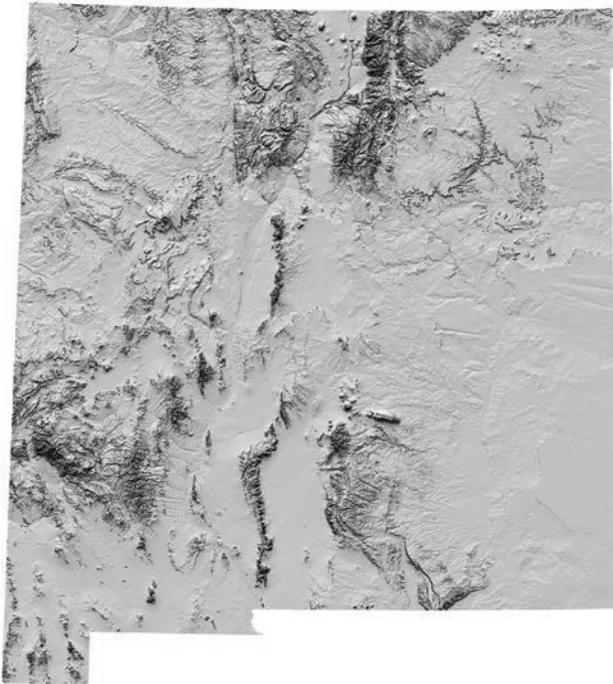
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Endnotes

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Appendix I

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Appendix I

Recommended Field Guides for New Mexico

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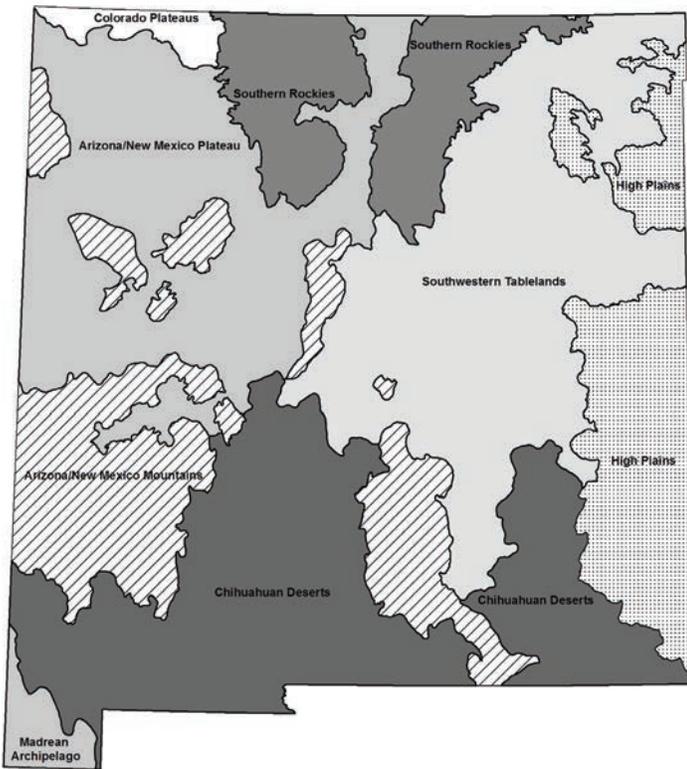
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Appendix II

School Yard Species List for New Mexico Ecoregions

(P = perennial, A =annual)

Community Name	Growth Habit	Scientific Name	Common Name	Duration	Family
Arizona/NM Plateau	Forb/herb	<i>Abronia fragrans</i>	Sweet sand verbena	P	Nyctaginaceae
		<i>Asclepias subverticillata</i>	Horsetail milkweed	P	Apocynaceae
		<i>Dalea candida</i>	White prairie clover	P	Fabaceae
		<i>Dimorphocarpa wislizeni</i>	Spectacle pod	A	Brassicaceae
		<i>Glandularia (Verbena) bipinnatifida</i>	Dakota mock vervain	P	Verbenaceae
		<i>Helianthus annuus</i>	Annual sunflower	A	Asteraceae
		<i>Heterotheca villosa</i>	Hairy false goldenaster	P	Asteraceae
		<i>Hymenoxys argentea</i>	Perky Sue	P	Asteraceae
		<i>Ipomopsis longiflora</i>	Long-flowered gilly	A	Polemoniaceae
		<i>Melampodium leucanthum</i>	Blackfoot daisy	P	Asteraceae
		<i>Mirabilis multiflora</i>	Colorado four O'clock	P	Nyctaginaceae
		<i>Penstemon jamesii</i>	James's penstemon	P	Plantaginaceae
		<i>Sphaeralcea coccinea</i>	Scarlet globemallow	P	Malvaceae
		<i>Zinnia grandiflora</i>	Rocky Mountain zinnia	P	Asteraceae
		Graminoid	<i>Aristida purpurea</i>	Purple three-awn	P
	<i>Bouteloua curtipendula</i>		Side oats grama	P	Poaceae
	<i>Bouteloua gracilis</i>		Blue grama	P	Poaceae
	<i>Hesperostipa (Stipa) comata</i>		Needle and thread grass	P	Poaceae
	<i>Oryzopsis hymenoides</i>		Indian ricegrass	P	Poaceae
	<i>Pleuraphis (Hilaria) jamesii</i>		Galleta grass	P	Poaceae
<i>Sporobolus airoides</i>	Alkali sacaton		P	Poaceae	
<i>Sporobolus cryptandrus</i>	Sand dropseed		P	Poaceae	
Shrub/tree	<i>Artemisia filifolia</i>		Sand sagebrush	P	Asteraceae
	<i>Artemisia frigida</i>		Fringed sagebrush	P	Asteraceae
	<i>Atriplex canescens</i>	Fourwing saltbush	P	Chenopodiaceae	
	<i>Ericameria (Chrysothamnus) nauseosa</i>	Rubber rabbitbrush	P	Asteraceae	
	<i>Fallugia paradoxa</i>	Apache plume	P	Rosaceae	
	<i>Juniperus monosperma</i>	One-seed juniper	P	Cupressaceae	
	<i>Krascheninnikovia lanata</i>	Winterfat	P	Amaranthaceae	
	<i>Pinus edulis</i>	Pinon pine	P	Pinaceae	
	<i>Rhus trilobata</i>	Skunkbush sumac	P	Anacardiaceae	

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School Yard Species List for New Mexico Ecoregions

(P = perennial, A =annual)

		<i>Yucca baccata</i>	Banana yucca	P	Agavaceae
Arizona/NM Mountains	Forb/herb	<i>Achillea millefolium</i> var. <i>occidentalis</i>	Western yarrow	P	Asteraceae
		<i>Asclepias tuberosa</i>	Butterfly weed	P	Apocynaceae
		<i>Penstemon linarioides</i>	Toadflax penstemon	P	Plantaginaceae
		<i>Penstemon pinifolius</i>	Pine-leaf penstemon	P	Plantaginaceae
		<i>Peritoma (Cleome) serrulata</i>	Rocky Mountain beeplant	A	Cleomaceae
		<i>Ratibida columnifera</i>	Mexican hat	B	Asteraceae
	Graminoid	<i>Bouteloua gracilis</i>	Blue grama	P	Poaceae
		<i>Elymus elymoides</i>	Squirreltail	P	Poaceae
		<i>Koeleria macrantha</i>	Junegrass	P	Poaceae
		<i>Muhlenbergia montana</i>	Mountain muhly	P	Poaceae
		<i>Poa fendleriana</i>	Muttongrass	P	Poaceae
		<i>Sporobolus cryptandrus</i>	Sand dropseed	P	Poaceae
		<i>Schizachyrium scoparium</i>	Little bluestem	P	Poaceae
	Shrub/tree	<i>Arctostaphylos pungens</i>	Pointleaf manzanita	P	Ericaceae
		<i>Berberis haematocarpa</i>	Red barberry	P	Berberidaceae
		<i>Cercocarpus montanus</i>	Mountain mahogany	P	Rosaceae
		<i>Juniperus deppeana</i>	Alligator juniper	P	Cupressaceae
		<i>Pinus edulis</i>	Pinon pine	P	Pinaceae
		<i>Pinus ponderosa</i>	Ponderosa pine	P	Pinaceae
		<i>Purshia (Cowaniana) stansburiana</i>	Cliffrose	P	Rosaceae
		<i>Rhus trilobata</i>	Skunkbush sumac	P	Anacardiaceae
		<i>Robinia neomexicana</i>	New Mexico locust	P	Fabaceae
		<i>Quercus gambelii</i>	Gambel oak	P	Fagaceae
		<i>Rosa woodsii</i>	Wood's rose	P	Rosaceae
		<i>Sambucus racemosa</i>	Red elderberry	P	Caprifoliaceae
		<i>Yucca baccata</i>	Banana yucca	P	Agavaceae
Chihuahuan Deserts	Forb/herb	<i>Baileya multiradiata</i>	Desert marigold	A	Asteraceae
		<i>Berlandiera lyrata</i>	Lyreleaf greeneyes (Chocolate Flower)	P	Asteraceae
		<i>Calylophus hartwegii</i>	Hartweg's sundrops	P	Onagraceae
		<i>Hoffmannseggia glauca</i>	Indian rushpea (Hog potato)	P	Fabaceae
		<i>Kallstroemia grandiflora</i>	Arizona poppy	A	Zygophyllaceae
		<i>Melampodium leucanthum</i>	Blackfoot daisy	P	Asteraceae
		<i>Penstemon ambiguus</i>	Gilia beardtongue	P	Plantaginaceae
		<i>Zinnia acerosa</i>	Desert zinnia	P	Asteraceae
	Graminoid	<i>Bouteloua eriopoda</i>	Black grama	P	Poaceae
		<i>Muhlenbergia porteri</i>	Bush muhly	P	Poaceae
		<i>Pleuraphis (Hilaria) mutica</i>	Tobosa grass	P	Poaceae
		<i>Sporobolus airoides</i>	Alkali sacaton	P	Poaceae

Appendix II

School Yard Species List for New Mexico Ecoregions

(P = perennial, A =annual)

		<i>Sporobolus flexuosus</i>	Mesa dropseed	P	Poaceae
	Shrub/tree	<i>Agave parryi</i>	Parry's agave	P	Agavaceae
		<i>Artemisia arbuscula</i>	Little sagebrush	P	Asteraceae
		<i>Artemisia tridentata</i> ssp. <i>tridentata</i>	Basin big sagebrush	P	Asteraceae
		<i>Atriplex canescens</i>	Fourwing saltbush	P	Chenopodiaceae
		<i>Chilopsis linearis</i>	Desert willow	P	Bignoniaceae
		<i>Echinocereus coccinea</i>	Scarlet hedgehog	P	Cactaceae
		<i>Fouquieria splendens</i>	Ocotillo	P	Fouquieriaceae
		<i>Opuntia macrocentra</i>	Purple pricklypear	P	Cactaceae
		<i>Prosopis glandulosa</i>	Mesquite	P	Fabaceae
		<i>Rhus microphylla</i>	Little-leaf sumac	P	Anacardiaceae
		<i>Yucca elata</i>	Soaptree yucca	P	Agavaceae
Colorado Plateaus	Forb/herb	<i>Eriogonum ovalifolium</i>	Cushion buckwheat	P	Polygonaceae
		<i>Eriogonum umbellatum</i>	Sulphur-flower buckwheat	P	Polygonaceae
		<i>Penstemon angustifolius</i>	broadbeard penstemon	P	Plantaginaceae
		<i>Penstemon eatonii</i>	Firecracker penstemon	P	Plantaginaceae
		<i>Sphaeralcea grossulariaefolia</i>	Gooseberry globemallow	P	Malvaceae
	Graminoid	<i>Achnatherum hymenoides</i>	Indian ricegrass	P	Poaceae
		<i>Elymus elymoides</i>	Squirreltail	P	Poaceae
		<i>Pleuraphis (Hilaria) jamesii</i>	Galleta grass	P	Poaceae
		<i>Sporobolus airoides</i>	Alkali sacaton	P	Poaceae
	Shrub/tree	<i>Artemisia frigida</i>	Fringed sagebrush	P	Asteraceae
		<i>Artemisia tridentata</i> ssp. <i>tridentata</i>	Basin big sagebrush	P	Asteraceae
		<i>Atriplex canescens</i>	Fourwing saltbush	P	Chenopodiaceae
		<i>Atriplex confertifolia</i>	Shadescale	P	Chenopodiaceae
		<i>Cercocarpus ledifolius</i>	Curl-leaf mountain mahogany	P	Rosaceae
		<i>Chrysothamnus viscidiflorus</i>	Yellow rabbitbrush	P	Asteraceae
		<i>Juniperus osteosperma</i>	Utah juniper	P	Cupressaceae
		<i>Pinus edulis</i>	Pinon pine	P	Pinaceae
		<i>Purshia (Cowaniana) stansburiana</i>	Cliffrose	P	Rosaceae
		<i>Sarcobatus vermiculatus</i>	Greasewood	P	Chenopodiaceae
Southern Rockies	Forb/herb	<i>Achillea millefolium</i> var. <i>occidentalis</i>	Western yarrow	P	Asteraceae
		<i>Aquilegia caerulea</i>	Blue columbine	P	Ranunculaceae
		<i>Erysimum asperum</i>	Western wallflower	P	Brassicaceae

Appendix II

School Yard Species List for New Mexico Ecoregions

(P = perennial, A =annual)

		<i>Hymenoxys hoopesii</i>	Orange mountain daisy	P	Asteraceae
		<i>Hymenoxys richardsonii</i>	Pinque	P	Asteraceae
		<i>Ipomopsis aggregata</i>	Scarlet gilia	B	Polemoniaceae
		<i>Iris missouriensis</i>	Rocky Mountain iris	P	Iridaceae
		<i>Lupinus argenteus</i>	Silver lupine	P	Fabaceae
		<i>Penstemon strictus</i>	Rocky Mountain penstemon	P	Plantaginaceae
		<i>Thermopsis montana</i>	Golden banner	P	Fabaceae
	Graminoid	<i>Elymus elymoides</i>	Squirreltail	P	Poaceae
		<i>Elymus trachycaulus</i>	Slender wheatgrass	P	Poaceae
		<i>Festuca idahoensis</i>	Idaho fescue	P	Poaceae
		<i>Koeleria macrantha</i>	Junegrass	P	Poaceae
	Shrub/tree	<i>Abies concolor</i>	White fir	P	Pinaceae
		<i>Amelanchier alnifolia</i>	Serviceberry	P	Rosaceae
		<i>Ceanothus fendleri</i>	Buckbrush	P	Rhamnaceae
		<i>Cercocarpus montanus</i>	Mountain mahogany	P	Rosaceae
		<i>Juniperus scopulorum</i>	Rocky Mountain juniper	P	Cupressaceae
		<i>Picea pungens</i>	Blue spruce	P	Pinaceae
		<i>Pinus ponderosa</i>	Ponderosa pine	P	Pinaceae
		<i>Populus tremuloides</i>	Quaking aspen	P	Salicaceae
		<i>Pseudotsuga menzeisii</i>	Douglas fir	P	Pinaceae
		<i>Quercus gambelii</i>	Gambel oak	P	Fagaceae
		<i>Rosa woodsii</i>	Wood's rose	P	Rosaceae
		<i>Sambucus racemosa</i>	Red elderberry	P	Caprifoliaceae
South-western Tablelands	Forb/herb	<i>Asclepias speciosa</i>	Showy milkweed	P	Apocynaceae
		<i>Glandularia (Verbena) bipinnatifida</i>	Dakota mock vervain	P	Verbenaceae
		<i>Heterotheca villosa</i>	Hairy false goldenaster	P	Asteraceae
		<i>Liatris punctata</i>	Spotted gayfeather	P	Asteraceae
		<i>Sphaeralcea coccinea</i>	Scarlet globemallow	P	Malvaceae
		<i>Tetraneuris scaposa</i>	Bitterweed	P	Asteraceae
	Graminoid	<i>Bouteloua curtipendula</i>	Sideoats grama	P	Poaceae
		<i>Bouteloua (Buchloe) dactyloides</i>	Buffalograss	P	Poaceae
		<i>Bouteloua gracilis</i>	Blue grama	P	Poaceae
		<i>Hesperostipa (Stipa) comata</i>	Needle and thread grass	P	Poaceae
		<i>Schizachyrium (Andropogon) scoparium</i>	Little bluestem	P	Poaceae
	Shrub/tree	<i>Artemisia filifolia</i>	Sand sagebrush	P	Asteraceae
		<i>Artemisia ludoviciana</i>	White sagebrush	P	Asteraceae

Appendix II

School Yard Species List for New Mexico Ecoregions

(P = perennial, A =annual)

		<i>Gutierrezia sarothrae</i>	Broom snakeweed	P	Asteraceae
		<i>Opuntia polyacantha</i>	Plains pricklypear	P	Cactaceae
		<i>Yucca glauca</i>	Plains yucca	P	Agavaceae
High Plains	Forb/herb	<i>Asclepias speciosa</i>	Showy milkweed	P	Apocynaceae
		<i>Dalea purpurea</i>	Violet prairie clover	P	Fabaceae
		<i>Engelmannia peristenia</i>	Engelmann's daisy	P	Asteraceae
		<i>Melampodium leucanthum</i>	Blackfoot daisy	P	Asteraceae
		<i>Sphaeralcea coccinea</i>	Scarlet globemallow	P	Malvaceae
	Graminoid	<i>Andropogon gerardii</i>	Big bluestem	P	Poaceae
		<i>Bouteloua curtipendula</i>	Sideoats grama	P	Poaceae
		<i>Bouteloua (Buchloe) dactyloides</i>	Buffalograss	P	Poaceae
		<i>Schizachyrium scoparium</i>	Little bluestem	P	Poaceae
	Shrub/tree	<i>Chilopsis linearis</i>	Desert willow	P	Bignoniaceae
		<i>Opuntia polyacantha</i>	Plains pricklypear	P	Cactaceae
		<i>Rhus microphylla</i>	Little-leaf sumac	P	Anacardiaceae
		<i>Quercus havardii</i>	Shinnery oak	P	Fagaceae
Madrean Archipelago	Forb/herb	<i>Acourtia thurberi</i>	Thurber's desert peony	P	Asteraceae
		<i>Asclepias angustifolia</i>	Arizona milkweed	P	Apocynaceae
		<i>Berberis haematocarpa</i>	Red barberry	P	Berberidaceae
		<i>Echinocereus fasciculatus</i>	Hedgehog cactus	P	Cactaceae
		<i>Trixis californica</i>	American threefold	P	Asteraceae
	Graminoid	<i>Bouteloua eriopoda</i>	Black grama	P	Poaceae
		<i>Bouteloua hirsuta</i>	Hairy grama	P	Poaceae
		<i>Hilaria belangeri</i>	Curly-mesquite	P	Poaceae
		<i>Sporobolus cryptandrus</i>	Sand dropseed	P	Poaceae
	Shrub/tree	<i>Agave parryi</i>	Parry's agave	P	Agavaceae
		<i>Agave palmeri</i>	Palmer's agave	P	Agavaceae
		<i>Fraxinus velutina</i>	Velvet ash	P	Oleaceae
		<i>Juniperus deppeana</i>	Alligator juniper	P	Cupressaceae
		<i>Pinus arizonica</i>	Arizona pine	P	Pinaceae
		<i>Quercus grisea</i>	Gray oak	P	Fagaceae
		<i>Rhus microphylla</i>	Littleleaf sumac	P	Anacardiaceae
		<i>Rhus virens</i>	Evergreen sumac	P	Anacardiaceae

Appendix III

Invasive Plant Species List for Ecoregions

Key to Ecoregions:

Arizona/NM Plateau = AP	Southern Rockies = SR
Arizona/NM Mountain = AM	South-western Tablelands = ST
Chihuahuan Deserts = CD	Western High Plains = HP
Colorado Plateaus = CP	Madrean Archipelago = MA

Common Name	Scientific Name	Description	Management Considerations	Eco-regions
Bull thistle	<i>Cirsium vulgare</i>	Biennial/perennial that infests disturbed areas such as ditches, roadsides, streams, and fence lines.	Proper identification is important – can be confused with native thistles like threatened Sacramento Mountain thistle; Mechanical removal should cut roots below soil surface and remove stems before flowering; Herbicides are effective; Do not mow during/after flowering to prevent seed dispersal; Do not use fire – it creates favorable conditions for growth.	AP, AM, CP, SR, ST, HP
Camelthorn	<i>Alhagi maurorum</i>	Herbaceous perennial that infests a wide range of areas, particularly semi-arid areas along rivers and floodplains where plant communities are degraded, as well as disturbed areas such as roadsides, ditches, and fields.	Preventing infestations and maintaining a healthy plant community are the best management methods; Hand removal is effective if most of the root system can be removed; Herbicides are effective; Mechanical removal techniques spread root fragments and are ineffective.	AP, HP, CD, ST
Canada thistle	<i>Cirsium arvense</i>	Perennial that infests disturbed sites such as roadsides and open fields, as well as hillsides, open forests, pastures, rangeland, crop fields, stream banks, and other riparian areas.	Early detection and eradication are the most effective control methods; Repeated cultivation, mowing (before seed production), or hand removal is effective; Herbicides are effective; Maintaining a healthy plant community can prevent establishment and slow spread.	AP, SR, AM
Crimson fountaingrass	<i>Pennisetum setaceum</i>	Tufted perennial grass that infests disturbed areas such as ditches, roadsides, and urban areas, as well as desert shrubland.	Prevention and early detection are the most effective control methods; Hand removal of individual plants is most effective in preventing new infestations; Herbicides are effective; Fire is not effective.	CD

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Russian knapweed	<i>Acroptilon repens</i>	Herbaceous perennial that invades pastures, degraded croplands, alfalfa fields, rangeland, roadsides, riparian areas, and irrigation ditches.	Prevention and early detection are essential; large infestations are extremely difficult to control; Prevention and maintenance of a healthy plant community are the best management methods; Herbicides are effective.	AP, AM, CP, SR, ST, HP
Diffuse knapweed	<i>Centaurea diffusa</i>	Herbaceous biennial (sometimes annual or short-lived perennial) that tolerates a wide range of conditions, but mostly infests disturbed areas such as roadsides, ditches, open fields, semi-arid deserts, rangelands, and grasslands.	Mechanical removal must remove at least 3-4 in. of root crown; Thirteen biological control agents have been introduced; Herbicides are effective with proper timing; Mow plants at late bud or early bloom to reduce seed production; Fire is not effective.	SR, AP, CP
Spotted knapweed	<i>Centaurea biebersteinii</i>	Herbaceous biennial to short-lived perennial that tolerates a wide range of conditions, but mostly infests disturbed areas such as roadsides, ditches, open fields, semi-arid deserts, rangelands, and grasslands	Preventing seed dispersal and establishing; competitive vegetation are essential; Mechanical removal must remove at least 3-4 in. of root crown; Thirteen biological control agents have been introduced; Herbicides are effective; Fire is not effective.	AP, SR, AM, ST CP
Musk thistle	<i>Carduus nutans</i>	Biennial that typically infests disturbed open areas, waste areas, stream banks, ditches, and roadsides.	Mechanical removal should cut roots below soil surface and remove stems before flowering; Herbicides are effective; Several biological controls exist but none are legal in NM; Do not use fire – it creates favorable conditions for growth; Do not mow during/after flowering to prevent seed dispersal; mow plants in late bud or early bloom to reduce seed production.	All
Purple starthistle	<i>Centaurea calcitrapa</i>	Annual to perennial that infests open fields, roadsides, grasslands, rangelands, and especially disturbed areas; also found in fertile or alluvial soil.	Physical removal before seed production; for single plants/small infestations; Herbicides are effective; Do not mow.	AP, CD, AM, SR

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Invasive Plant Species List for Ecoregions

Saltcedar	<i>Tamarix</i> Spp.	Small shrubs or trees that infest riparian areas such as rivers, streams, lake and pond shores, and irrigation ditches, as well as roadsides and rangeland.	Physical removal is only effective if the root crown is removed; Herbicides are effective, but above-ground tissue must be removed after treatment; Individual tree methods should be utilized in low density stands; Established native vegetation can out-compete saltcedar seedlings.	ALL
Scotch thistle	<i>Onopordum acanthium</i>	Biennial that infests disturbed sites such as roadsides, ditches, and open fields, as well as pastures, rangelands, grasslands, riparian areas, and irrigation ditches.	Physical removal before seed production is effective for small infestations; Minimizing open areas and establishing competitive plants, especially perennial grasses, can discourage invasion; Herbicides are effective.	AP, SR, HP, CP
Dalmatian toadflax	<i>Linaria dalmatica</i>	Herbaceous perennial that invades disturbed areas along roadsides, ditches, abandoned lots and fields, rangelands, riparian communities, and crop fields.	Maintenance of a healthy plant community and prevention are the best management methods; Physical removal is largely ineffective; Numerous effective biological control agents have been introduced; Herbicides are effective.	AP, SR, AM, CP
Leafy spurge	<i>Euphorbia esula</i>	Herbaceous perennial that is adapted to many soil types and habitats; typically invades disturbed and undisturbed areas such as pastures, rangelands, abandoned croplands, roadsides, wetlands, woodlands, floodplains, riparian areas, mountain ridges, and prairies.	Maintenance of a healthy plant community and prevention are the best management methods; Physical removal is largely ineffective; Numerous effective biological control agents have been introduced; Herbicides are effective.	SR, AP, AM
Malta starthistle	<i>Centaurea melitensis</i>	Annual (occasionally biennial) that infests disturbed areas such as roadsides and open fields, as well as rangelands, grasslands, open woodlands, pastures, and crop fields.	Prevention and early detection are the most effective control methods; Frequent cultivation is effective; Mow plants in late bud or early bloom to reduce seed production; Burning is effective if done before seed production; Herbicides are effective.	AM, CD, HP

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Russian olive	<i>Elaeagnus angustifolia</i>	A perennial tree or large shrub that infests grasslands, rangelands, woodlands, desert shrubland, and especially riparian areas, as well as disturbed areas such as road-sides, ditches, and open fields.	Prevention and early detection are the most effective control methods; Mowing saplings and cutting or removing mature trees are all effective controls if repeated often; Herbicides are somewhat effective.	ALL
Yellow toadflax	<i>Linaria vulgaris</i>	Herbaceous perennial that aggressively invades disturbed communities such as roadsides, graded areas, abandoned lots, rangelands, and riparian communities.	Maintenance of a healthy plant community and prevention are the best management methods; Physical removal is effective if continually repeated for 5-15 years to deplete seed bank; Revegetation with competitive species is effective; Biological control agents have been approved for use; Herbicides are effective.	SR, AP
African rue	<i>Peganum harmala</i>	Perennial that infests disturbed areas such as roadsides, open fields, and ditches, as well as arid and semi-arid desert area.	Prevention and early detection are the most effective control methods; Physical removal is effective if most or all of the root system is removed; Herbicides are effective.	AP, CD, MA
Cheatgrass	<i>Bromus tectorum</i>	Annual grass that infests disturbed areas such as roadsides, open fields, and ditches, as well as crop fields, rangelands, grasslands, and desert areas.	Maintenance of a healthy plant community and prevention are the best management methods; Burning before seed dispersal will destroy seed but may leave the site susceptible to re-invasion in following years: Mowing within a week after flowering will reduce seed production; Herbicides are effective.	ALL
Hoary cress	<i>Cardaria sp.</i>	Perennial that infests moist areas such as irrigated pastures, rangelands, hay fields, and other crop fields; also infests disturbed sites such as roadsides, railways, and ditches. Three species occur in New Mexico: lens-podded hoary cress (<i>C. chalapensis</i>), heart-podded hoary cress (<i>C. draba</i>), and globe-podded hoary cress (<i>C. pubescens</i>); heart-podded is most common.	Physical removal must remove root system; Repeated cultivation 1-2 times per month for 2-4 years is effective; Mowing at early flower growth stage may lower stem density and reduce seed production; Herbicides are effective.	ALL

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Oxeye daisy	<i>Leucanthemum vulgare</i>	Perennial found in a variety of habitats including rangelands, grasslands, roadsides, open fields, ditches, and other disturbed areas; grows well in poor soils.	Physical removal must remove root system; Cultivation in summer to a depth of 6 in. followed by repeated shallow cultivation is effective at destroying roots and seedlings; Herbicides are effective.	AP, SR, AM, HP, CP, ALL
Perennial pepperweed	<i>Lepidium latifolium</i>	Creeping herbaceous perennial found mostly in riparian areas, irrigation ditches, floodplains, and wetlands.	Maintenance of a healthy plant community and prevention are the best management methods; Hand pull all roots and seedlings; Mowing is not an effective control method, but can prevent seed formation if done before flowering; Herbicides are effective.	AP, SR, CP, AM, CD, ST
Poison hemlock	<i>Conium maculatum</i>	Biennial (sometimes annual or short-lived perennial) that typically infests open fields, pastures, ditches, riparian areas, and crop fields.	Hand pulling or cutting below the root crown is effective for small infestations; Repeated cultivation or mowing (before seed production) is effective for controlling large infestations; Herbicides are effective.	AP, CP, SR, CD, ST, AM
Siberian elm	<i>Ulmus pumila</i>	A deciduous tree that invades rangelands, grasslands, pastures, semi-arid areas, and riparian areas, as well as disturbed areas such as roadsides, ditches, and open fields.	Physical removal is effective for seedlings or small trees; Girding is effective for mature trees if performed properly; Herbicides are effective.	ALL
Tree of heaven	<i>Ailanthus altissima</i>	Deciduous tree that can tolerate shade, pollution, and harsh soil conditions; typically infests disturbed areas such as road-sides, ditches, and waste areas, as well as natural sites such as riparian areas and woodlands.	Maintenance of a healthy plant community and prevention are the best management methods; Physical removal is effective only if root crown and creeping lateral roots are removed; Herbicides are effective.	ALL
Chicory	<i>Cichorium intybus</i>	Biennial or perennial that infests disturbed areas such as roadsides, railroads, and waste grounds. Chicory plants resemble dandelion plants when in rosette stage.	Cultivation is effective; No known biological controls exist; Mowing is not effective; Herbicides are effective.	CP, AP, SR, CD, AM

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Spiny cocklebur	<i>Xanthium spinosum</i>	Annual plant that infests disturbed areas such as roadsides, ditches, fields, pastures, orchards, riparian areas, and waste areas.	Manual removal is effective, especially before burs develop; Do not cut and leave the plants with immature burs on the site because they can still develop viable seed; Some herbicides are effective.	AM, AP, CD, HP
Giant cane	<i>Arundo donax</i>	Bamboo-like perennial grass that infests riparian areas, floodplains, and irrigation ditches.	Physical removal must remove rhizomes and stem fragments; Herbicides are effective, especially when used in conjunction with cutting.	CD, AP, SR
Purple loosestrife	<i>Lythrum salicaria</i>	Perennial found in wetlands along rivers, streams, lakes, ponds, floodplains, reservoirs and ditches as well as some disturbed areas.	Prevention and early detection are the most effective control methods; Physical removal before flowering for single plants or small infestations; Several effective biological control agents have been introduced; Herbicides are effective; Do not mow.	CD, AM, SR, AP
Common teasel	<i>Dipsacus fullonum</i>	Biennial/perennial that infests disturbed areas such as fields, roadsides, waste grounds, and ditches.	Mowing flowering stems prior to seed production is effective.	CD, AM, AP
Ravennagrass Or Pampasgrass	<i>Saccharum ravennae</i>	Perennial that infests the margins of riparian zones, marshes, and ditches. (Tall ornamental grass that forms clumps)	Mowing and burning are not effective; Removing the roots is effective; Herbicides are effective.	AP, CD

Source: Troublesome Weeds of New Mexico by Jamshid Ashigh, James Wanstall and Frank Sholedic, New Mexico State University College of Agricultural, Consumer and Environmental Sciences Cooperative Extension Service, Las Cruces, New Mexico, 2010: http://www.nmda.nmsu.edu/wp-content/uploads/2012/04/troublesome_weeds_nm.pdf

Appendix IV

New Mexico Ethnobotany Plant List: Food Plants

FOOD PLANTS			
Common Name	Scientific Name	Use	Native American Tribe or Pueblo
New Mexico maple	<i>Acer glabrum</i> var. <i>neo mexicanum</i>	Sap collected and boiled to obtain syrup and sugar	Apache, Chiricahua, Mescalero
Boxelder	<i>Acer negundo</i>	Dried food: Inner bark scrapings dried and kept for winter use Sweetener: Inner bark boiled until sugar crystallizes out of it	Apache, Chiricahua, Mescalero
Indian ricegrass	<i>Achnatherum hymenoides</i>	Ground seeds used as a staple before the availability of corn	Zuni (staple), Apache, White Mountain
Giant hyssop	<i>Agastache pallidiflora</i> var. <i>neomexicana</i>	Used as one of the most important foods	Comanche (staple), Mohave (staple), Apache (staple), Ute (staple)
		Leaves used for flavoring	Laguna, Acoma
Agave	<i>Agave</i> spp.	Roots baked and eaten; crowns with leaves removed eaten as greens in winter; central flowering stalks eaten as greens in spring before they emerged; stalks roasted, boiled or eaten raw	Apache, Comanche, Mohave, Ute, Chiricahua, Mescalero Staple for all
Rocky Mountain Indian parsley	<i>Aletes anisatus</i>	Raw leaves eaten as a relish or cooked leaves eaten as greens	Isleta
Iodinebush	<i>Allenrolfea occidentalis</i>	Food Staple: Seeds harvested, winnowed, parched, ground and the meal eaten	Mohave
Onion	<i>Allium</i> spp.	Bulbs used for food	Apache, Chiricahua, Mescalero, Acoma, Laguna, Isleta, Hopi, Tewa, Navajo, Ute
		Onions used to flavor soups and gravies	Apache, Chiricahua, Mescalero, Acoma, Laguna, Pueblo
Pigweed	<i>Amaranthus</i> spp.	Eaten without preparation or cooked as greens or mixed with other food	Hopi, Apache, Pueblo, Chiricahua, Cochiti, Mescalero, Acoma, Mohave, Zia, Laguna, Isleta, Jemez, Navajo
		Seeds winnowed, ground into flour and used to make bread	Apache, Chiricahua, Hopi, Mescalero, Laguna, Zia, Acoma, Navajo
		Young plants cooked and dried for winter use	Acoma, Laguna, Mohave
Utah serviceberry	<i>Amelanchier utahensis</i>	Fruit used for food	Isleta, Navajo, (Ute- <i>A. alnifolia</i>)
		Berries dried for winter use	Navajo
Saltbush	<i>Atriplex</i> spp.	Fruits expanded calyx eaten for food	Acoma, Laguna
		Fresh young leaves eaten or boiled and eaten as greens or with plant products and meats for flavoring	Isleta, Acoma, Laguna, Cochiti, Hopi, Navajo, Pueblo, Isleta
		Seeds mixed with ground corn to make a mush	Zuni
		Flowers used to make puddings	Navajo, Hopi
Mule's fat	<i>Baccharis salicifolia</i>	Young shoots roasted and eaten as a famine food	Mohave
Colorado barberry	<i>Berberis fendleri</i>	Berries used for food	Jemez

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New Mexico Ethnobotany Plant List: Food Plants

Sego Lily	<i>Calochortus nuttallii</i>	Bulbs used for starvation food	Ute
Fendler's ceanothus	<i>Ceanothus fendleri</i>	Berries sweetened with sugar and used for food	Acoma, Acoma, Laguna
Netleaf hackberry	<i>Celtis laevigata</i> var. <i>reticulata</i>	Berries eaten fresh or dried for winter use	Acoma, Apache, Chiricahua, Pueblo Papago, Mescalero, Laguna
		Fruit used to make jelly	Apache, Chiricahua & Mescalero
Lambsquarters or goosefoot	<i>Chenopodium</i> spp.	Leaves or stalks eaten without preparation or cooked as greens	Apache, Chiricahua, Hopi, Mescalero, Papago, Pueblo, Zuni, Mohave, Papago
		Seeds ground and eaten as a nutrient	Navajo, Zuni,
Spiny chloracantha	<i>Chloracantha spinosa</i>	Starvation Food: Young shoots roasted and eaten	Mohave
Rocky Mountain beeplant	<i>Cleome serrulata</i>	Seeds used to a make meal or bread	Acoma, Laguna, Zia, Isleta, Isleta, Navajo
		Leaves, shoots, and buds used for food as greens	Hopi, Acoma, Zia (staple), Laguna, Zuni, Isleta, Jemez, Tewa, Navajo, San Felipe
		Young plants dried for winter use	Navajo
		Used as a spice	Navajo
Springparsley	<i>Cymopterus</i> spp.	Plant eaten as vegetable	Navajo, Acoma, Laguna, Apache, Chiricahua, Cochiti, Mescalero
		Roots eaten raw	Apache, Chiricahua & Mescalero
White prairieclover	<i>Dalea candida</i> var. <i>oligophylla</i>	Staple food: Roots dried and ground into meal or flour	Acoma, Laguna, San Felipe
Common sotol	<i>Dasyliion wheeleri</i>	Stalks roasted, boiled or eaten raw	Acoma, Laguna, Apache, Chiricahua, Mescalero
		Used to make a beverage	Apache, Chiricahua, Mescalero
		Crowns baked, pounded and dried for winter use	Apache, Chiricahua, Mescalero
Tansy mustard	<i>Descurainia</i> spp.	Seeds threshed, winnowed, ground and the flour used to make bread or boiled and eaten	Apache, Chiricahua, Mescalero
		Young plants boiled as greens	Cocopa (staple), Pueblo, Hopi
		Young plant dried and stored	Pueblo
Hedgehog cactus	<i>Echinocereus fendleri</i>	Raw fruit used for food	Apache, Chiricahua, Mescalero
		Stems pit roasted and eaten	Cochiti
Kingcup cactus	<i>Echinocereus triglochidiatus</i>	Water extracted from pulp in emergencies	Isleta
		Pulp macerated and cooked with sugar to make preserves, cakes or candy	Isleta
		Fruits, with spines removed by burning, eaten fresh	Isleta, Acoma, Laguna
		Stems pit roasted and eaten	Cochiti
Woodland strawberry	<i>Fragaria vesca</i>	Raw fruits eaten	Apache, Chiricahua, Cochiti, Mescalero, Isleta, Navajo
Sunflower	<i>Helianthus</i> spp.	Seeds ground, sifted, made into flour or dough and baked	Apache, Chiricahua & Mescalero, Pueblo
		Seeds winnowed, parched, ground and eaten as pinole or stored for winter	Mohave (staple)
Hymeno-pappus	<i>Hymenopappus</i> spp.	Leaves boiled, rubbed with cornmeal and baked into bread	Ute, Hopi
		Leaves and stems used to make a beverage	Isleta
Walnut	<i>Juglans</i> spp.	Nuts used for food	Comanche, Apache, Chiricahua, Mescalero

Appendix IV

New Mexico Ethnobotany Plant List: Food Plants

Juniper	<i>Juniperus</i>	Raw fruit eaten fresh; berries boiled and made into jelly or preserves; Berries boiled, ground or mashed and used with other foods; berries pounded with yucca fruit to make a gravy or drink	Apache, Chiricahua & Mescalero, Comanche
Pale wolfberry	<i>Lycium pallidum</i>	Berries eaten raw when perfectly ripe or boiled	Zuni
Red barberry	<i>Mahonia haematocarpa</i>	Berries eaten fresh or used in preserves	Apache, Mescalero, Chiricahua
Canadian mint	<i>Mentha arvensis</i>	Leaves used as flavoring	Apache, Chiricahua, Mescalero
Red mulberry	<i>Morus rubra</i>	Fruits eaten for food	Comanche
Deergrass	<i>Muhlenbergia rigens</i>	Seeds ground, mixed with corn meal and water and made into a mush	Apache
Whipple cholla	<i>Opuntia whipplei</i>	Fruit, with the spines rubbed off, dried for winter use	Zuni, Apache
		Dried fruit ground into a flour, mixed with parched corn meal and made into a mush	Zuni
Prickly pear	<i>Opuntia</i> spp.	Fruits eaten for food or dried for winter use	Comanche, Apache
		Seeds roasted, mixed with corn; Pads eaten fresh	Apache
Piñon pine	<i>Pinus edulis</i>	Nuts gathered in great quantities, toasted and stored for winter use	Zuni, Acoma, Tewa, Laguna, Jemez, Apache (staple), Chiricahua, Mescalero, Pueblo, Navajo (staple), Isleta (staple)
		Seeds mixed with yucca fruit pulp to make a pudding; secretion from the trunk chewed	Apache, Chiricahua, Mescalero
		Nuts gathered in large quantities to save and sell	Jemez
Narrowleaf cottonwood	<i>Populus angustifolia</i>	Buds used for food and as chewing gum	Zuni, Apache, Navajo
Honey mesquite	<i>Prosopis glandulosa</i>	Pods made into a meal and used for food	Comanche Food (staple)
Rio Grande cottonwood	<i>Populus wislizeni</i>	Buds used for food and as chewing gum	Zuni, Apache, Chiricahua, Navajo, Mescalero
Quaking aspen	<i>Populus tremuloides</i>	Inner bark scraped off and baked in the form of cakes or eaten raw	Apache, Chiricahua, Mescalero
Honey mesquite	<i>Prosopis glandulosa</i>	Seeds ground into flour and used in pancakes	Chiricahua, Apache (staple), Mescalero (staple)
		Beans boiled, pounded or ground, hand kneaded and made into a flour, jam, drink, or pudding; pods dried and stored	Chiricahua, Apache, Mescalero
		Root used to flavor drinks	Chiricahua, Apache, Mescalero
Chickasaw plum	<i>Prunus angustifolia</i>	Stored fruits used for food	Comanche
Chokecherry	<i>Prunus</i> spp.	Berries eaten fresh or dried and stored: ground, formed into cakes and dried	Apache, Mescalero, Chiricahua
Oak	<i>Quercus</i> spp.	Acorns eaten whole and raw, ground or boiled	Comanche (famine), Apache, Chiricahua, Mescalero
		Acorns ground into flour and used to make bread	Apache
Skunkbush sumac	<i>Rhus trilobata</i>	Berries eaten fresh, used for a jam, or drink or ground into meal	Ute, Apache (staple) Chiricahua, Mescalero

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Currant	<i>Ribes</i> spp.	Berries eaten fresh or made in jelly	Zuni, Comanche, Apache, Chiricahua, Mescalero, Ute
		Fruit made into cakes for use during winter	Apache, Chiricahua, Mescalero
		Leaves eaten with uncooked mutton fat or deer fat	Zuni
New Mexico locust	<i>Robinia neomexicana</i>	Pods eaten raw; pods cooked and stored; fresh flowers cooked with meat or bones	Apache, Chiricahua, Mescalero
Woods' rose	<i>Rosa woodsii</i> var. <i>woodsii</i>	Rose hips eaten fresh; rose pulps squeezed into water and boiled to make jelly	Apache, Ute, Chiricahua, Mescalero
Scarlet elderberry	<i>Sambucus racemosa</i>	Berries used for food; fruit cooked with a sweet substance, strained and eaten as jelly	Apache, Chiricahua Mescalero
Broadleaf cattail	<i>Typha latifolia</i>	Roots used for food; stem bases eaten raw or cooked	Apache, Chiricahua, Mescalero
Wild grapes	<i>Vitis</i> spp.	Fruit eaten fresh or dried	Apache, Chiricahua, Mescalero, Comanche
		Juice boiled to make wine	Apache
Banana yucca	<i>Yucca baccata</i>	Fruits pared and eaten raw or boiled and skinned; fruit made into conserves or syrup	Zuni
		Young leaves cooked in soups or with meat; flowers eaten as food only if obtained at the proper time; fruit roasted, split, seeds removed and pulp ground into large cakes; fruits used to make a drink; pods dried for future use	Apache, Chiricahua, Mescalero
Soaptree yucca	<i>Yucca elata</i>	Flowers boiled and eaten as a vegetable	Apache (staple), Mescalero (staple), Chiricahua
Small soapweed	<i>Yucca glauca</i>	Seed pods and flowers boiled and eaten. Stems baked, dried, broken into pieces, softened and eaten. Trunks pit cooked, pounded and made into flour; stored for future use	Apache, Chiricahua, Mescalero, Zuni
		Pods dried for future use	Apache

Appendix IV

New Mexico Ethnobotany Plant List: Cordage, Basket, & Dyes

CORDAGE, BASKETS, AND DYE			
Common	Scientific Name	Uses	
Agave	<i>Agave</i> spp.	Plant fibers used to make rope	Navajo, Southwest
Lechuguilla	<i>Agave lechuguilla</i>	Leaves used to make rough cordage	Southwest
Thinleaf alder	<i>Alnus incana</i> spp. <i>tenuifolia</i>	Soaked bark rubbed on buckskin as a red dye	Acoma, Laguna, Tewa
		Bark, mountain mahogany bark and birch bark boiled together and used as red dye	Jemez, Isleta
		Powdered bark used as a red-brown dye	Navajo, Zuni
Spreading dogbane	<i>Apocynum androsaemifolium</i>	Stems dried, pounded and used to make twine	Southwest
Milkweed	<i>Asclepias</i> spp.	Plant made into string and rope	Zuni, Tewa
Water birch	<i>Betula occidentalis</i>	Bark, mountain mahogany bark and alder bark boiled together and used as red dye	Jemez
Wholeleaf Indian paintbrush	<i>Castilleja integra</i>	Root bark used with minerals to color deerskin black	Zuni
True mountain mahogany	<i>Cercocarpus montanus</i>	Root bark, alder root bark and wild plum root bark used to make a red dye	Isleta
		Bark, alder bark and birch bark boiled together and used as red dye to paint moccasins	Jemez
		Used as a red dye for baskets	Navajo, Laguna, Acoma
Rocky Mountain beeplant	<i>Cleome serrulata</i>	Roots formerly used to make a dye	Isleta
Golden tickseed	<i>Coreopsis tinctoria</i> var. <i>tinctoria</i>	Blossoms used with other flowers as a mahogany red dye for yarn	Zuni, Apache
Rubber rabbitbrush	<i>Ericameria nauseosa</i> ssp. <i>nauseosa</i> var. <i>bigelovii</i>	Blossoms used to make a yellow dye	Zuni, Navajo, Apache, Hopi, Tewa
		Bark used to make a green dye	Hopi, Navajo
Fragrant ash	<i>Fraxinus cuspidata</i>	Wood used to make weaving tools.	Navajo
Western purple cranesbill	<i>Geranium atropurpureum</i>	Split epidermis used to sew moccasins. (Cordage)	Jemez
Upland cotton	<i>Gossypium hirsutum</i>	Fuzz made into cords	Zuni
Littleleaf ratany	<i>Krameria erecta</i> ; <i>Krameriaceae</i>	Roots used as a red dye for garments	Southwest
Lithospermum	<i>Lithospermum</i> spp.	Ground flowers used to make yellow paint	Acoma, Laguna
Sacahuista	<i>Nolina microcarpa</i>	Leaves used to make baskets for storage and washing of grains	Southwest
		Leaves used to make cords, ropes and whips	Southwest, Isleta
		Leaves woven together into baskets	Jemez
		Plant used to make a dye for blankets	Navajo

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New Mexico Ethnobotany Plant List: Cordage, Basket, & Dyes

Twoneedle piñon	<i>Pinus edulis</i>	Gum from old and new trees used as a red paint for jars and bowls	Jemez
		Gum used to prepare certain dyes	Hopi, Navajo, Tewa
Velvet mesquite	<i>Prosopis velutina</i>	Used as the warp element of baskets	Southwest
American plum	<i>Prunus americana</i>	Root bark, alder root bark and mountain mahogany root bark used to make a red dye	Isleta
Woolly paperflower	<i>Psilostrophe tagetina</i>	Blossoms used to make a yellow dye	Zuni, Acoma and Laguna
Oak	<i>Quercus</i> spp.	Twigs used as the framework of a temporary carrying basket	Navajo
Skunkbush sumac or Pubescent squawbush	<i>Rhus trilobata</i>	Stems used to make the warp and weft of baskets	Southwest
		Leaves used to make black dye for baskets and leather	Navajo
Sandbar willow	<i>Salix exigua</i>	Young branches used to make baskets.	Acoma, Laguna, Isleta
Narrowleaf yucca	<i>Yucca angustissima</i>	Leaves split and used as string	Southwest
Banana yucca	<i>Yucca baccata</i>	Leaves used for the main portion of the baskets; split leaves used as tying material	Southwest
		Leaves boiled, chewed and made into a double-stranded cord	Zuni
Soaptree yucca	<i>Yucca elata</i>	Leaves woven into shallow or tray baskets to carry prepared mescal home	Apache, Chiricahua, Mescalero
Small soapweed	<i>Yucca glauca</i>	Leaves used to make "moccasin strings" and cords	Southwest
		Used to make sifting baskets	Tewa
Torrey's yucca	<i>Yucca torreyi</i>	Roots used to produce a red pattern in baskets	Apache
		Leaves used for baskets	Apache
Rocky mountain zinnia	<i>Zinnia grandiflora</i>	Flowers rubbed into buckskin as a yellow dye	Acoma, Laguna

New Mexico Ethnobotany Plant List: Medicinal Plants

MEDICINAL PLANTS			
Snowball sand verbena	<i>Abronia fragrans</i>	Fresh flowers eaten for stomachaches	Zuni
		Plant used for stomach cramps	Navajo
		Plant used as purification and to cause vomiting and sweating	Navajo
		Plant used for insect bites	Navajo
		Plant used for boils	Navajo
Western yarrow	<i>Achillea millefolium</i>	Plant used as a fever medicine	Navajo
		Plant used for headaches caused by weak or sore eyes	Navajo
New Mexico giant hyssop	<i>Agastache pallidiflora</i> ssp. <i>neomexicana</i>	Plant used for fever	Navajo, Ramah
		Plant used as fumigant for "deer infection"	Navajo, Ramah
		Dried, pulverized root used as dusting powder for sores or cankers	Navajo, Ramah
		Plant used for bad coughs	Navajo, Ramah
Cuman ragweed	<i>Ambrosia psilostachya</i>	Infusion of plant given to women during difficult labor	Acoma, Laguna
Slimleaf burr	<i>Ambrosia tenuifolia</i>	Plant used to facilitate delivery of the placenta after childbirth	Navajo
Yerba mansa	<i>Anemopsis californica</i>	Poultice of green, chewed leaves applied to burns	Acoma, Laguna

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New Mexico Ethnobotany Plant List: Medicinal Plants

		Infusion of leaves used as a disinfectant on open wounds	Acoma, Laguna, Isleta
		Infusion of leaves taken for lung hemorrhages	Isleta
		Poultice of damp leaves used on open wounds	Isleta
Indianhemp	<i>Apocynum cannabinum</i>	Plant used for immersion in cold water	Navajo
		Infusion of plant used by mothers to produce more and richer milk	Acoma, Laguna
Western red columbine	<i>Aquilegia elegantula</i>	Infusion of plant used as a blood purifier	Acoma, Laguna
Mancos columbine	<i>Aquilegia micrantha</i>	Plant used to deliver placenta	Navajo
		Plant used as a hemostatic	Navajo
Chiricahua mountain columbine	<i>Aquilegia triternata</i>	Plant used as a ceremonial fumigant for headaches or other severe pain	Navajo
Pacific wormwood	<i>Artemisia campestris</i> ssp. borealis var. scouleriana	Plant used as a ceremonial fumigant ingredient	Navajo
Fringed sagewort	<i>Artemisia frigida</i>	Infusion of plant used as a stomach medicine	Isleta
Foothill sagewort	<i>Artemisia ludoviciana</i> ssp. ludoviciana	Crushed plant rubbed on body as a liniment for soreness or stiffness	Acoma, Laguna
Sagebrush	<i>Artemisia</i> spp.	Infusion of leaves used for fevers	Acoma, Laguna
		Infusion of plant used to bathe body parts for rheumatism	Acoma, Laguna
		Compound decoction of leaves boiled into a thick paste used as a salve or liniment for athletes	Acoma, Laguna
		Plant used as an ingredient in the sweatbath	Acoma, Laguna
		Infusion of plant taken or applied to a weak patient as a strengthener	Acoma, Laguna
		Compound decoction of leaves boiled into a thick paste used as a salve or liniment for horses	Acoma, Laguna
		Decoction of leaves thickened with sugar and used for constipation	Isleta
		Leaves used for all stomach troubles	Jemez
Big sagebrush	<i>Artemisia tridentata</i>	Leaves in shoes used for athlete's foot infection, fissures between toes and foot deodorant	Zuni
		Plant used for constipation	Navajo
		Infusion of plant taken and used as a lotion for water snake bites	Navajo
		Infusion of leaves used for body aches	Zuni
		Plant used for religious and medicinal ceremonies	Navajo
		Infusion of leaves taken as a cold medicine	Zuni
Louisiana sagewort	<i>Artemisia ludoviciana</i>	Leaves chewed and used for insect and spider bites	Comanche
	<i>Astragalus</i> sp.	Plant used as a lotion for illness from exposure	Navajo
		Plant used as an emetic	Navajo
		Plant used for any disease of the ears	Navajo
		Plant used for mumps	Navajo
		Plant used as a lotion and poultice of plant applied to ringworm	Navajo
		Plant used as a lotion and poultice of plant applied to ringworm.	Navajo
		Plant used for stomach disorders	Navajo
Silverscale saltbush	<i>Atriplex argentea</i>	Poultice of chewed root applied to sores and rashes	Zuni
		Stimulant, ant bites-reduce swelling and pain, emetic, stomach disease	Isleta, Jemez, Navajo, Acoma, Laguna

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New Mexico Ethnobotany Plant List: Medicinal Plants

Brickellia	<i>Brickellia ambigens</i>	Dried, ground leaves mixed with water and used as a salve	Acoma, Laguna
		Infusion of plant used for flatulency and overeating	Acoma, Laguna
		Infusion of plant used as liver medicine	Acoma, Laguna
California brickellbush	<i>Brickellia californica</i>	Plant used as a lotion on infant sores caused by prenatal infection	Navajo
Tasselflower brickellbush	<i>Brickellia grandiflora</i>	Dried, ground leaves mixed with water and used as a salve	Acoma, Laguna
		Infusion of plant taken for flatulency and overeating	Acoma, Laguna
		Infusion of plant used as a liver medicine	Acoma, Laguna
Narrowleaf brickellbush	<i>Brickellia oblongifolia</i> var. <i>linifolia</i>	Plant lotion used on infant ear and finger sores caused by prenatal infection	Navajo
Seep willow	<i>Baccharis</i> spp.	infusion used to bathe the head for headaches and as a rub for swelling	Acoma, Laguna
Rabbit brush	<i>Chrysothamnus</i> spp.	Decoction of entire plant, except the roots, used as a bath for fevers	Isleta
		Small bit of stem used in cavities for toothache	Isleta
		Decoction of entire plant, except the roots, taken for venereal diseases	Isleta
		Plant used for chest colds	Jemez
		Plant used as a gargle	Jemez
Spring parsley	<i>Cymopterus</i> spp.	Plant eaten as a stomach medicine	Acoma, Laguna
		Infusion of plant taken and used as a lotion for wounds	Navajo
		Plant used for backache	Navajo
		Plant used to settle stomach after vomiting from swallowing a fly	Navajo
Sacred thornapple	<i>Datura wrightii</i>	Infusion of leaf used as wash for wounds of sheep after castration	Navajo
		Poultice of crushed leaves or roots used for boils	Acoma, Laguna
		Powdered roots used in the religious-medicine ceremonies	Apache
		Poultice of plant applied for sprains and fractures	Navajo
		Used as a narcotic	Zuni, Ute, Navajo
Mountain tansy mustard	<i>Descurainia incana</i> ssp. <i>incisa</i>	Plant used as a lotion for frozen body parts	Navajo
		Plant used as a lotion for sore throats	Navajo
Tourist plant	<i>Dimorphocarpa wislizeni</i>	Crushed seeds and leaves inhaled for catarrh or sore nose	Acoma, Laguna
		Infusion of plant taken and used as lotion for centipede or sand cricket bites	Navajo
		Poultice of plant applied to hemorrhoids	Navajo
		Plant chewed by children to strengthen teeth	Navajo
		Flower and fruit eaten as an emetic for stomachaches	Zuni
Purple cone flower	<i>Echinacea</i> spp.	Decoction of root taken for sore throat Root held against tooth for toothaches	Comanche
Torrey's jointfir	<i>Ephedra torreyana</i>	Infusion of stems used as a cough medicine	Acoma, Laguna
		Stems used as an ingredient in the sweatbath	Acoma, Laguna
		Infusion of stems taken or stems chewed for kidney or bladder trouble	Acoma, Laguna
		Decoction of leaves and stems used to make a lotion for itching skin	Isleta
Buckwheat	<i>Eriogonum alatum</i> spp.	Plant used as a lotion for rashes	Navajo
		Root eaten for stomach problems	Zuni, Navajo
		Infusion of plant used for kidney disease	Navajo
		Poultice of plant applied to back for leg paralysis	Navajo
		Plant smoked for snakebites	Navajo
		Plant used as a lotion for bear or dog bite	Navajo
		Roots chewed for a heart medicine	Acoma, Laguna
		Infusion of roots used for despondency	Acoma, Laguna
		Root soaked in water and used as a wash for sore eyes	Zuni

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New Mexico Ethnobotany Plant List: Medicinal Plants

		Fresh or dried root eaten for stomachaches	Zuni
		Plant used for backaches and sideaches.	Navajo
		Infusion of roots used for lightning shock (sedative)	Acoma, Laguna
		Leaves used for sore throats	Navajo
		Plant used during confinement after childbirth	Navajo
		Hot infusion of plant given to mothers after childbirth for fever	Acoma, Laguna
		Infusion of plant used as a douche after childbirth	Acoma, Laguna
		Plant used as a disinfectant and emetic for biliousness	Navajo
Showy frasera	<i>Frasera speciosa</i>	Poultice of large, salted leaves applied to the head for headaches.	Isleta
		Decoction of large, fleshy root used as a lung medicine for asthma	Isleta
		Ground plant sprinkled on incision when castrating livestock	Navajo
Velvetweed	<i>Gaura mollis</i>	Fresh leaves used in pillows to overcome insomnia	Acoma, Laguna
		Fresh, soft leaves worn as a headband for their cooling effect in hot weather	Isleta
		Plant used as a disinfectant	Navajo
		Poultice of plant applied for postpartum sore breast	Navajo
		Fresh or dried root chewed by medicine man before sucking snakebite and poultice applied to wound	Zuni
Gumweed	<i>Grindelia sp.</i>	Infusion of plant used for severe stomachache	Acoma, Laguna
		Poultice of flower applied to ant bites	Zuni
		Fresh or dried root chewed by medicine man before sucking snakebite and poultice applied to wound	Zuni
		Decoction of dried, ground plant used as a wash for cuts	Jemez
Broom snakeweed	<i>Gutierrezia sarothrae</i>	Strong, black infusion of crushed plant used as a rub for rheumatism	Acoma, Laguna
		Chewed leaf juice taken for and rubbed on rattlesnake bites	Acoma, Laguna
		Infusion of plant used as an eyewash	Acoma, Laguna
		Used for purification	Acoma, Laguna
		Poultice of moistened leaves used for bruises	Isleta
		Infusion of leaves used as a bath for fever	Isleta
		Infusion of leaves used for venereal diseases	Isleta
		Decoction of plant used for sores	Jemez
		Decoction of plant taken by women after childbirth following the cedar decoction	Jemez
		Plant used for headaches and as a sedative	Navajo
		Plant used for bloody diarrhea and gastro-intestinal disease	Navajo
		Infusion of whole plant used for muscle aches	Zuni
		Infusion of whole plant taken to increase strength for urinary retention	Zuni
Alumroot	<i>Heuchera spp.</i>	Decoction of root taken as needed for internal pain	Navajo, Ramah
		Poultice of split root applied to infected sores, swellings and fractures	Navajo, Ramah
		Plant used for rat bites and a sedative	Navajo
Gilia	<i>Ipomopsis spp.</i>	Poultice of plant applied to sores	Navajo
		Plant used as a cathartic and emetic and blood purifier	Acoma, Laguna, Navajo
		for spider bites and for stomach disease	Navajo
		Poultice of dried, powdered flowers and water applied to remove hair on newborns and children	Zuni
Oneseed juniper	<i>Juniperus monosperma</i>	Infusion of staminate cones used for diarrhea or bark chewed as a laxative	Jemez, Acoma, Laguna
		Chewed bark taken for or applied to spider bites	Acoma, Laguna
		Plant used as an ingredient in the sweatbath	Acoma, Laguna
		Ground leaves mixed with salt and used in ears to eliminate bugs	Acoma, Laguna
		Infusion of cedar bark used for bathing and washing sore feet	Isleta

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New Mexico Ethnobotany Plant List: Medicinal Plants

		Fusion of leaves used for gynecological aids	Isleta, Jemez, Zuni
		Infusion of leaves taken to prevent conception	Zuni
		Seeds eaten for headaches	Navajo
Narrowleaf gromwell	<i>Lithospermum incisum</i>	Plant used for colds and coughs and oral contraceptive	Navajo
		Plant used as an oral contraceptive	Navajo
		Powdered root mixed with bum branch resin and used for abrasions and skin infections; Infusion of root taken for stomachache; root taken for kidney problems	Zuni
Star milkvine	<i>Matelea biflora</i>	Root paste used for bruises, broken bones, stomach pain, and menstrual cramps	Comanche
Red barberry	<i>Mahonia haematocarpa</i>	Inner wood shavings soaked in water and used as an eyewash	Apache, Mescalero
Colorado four o'clock	<i>Mirabilis multiflora</i>	Plant used for rheumatism for "swellings" and various mouth disorders	Navajo, Nambe
		indigestion	San Ildefonso
		eye infection	Santa Clara
		Powdered root mixed with flour, made into a bread and used to decrease appetite	Zuni
Cholla and Prickly pear	<i>Opuntia</i> sp.	Stems scorched, split and used for infections and cuts.	Apache, Mescalero
		Liquid extract of boiled roots used as antidiarrheal drug and laxative	Apache
		Poultice of peeled stalks applied to burns	Apache
Piñon pine	<i>Pinus edulis</i>	Leaves chewed for venereal diseases	Apache
		Pitch used on open sores	Zuni, Isleta, Acoma, Laguna
		Infusion of foliage used as an emetic to clean the stomach	Navajo, Acoma, Laguna
Skunkbush sumac	<i>Rhus trilobata</i>	Infusion of leaves used as a stomach wash	Acoma, Laguna
		Infusion of bark used as a douche after childbirth	Acoma, Laguna
		Berries used for a mouth wash	Acoma, Laguna
		Bark chewed for sore gums	Jemez
		Plant used as a lotion for poison ivy dermatitis and for bowel troubles.	Navajo
Juniper mistletoe	<i>Phoradendron juniperinum</i>	Crushed plant given to children for diarrhea and used as a rub for rheumatism	Acoma, Laguna
		Plant used for warts	Navajo
		Infusion of whole plant taken as an emetic for stomachaches	Zuni
Velvet mesquite	<i>Prosopis velutina</i>	Poultice of chewed leaves applied for red ant stings.	Papago
		Poultice of pulverized gum applied to sores	Papago
Sandbar willow	<i>Salix exigua</i>	Infusion of bark taken for coughs and sore throat	Zuni
		Root taken for kidney problems	
Yucca	<i>Yucca</i> spp.	Emulsion used in cases of snake or insect bites	Apache
		Plant used as a laxative	Navajo
		Infusion of tender heart shoots used for weakness	Acoma, Laguna
		Infusion of tender heart shoots used for weakness	Acoma, Laguna
		Crushed root used in purification	Hopi
		Root mixed with ground stolons from vine mesquite grass & used as a hair wash to make the hair grow	Isleta
		Root used as a strong laxative	Hopi

The majority of the table data originated from the Native American Ethnobotany Database website: <http://naeb.brit.org/>

Appendix V

MAKE YOUR OWN QUADRAT FRAME

Option 1:

4 – 1 meter x ½ inch PVC tubing pieces

4 right angle elbows

PVC adhesive

Build a one-meter-square quadrat frame using PVC tubing. Affix one elbow to each 1-meter piece with PVC adhesive. Transport frame as 4 pieces. Assemble the frame at monitoring site by joining the 4 pieces into a square.

Option 2:

4 – 1 meter sticks or lathe

4 screws with wing nuts

Overlap the meter sticks at the end in a right angle. Have someone hold while you drill through both sticks. Insert screw and wing nut, attaching the two. Repeat for the other two meter sticks. Now overlap the ends of the two pieces and drill making a square. Wing nuts can be loosened to fold up the square for easier transporting.

Option 3:

2 – 1 meter x ½ inch PVC tubing sleeves

4+ meters of non-stretch twine or light rope

1 small snap

Thread the two tubing sleeves onto the twine and tie a small loop in the end of the twine. Measure 4 meters of twine, plus an inch or two more, and cut. Tie the snap onto this end. The final length of your twine should measure 4 meters from the end of the loop to the end of the snap. Attach the snap to the small loop of twine to make an overall 4-meter loop. Stretch the loop using the tubing, making a square shape, and lay on the ground. This is best used with stakes or flags to secure the corners into a rigid square. (Hint: double check twine measurement after tying; you may need to adjust your knots to make a 4-meter loop)

Using your quadrat frame:

Make sure that your quadrat can be taken apart or folded up for carrying. It is best to leave one corner of the quadrat unattached so you can unfold the quadrat and slide it under the vegetation into place. If all four sides are fixed, you must place the quadrat over the vegetation, which can be difficult with tall plants, shrubs, or trees.

