Section I
NATURAL HISTORY OF THE COAST REDWOODS

Chapter 1 of this section introduces the three species of "redwood," and discusses what is so special about the coast redwood, *Sequoia sempervirens*. Chapter 2 provides a review of basic scientific and ecological principles, especially as they pertain to the coast redwood ecosystem. Chapter 3 reviews some of the major environmental concerns about the coast redwood ecosystem. Chapter 4 provides information about some of the most common or most important organisms found in the coast redwood forest.

This is not intended to be a comprehensive or detailed summary of the science associated with studies of an individual species such as the coast redwood, nor of a complex ecosystem such as the redwood forest. It does provide basic background for teachers and others who may not have extensive backgrounds in forestry or forest ecology. Elementary students need not learn all of this information. However, teachers who have a good background in the natural history of the redwoods will be better able to take advantage of "teachable moments" while with students in redwood parks and forests.

The study of science enables students to understand how the world works, to appreciate nature's beauty, wonder, and importance, and to fund one's place in the world. While the learning of vocabulary is not an end in itself, a working knowledge of scientific terms makes learning and communicating easier. Likewise, discovering the etymology of words facilitates the understanding of both scientific and non-scientific terms. Throughout *Redwood Ed*, **bold** type emphasizes important vocabulary that will help clarify the information being reviewed. (See Appendix II for a glossary of terms.)

Chapter 1
The Redwoods

There are three species of trees that are commonly referred to as "redwoods." All three species have until recently been classified in the family Taxodiaceae, which includes other trees such as the "bald cypress" of the southeastern U.S., a type of Japanese cedar, and a Chinese tree mistakenly called a "fir." They are now classified in the cypress family, Cuppressaceae. Some other trees are sometimes called redwood, including Montezuma bald cypress, *Taxodium mucronatum*, which is the national tree of Mexico. Other related species of "redwood" occur in various parts of Asia. There are even three species of "Tasmanian redwood," *Athrotaxis* spp. (Helfer, 1966). (See Chapter 4 for a discussion of naming and classification of organisms.)

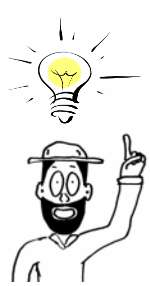
Each of the three species of trees that will be referred to as redwood in *Redwood Ed* is classified in its own genus, and they are the sole living representatives of those genera. The three types of "redwoods" are:

- The coast redwood: *Sequoia sempervirens*
- The giant Sequoia, big tree, or Sierra redwood: *Sequoiadendron giganteum*
- The dawn redwood: *Metasequoia glyptostroboides*

Cuppressaceae is an ancient family of trees, dating back to the middle of the Triassic period (about 240 million years ago). Redwoods thrived during the days of the dinosaurs. In these ancient times, various related genera and species were spread throughout Europe, North America and Asia, even extending into Australia. As climates changed and glaciers came and went, various species became extinct, leaving only the three relict species living in divergent and very limited areas.

An example of these ancient redwoods can be seen at the Petrified Forest in Calistoga, northeast of Santa Rosa. Here students can see petrified redwood trees that were apparently knocked over by a volcanic explosion. As the wood decayed, it was replaced by minerals, resulting in "petrified wood."

Teaching Idea



Group tours are available at The Petrified Forest. See the web site at:

< www.petrifiedforest.org >

See figure 1 on page 9.

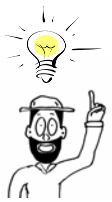
Figure 1. The first entry of an automobile into the "petrified forest," September 10, 1911. (Photo courtesy of The Petrified Forest)

The Dawn Redwood

The dawn redwood, *Metasequoia*, once lived throughout the high northern latitudes. It was thought to be extinct until 1944, when a Chinese botanist found some living specimens in central China, where it was called the water-larch or water-pine and was fed to cattle. In 1946 it was "officially" classified. A tree thought to have been extinct for 20 million years was found to be thriving! By 1948 the attractive tree was being planted in many places throughout the world. It is a good thing that the seeds were spread and planted, because by 1980, no dawn redwood seedlings or young trees could be found in the valley where they were rediscovered, apparently because of human population growth in the area (Barbour *et al.,* 2001).

The dawn redwood, unlike the coast redwood or the giant Sequoia, is **deciduous**, losing its leaves (needles) in the winter. Its leaves and cones resemble those of the coast redwood very closely; in fact, *Metasequoia* fossils were often mistakenly identified as *Sequoia*.

Teaching Idea



The Save-the-Redwoods League has produced a booklet about the dawn redwood. Redwoods of the Past, by Ralph Chaney (1990), includes pictures of fossils, a map showing the distribution of the dawn redwood and coast redwood, and a variety of pictures of Metasequoia. See Appendix III for the League's contact information. An accounting of the dawn redwood's discovery can also be found in Barbour et al. Coast Redwood (2001).

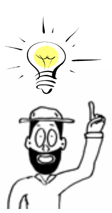
The Giant Sequoia

The giant Sequoia redwood was once common in northern North America, but climate changes reduced its range until only one species, *Sequoiadendron giganteum*, remains. These magnificent trees are confined to about 75 scattered groves on the western side of the Sierra Nevada, from the south fork of the American River to the southern Sierra.

The giant Sequoias are the most massive things to have ever lived on Earth.* While they don't match the coast redwood in height, their girth can be massive. The "General Sherman Tree," in Sequoia National Park, is 275 feet tall, 27 feet in diameter, and over 80 feet in circumference. Its lowest branch is about 150 feet above ground, 6 feet in diameter at its base, and 150 feet long. Giant Sequoias can live to be over 3,500 years old, making them among the oldest living things. Giant Sequoias were extensively logged during the gold rush even though they tended to shatter upon hitting the ground. Most are now protected in state and federal parks, although some are still commercially harvested.

*What constitutes a single "living thing" isn't as simple as one might think. Mushrooms have root-like structures called mycelia which can cover many acres and sprout many mushrooms above ground. If all of those mycelium-connected mushrooms are considered to be one organism, such an organism may be the largest living thing. Similarly, several coast redwoods may sprout from the root system of a fallen tree. If all of those sprouts from the common root system are considered to be a single organism, their mass may exceed that of the largest giant Sequoia.

Teaching idea

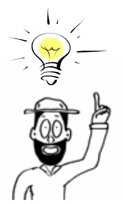


Many parks and schools have planted dawn redwoods and giant Sequoias. If you are visiting a park, find out whether they have specimens to which you can compare the coast redwood.

The Coast Redwood

The coast redwood, *Sequoia sempervirens*, is the subject of this guide. As a species, it appeared in western North America at least 23 million years ago, but other species of redwood-like trees were here long before that. Some authors date *S. sempervirens* to around 60 million years ago (Noss, 2000). Eight to ten thousand years ago, *Sequoia sempervirens* ranged farther south, but since the climate has become drier and warmer, its range has moved farther north while the southern part of its range has constricted.

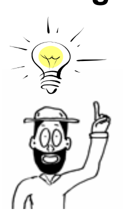
Teaching Idea



All three types of redwoods can be purchased from nurseries and will grow throughout the coast redwood region and beyond. Work with local nurseries, parent-teacher groups, timber companies, and environmental groups such as those listed in Appendix III to obtain young trees of all three types and, with students, plant them on the school grounds. This might be done on Arbor Day or Earth Day in conjunction with a ceremony honoring an individual, a group or company, or even the trees themselves for their contributions to our society. Consider some sort of time capsule or plaque.

Prior to planting, be sure that there is adequate space for a tree that will someday be quite large, that there is adequate water, etc. Check with your buildings and grounds staff.

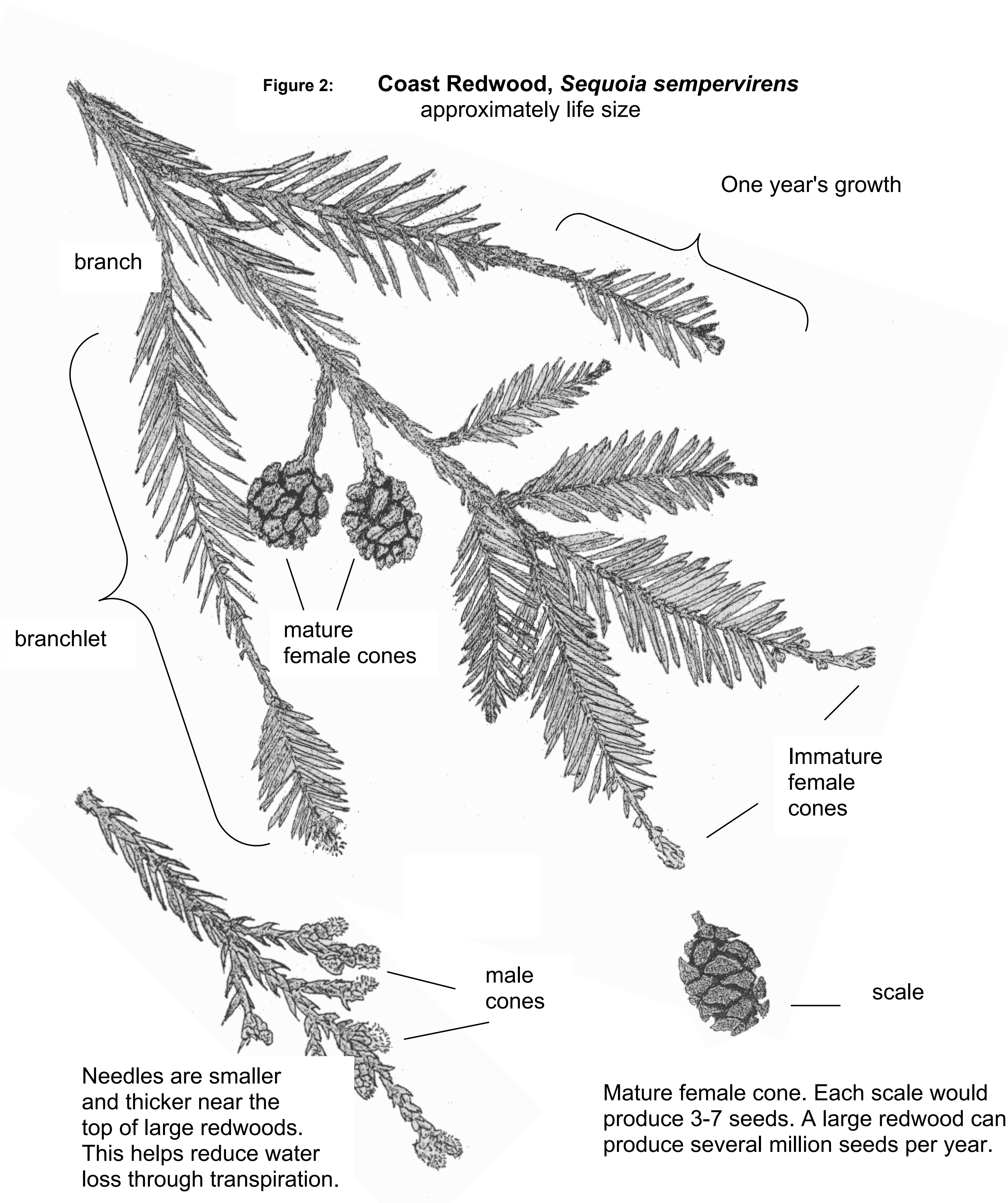
Teaching Idea



If you plant trees, start collecting baseline data…height, diameter at base, diameter breast height, diameter of the area beneath the branches. Take photographs with a student holding a yard stick for comparison. Record this information and update it annually. Compare the three species for such things as growth rate, diameter of the area beneath the branches, insects found on or around the trees, or other things that students notice and can record for comparison over the years. If you do this, plant them in similar sunlight and soil conditions and arrange to have them watered similarly.

Another possible study can be done on trees of the same species growing under different conditions. Trees can be planted in full sun, partial shade, and full shade, or can have different watering schedules. Compare growth rates, needle size, density of branches and twigs, or other characteristics.

Figure 2: **Coast Redwood, *Sequoia sempervirens***
approximately life size



Needles are smaller and thicker near the top of large redwoods. This helps reduce water loss through transpiration.

Mature female cone. Each scale would produce 3-7 seeds. A large redwood can produce several million seeds per year.

Drawings from *Life History and Ecological Guide to the Coast Redwood, Sequoia sempervirens*, by Daniel J. Miller.

Figure 3: **Giant Sequoia, *Sequoiadendron giganteum***

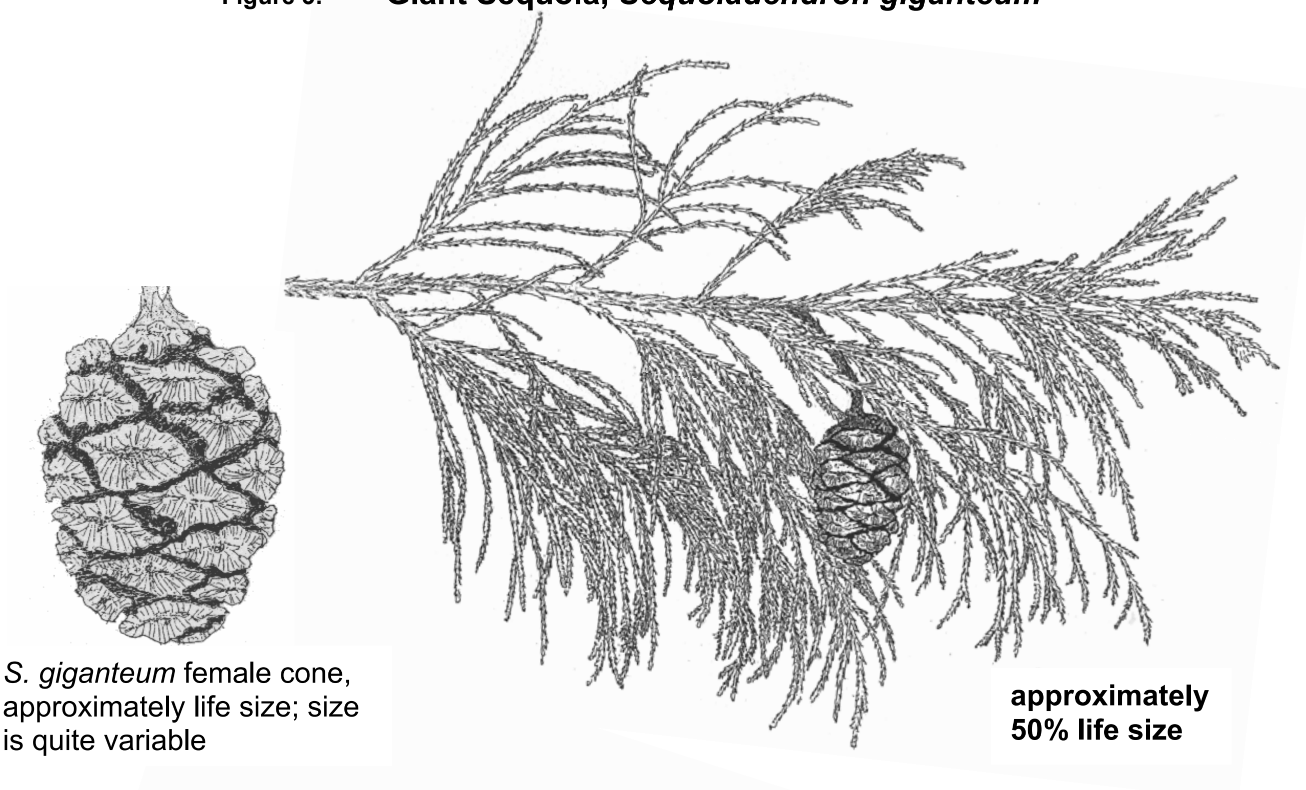
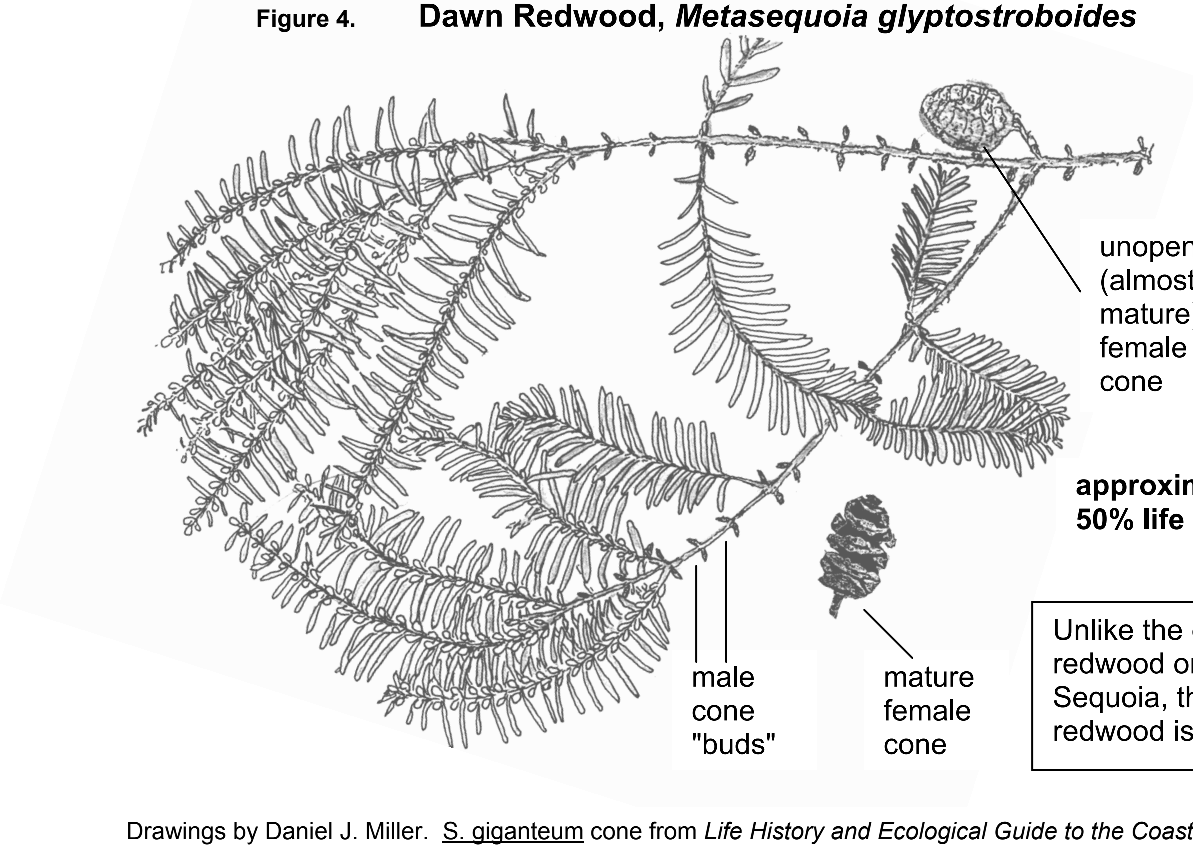


Figure 4. **Dawn Redwood, *Metasequoia glyptostroboides***



Unlike the coast redwood or the giant Sequoia, the dawn redwood is deciduous.

Drawings by Daniel J. Miller. S. giganteum cone from *Life History and Ecological Guide to the Coast Redwood, Sequoia sempervirens*, by Daniel J. Miller.

Chapter 2
The Science and Ecology of the Coast Redwood

What's so special about coast redwoods?

The coast redwood, *Sequoia sempervirens*, is a very special tree, scientifically, commercially, and aesthetically.

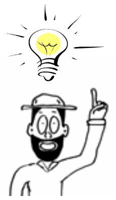
Coast redwoods grow to the greatest height of any tree.* Like most records, the record for the tallest tree changes as new trees are discovered and measured and former champions die or are damaged. In 1963, a survey team from National Geographic Society found a group of trees in the Redwood Creek area of Humboldt County that were believed to be the tallest trees in the world. The Tall Tree or Libby Redwood, as it is called, was measured at 367.8 feet. Since then it has lost several feet of height due to dieback of its tip, and sediments from flooding have also raised the surrounding forest floor. Steve Sillett, an associate professor at Humboldt State University, has since measured a redwood in Humboldt State Redwoods Park at 370.1 feet tall. In the fall of 2006, three redwoods in Redwood National Park were measured at over 371 feet tall, with the tallest, called the Hyperion Tree, at 378.1 feet (Geniella, 2006). According to the Save-the-Redwoods League, the Hyperion Tree has subsequently been re-measured and found to be 379.1 feet tall!

*There have been claims of taller Douglas-fir trees and eucalyptus, but the coast redwoods reach the greatest verified height among trees living today.

Many studies have been done to try to determine how water can reach the top of a redwood tree that is over 300 feet tall. The process isn't thoroughly understood, but the processes of **cohesion**, **adhesion**, and **capillary action** seem to play an important part. Essentially, water molecules "stick" together, so that when a water molecule evaporates from a needle, through a process called **transpiration**, it "pulls" the next molecule upward. That molecule of water, in turn, pulls the next one and so forth. These processes don't completely explain how the water reaches the top of such a tall tree, though. It may be that water-conducting tissues of redwoods are more efficient than those of most trees. More research needs to be done to understand this basic yet complex issue.

See the activity "Let's Stick Together" in section IV.

Teaching Idea



When in a grove of redwoods, ask the students to state some ideas about how the trees can get water up to the top leaves. Record their ideas and follow up when you return to the classroom with the activity "Let's Stick Together!" from Section IV.

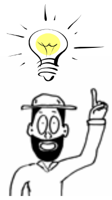
Coast redwoods reach great diameters. The giant Sequoias of the western Sierra reach a larger circumference, over 40 feet at the base and 25-30 feet near the base, but the coast redwoods can reach great size, too. Coast redwoods can reach diameters over 30 feet at the base and 12-18 feet near the base, although most are much smaller.

Figure 5

Figure 6

(Photos courtesy of The Clarke Museum)

Teaching Idea



*When measuring the size of trees, foresters generally measure the circumference at "breast height" (4.5 feet), and use that to calculate the diameter at breast height (**dbh**). (Actually, they use a special tape measure that does that calculation for them. See the activity "Making a Forester's Diameter Tape" in Section IV.) This is especially important in the case of the coast redwood because the base often flares out significantly, resulting in a trunk that may be quite a bit smaller when measured several feet above ground level. Using the diameter of the tree or log and its height or length, foresters estimate the volume of lumber that the tree or log can provide.*

Since circumference equals pi times the diameter, the diameter equals circumference divided by pi.

$$C = \pi \times d \qquad\qquad d = C \div \pi$$

Work with students to practice converting circumferences of circles to diameters. You can also work on rounding off and approximating. For example, have the students calculate the difference between using 3.14 for pi and using 3.1 or 3 when calculating the diameter of a tree with a given circumference. Is the error greater if the circumference is greater?

e.g.: If the circumference is 10 feet, using 3.14 gives a diameter of about 3.18 feet, while using 3 for pi yields a diameter of about 3.33 feet, a difference of 0.15 ft.

If the circumference is 20 feet, using 3.14 gives a diameter of about 6.37 feet, while using 3 for pi yields a diameter of about 6.67 feet, a difference of 0.3 ft.

See the activities "Making a Forester's Diameter Tape" and "Redwood Pi" in Section IV.

<u>Coast redwoods can have a huge volume of wood</u>. According to Noss (p. 92), the largest giant Sequoia has a trunk wood volume of almost 1,500 cubic meters. The largest coast redwood has a volume of over 1,000 cubic meters. The next largest tree, a western red cedar, has a volume of barely 500 cubic meters. Studies indicate that a healthy stand of redwoods may have more **biomass** than any other **ecosystem** on earth! The greatest known biomass of standing vegetation on earth occurs in a redwood forest stand, where there may be over 1,400 metric tons of biomass per acre (Veirs, 1996).

A single tree in Humboldt County has an estimated volume of 361,336 board feet, which is enough to build 22 five room houses!

See the activity "How Big?" in Section IV.

Coast redwoods can grow rapidly.
While trees living in the shade grow relatively slowly, redwoods growing in optimal conditions can grow quite rapidly. A stand of vigorously growing redwoods can grow up to 2000 board feet per acre per year between the ages of 40 and 60, which is enough wood to build an average-sized house every five years. They are the fastest growing **softwood** species in the United States (California Redwood Association, 1990).

Since redwood trees can be re-grown in a relatively short time, they are considered a renewable resource. Unlike iron, concrete, or plastics, new redwood trees can be grown where the original forest stands have been removed, but it should be noted that a **second-growth** forest is not the same as an ancient forest.

Coast redwoods can live a very long time. The oldest trees are probably the bristlecone pine trees of the Sierra, which have been measured to be over 4,000 years old. The giant Sequoias can live to be 3,500 years old. (Some earlier measurements indicated up to 4,000 years, but more current research indicates a lower age limit for the giant Sequoia.) The oldest coast redwoods are about 2,200 years old (Schneider, 1988).

It is interesting to note that the redwoods with the largest diameters are not necessarily the oldest. The largest specimens are usually found in alluvial flats or flood plains of coastal rivers. The access to sunlight, water, and nutrients provided by periodic flooding in these areas provides optimal growth conditions. While these trees are adapted to withstand the flooding, they usually succumb within a thousand years or so. Some trees in more protected areas can grow older, but they generally don't grow as large.

Coast redwoods can sprout new trees from stumps or damaged trees. While many kinds of **hardwood** trees will produce sprouts from stumps or damaged trunks, few softwood trees (**conifers)** do so. Redwood stumps sprout so prolifically that early homesteaders had trouble keeping new trees from growing in cleared fields, and stump sprouting is a major source of "new" trees in logged stands. Since a stump sprout already has a built-in root system, stump sprouts grow much more rapidly than seedlings. A stump sprouted sapling may grow as much in one year as a seedling grows in seven years. Occasionally, a falling redwood branch will impale itself into the ground, sprout roots and branches, and form a new tree. Logs awaiting milling will often sprout new branches as they sit at the sawmill.

An interesting question arises from the coast redwood's tendency to sprout new trees from stumps, roots, or even branches. If a tree is cut or is otherwise injured, coast redwoods often sprout new trees from the old stump. Is that sprout a new tree, or is it still the original tree? If it is still the original tree, and the sprouted tree subsequently sprouts new sprouts, are they still the original tree? If redwoods do this for several generations, and if the sprouted trees are considered to still be the original tree, some trees may be several thousand years old even though they don't have the growth rings to show it! (Other trees, such as quaking aspen, also stump sprout readily.)

The species name for the coast redwood is *sempervirens*, which means "ever living." The stump sprouting and longevity of the trees make this an apt species name!

Coast redwoods resist fire, insects, and disease. Redwood's resistance to fire is due in part to its thick, fire-resistant bark. The bark will burn if thoroughly dry, but it is very absorbent and holds moisture. Also, as compared to fir and pine, the wood and bark of coast redwoods contain relatively little flammable pitch.

Chemicals called **tannins** give redwood its distinctive color and also provide resistance to insects and fungus-caused diseases. (Apparently the insects don't like the taste of the tannins.) This resistance to rot earned redwood a well-deserved reputation as a wood that could be used for such things as fence posts, grape stakes, and railroad ties where the wood is in contact with the ground.

Tannins accumulate in the wood over time, and older trees generally have more tannins than younger trees. Due to the accumulated tannins, the **heartwood** of old redwoods is generally darker than that of young redwoods, and young growth redwood lumber, with less accumulation of tannins, is generally not as decay resistant as old-growth redwood lumber.

Lumber from coast redwoods is superior to other kinds in many respects. When different kinds of wood are compared for their commercial properties, redwood has earned the highest ratings in such things as durability, resistance to fire, glue-holding ability (important when joining small pieces to make larger boards), capacity to accept paint or stains, dimensional stability (not shrinking or expanding too much when dry or wet), and resistance to termites and rot. These properties make it especially useful for exterior applications such as decking, siding, and fences. Most redwood is relatively lightweight when dry (Simpson Timber Company, 2003). When combined with its beauty and ability to grow rapidly, these properties have earned redwood the reputation as a commercial "wonder wood" (Adams, 1969?). Redwood doesn't do as well as some other woods such as Douglas-fir in "compression" tests, though, so it generally isn't used for wall studs.

When considering redwood as lumber, it is important to distinguish between wood coming from slow growing ancient trees and wood coming from rapidly growing trees such as "young-growth" forests typically produce. The close grained, clear, dark red wood with large amounts of insect- and rot-resistant tannins generally comes (or came) from large old redwoods such as those logged prior to the 1970s. Very few of these "**old-growth**" trees remain available to loggers, so most redwood found in lumber yards comes from young-growth trees which have not had the time to deposit large amounts of tannins, and generally have more knots.

See the activity "Fence Post Studies" in section IV.

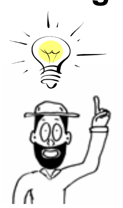
Coast redwoods are the state tree…actually ***a*** state tree. In 1931, the "California Redwood" was named the official state tree. However, the bill did not distinguish between the giant Sequoia and the coast redwood. In 1951, it was decided that the state tree designation would be shared by the two species.

General Ecological Principles

What is Ecology?

Ecology is the study of an environment, the organisms that live in the environment, and their interactions. Some people use the term "ecology" to mean conservation or environmental protection. In *Redwood Ed*, we will use the scientific meaning…the study of interactions and interconnectedness of organisms and their environment, including such factors as light, soil, water, and air.

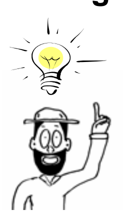
Teaching idea



When introducing the term "ecology," it might be useful to discuss the word roots of the term. "Eco-" comes from the Greek term for home, and "–ology" means " the study of." So, ecology is, literally, the study of our home. Looking at the earth as our home can be very helpful when discussing environmental concerns. Introducing the word roots can also be helpful when discussing other "ologies" such as biology, geology, zoology, etc. It is also good to encourage the proper and specific use of terms. People sometimes say they're "protecting the ecology." Do they really mean that they're protecting the study of the environment? Or do they mean that they're protecting the environment?

The physical parts of the environment are called the **abiotic factors**. These include such things as temperature, light, humidity, soil nutrients, and substrate type. **Biotic factor**s are those that result from living things and their interactions with each other. Some specific abiotic and biotic factors of the coast redwood forests will be discussed in the later part of this chapter, but let us first review some basic ecological principles and vocabulary.

Teaching Idea



An important part of ecological studies deals with how organisms meet their needs for energy, materials, water, etc. Have students list their own needs and how they are met. Discuss true "needs," which are few, as distinguished from "wants," which are usually many. Also discuss the prices that we pay, not just in terms of money, for satisfying our needs and wants.

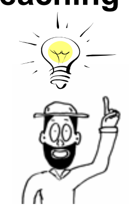
Cycles

There are many **cycles** in nature, and they are important to all organisms in all places, including people. Described below are some simplified versions of some of the important natural cycles.

Unlike energy, matter (chemical substances…the "stuff" of which everything is made) remains in the environment. It is neither created nor destroyed except in very unusual (on Earth) circumstances. This "**Law of Conservation of Matter**" is a basic law of nature, and warrants discussion with the students. It gives us the basis for the need to recycle, explains why we can't just create new stuff from nothing, and also explains why pollutants don't just "go away."

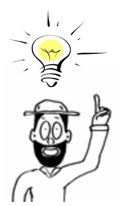
One place where the Law of Conservation of Matter plays a role in the redwood forest is in the **decomposition** of dead material. Bacteria, fungi, and other organisms "recycle" dead limbs, leaves, and organisms through the process of decomposition. Branches, tree tops, and other woody debris from logging are also decomposed or burned. Burning simply changes the wood into smoke and ash, recycling the materials in another way.

Teaching Idea



One way to help students to remember the main organisms involved with decomposition is "F.B.I."…fungi, bacteria, and insects.

Teaching Idea

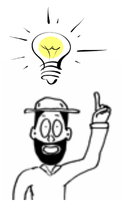


Ask a student to throw away a piece of trash (or to tell how he or she would throw away a piece of trash). The student will doubtless throw it into the trash can. Point out that the trash can isn't really "away." It is just a different place, and the custodian will put it into a dumpster after school. The dumpster, of course, isn't really away either. The contents of the dumpster will go into a garbage truck, which will take it to a landfill – it's still not really gone! Also point out that where there is now a landfill, there was once a field, forest, or some other natural environment. There is no "away!" Whether we like it or not, the matter that we have on Earth, including our pollution, will stay with us, and we can't create more matter. We can, however, change it, from useful matter to trash, or, sometimes, from trash to useful matter.

The Water Cycle

Energy from the sun causes water from the Earth's surface to evaporate and enter the air as water vapor. As water vapor cools, it forms clouds. Further cooling results in precipitation as rain, snow, or hail. Fog is formed when moist air near the ground cools, and "fog drip" is a very important source of water for the coast redwoods.

Teaching Idea



Have students tell what happens when they exhale their warm, moist breath on a cold day, either into the air or onto a mirror or window. This condensed water is similar to a cloud of fog.

Depending on where precipitation falls, it may re-enter surface water systems such as lakes, streams, and oceans, or it may fall onto the ground. Surface water may flow downhill as runoff in a stream, soak into the ground, or evaporate, starting the cycle again. A healthy forest has a rich soil with an abundance of organic material that absorbs and holds a lot of moisture.

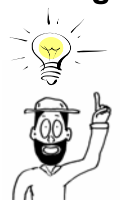
See the activity "Water Cycle in a Jar (or Two)" and "Have a Foggy Idea" in Section IV.

If water enters the ground, it may be absorbed by plants, join the underground water system (**aquifer**), or it may re-emerge as a spring.

Plants move water through their **vascular systems**, consisting primarily of xylem and phloem cells produced by the **cambium** layer. The **xylem** moves water and minerals upward from the roots, while the **phloem** brings carbohydrates produced by the leaves to the other cells throughout the plant.

Some of the water taken up by the roots is used in **photosynthesis** and some is expelled through their leaves by a process called transpiration. Transpiration is water loss through the leaves of a plant, and it plays a very important role in the redwood forest. Warm, dry air increases water loss through transpiration. Fog decreases transpiration and is a major factor in determining where coast redwoods can (or cannot) grow.

Teaching Idea



When discussing transpiration, compare it to perspiration.

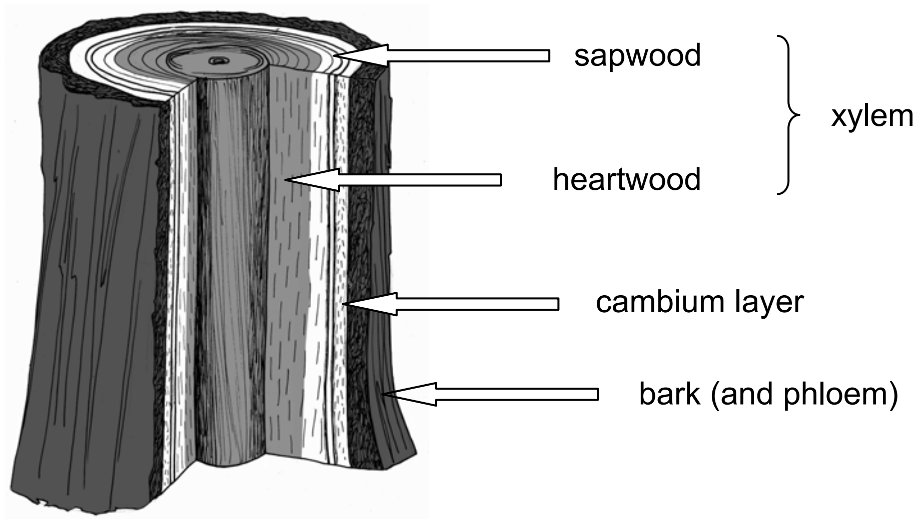


Figure 7

The living, active sapwood and the inactive heartwood make up the xylem, while the phloem is just beneath the bark, and is sometimes considered to be part of the bark.

See the activity "Transpiration" in Section IV.

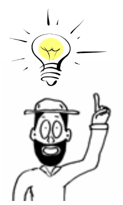
Students are often interested to find out that every bit of water that they drink has been used by thousands of other organisms during its existence on Earth. The water that they drink today, for example, was probably once part of a dinosaur. The same holds true for the other substances in our bodies.

Water and the water cycle are extremely important to the coast redwoods and are further discussed below.

<u>The Oxygen/Carbon Dioxide Cycle, and Photosynthesis</u>

Oxygen enters the air primarily through the process of photosynthesis. In photosynthesis, plants use carbon dioxide and water to produce complex molecules of sugars. In the process, oxygen is released into the environment as a byproduct. On land, this oxygen "waste product" enters the air. In aquatic environments it may be dissolved into the water as it is released by plants or it may be released as tiny bubbles.

Teaching Idea



Place a sprig of a leafy plant, or an aquatic plant such as Elodea from an aquarium/fish supply store, in some water. Have students closely observe the small bubbles that form on the leaves. Then place the plant (still in the water) in the sun or under a bright light. Look for more bubbles of oxygen as the plant's photosynthesis increases. (Because gases dissolve more readily in cool water, some of the bubbles will be due to air coming out of the solution. This property of cool water to hold more dissolved air/oxygen is important to fish such as salmon and trout. They require cool water. Removal of shade cover over streams can reduce their ability to support trout or salmon populations. See the activity "Fantastic Photosynthesis" in Section IV.)

Plants and other organisms use the sugars produced in photosynthesis as an energy source through the process of **respiration**. Respiration is a chemical process in which cells use oxygen and food such as sugars to release energy from the food, producing carbon dioxide and water in the process. (Students often confuse respiration, which is a chemical process, with breathing, which is the physical act of taking air in (inhaling) and exhaling waste from the lungs.)

As cells use oxygen in respiration, they produce **carbon dioxide** (CO_2). Carbon dioxide is a waste product which must be expelled into the environment. During the daytime, carbon dioxide is removed from the environment by plants and some one-celled organisms in the process of photosynthesis, for which carbon dioxide is a raw material.

Forests play a very important role in the production of the oxygen on which we all depend. When trees (or other plants) are replaced by buildings or pavement, less oxygen is produced. A vigorously growing forest produces a lot of oxygen. Not only does photosynthesis produce oxygen, but it also takes carbon dioxide out of the air. Carbon dioxide is a major **greenhouse gas** that is a significant factor in **global warming,** or the **greenhouse effect**. Forests, therefore, not only replenish oxygen, but they also help remove excess carbon dioxide.

See the activity "Global Warming" in Section IV.

The Nitrogen Cycle:

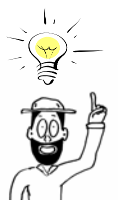
The element nitrogen makes up about 78% of the air. Nitrogen is an important raw material for many chemicals that organisms need to produce, including amino acids, which are building blocks for proteins, and nucleic acids, which form DNA. Most organisms, however, cannot use the nitrogen found in the air.

Some organisms, especially certain bacteria and some lichens, are able to use atmospheric nitrogen to form simple compounds such as nitrates. Plants, in turn, use the nitrates to form various more complex nitrogen-containing compounds. Animals, including people, get nitrogen from their foods.

Nitrogen compounds form an important part of animals' waste products. They provide fertilizer that is used by plants both on land and in the water. Nitrogen is also important because it is a necessary component of proteins, which are such an essential group of chemicals that they are sometimes referred to as the building blocks of life.

When organisms die, the nitrogenous compounds, as well as the other chemicals found in their bodies, are returned to the environment through the process of decomposition. Decomposition is accomplished through the action of various bacteria, fungi, and insects.

Teaching Idea



It is interesting to discuss what would happen if we didn't have bacteria and fungi to decompose dead organisms. Students will quickly understand that un-decomposed bodies would accumulate. More importantly, perhaps, chemicals needed by living things would be tied up in the un-decomposed bodies, depriving living organisms of the nutrients that they need.

See the activity "Duff Dwellers" in Section IV.

<u>Energy</u>

Most of the Earth's energy comes from the sun. Some of the sun's energy is reflected back into space by the atmosphere even before it reaches the Earth's surface. Other solar energy is absorbed by the atmosphere, oceans, and land, and is re-radiated into space as heat.

Of the energy that does reach the Earth's surface, some is reflected, some is absorbed as heat energy, and some is used by plants in the process of photosynthesis. Most of the energy that is absorbed is radiated back out to space at night. The energy stored in chemicals by photosynthesis is returned to the environment when the organisms use the sugars produced by photosynthesis in the process of respiration.

As a result of all of these processes, energy is said to "flow through" the environment, constantly coming to Earth and being re-radiated back out into space. This is in contrast to matter, which is constantly recycled on earth through natural processes. The vast majority of organisms on Earth depend on the sun for a constant supply of energy.

An important aspect of energy in an ecosystem is the temperature range produced by sunlight. The coast redwood has a fairly narrow range of temperature tolerances. Unlike the giant Sequoias and dawn redwoods, the coast redwoods do not do well where the ground freezes in the winter. While the presence of fog, especially in the summer, is a major reason that the coast redwoods live near the coast, the temperature moderating influence of the Pacific Ocean is another.

Niches and Trophic Levels

Human communities have people who fill various roles, such as growing food, producing various products, cleaning up the waste, and providing a variety of other services. Natural communities also have a variety of organisms that fulfill a variety of roles. The roles or jobs of organisms are called their **niches**. A redwood tree, for example provides food for some organisms. It also provides shade. Some animals, and even plants, live in redwood trees. All such roles combine to describe an organism's niche. One important part of an organism's role is its **trophic level**, or the place it has in a **food chain**.

The basic group of organisms on which all others depend is the **producers**. It is the producers that use the process of photosynthesis to produce complex chemicals upon which life depends. The most obvious producers in the redwood forest are the trees, but others, such as the ferns, mosses, and flowering plants, are also important.

Organisms that don't photosynthesize, such as animals, are called **consumers** because they obtain their energy from the food that they eat or consume. Consumers are often further divided into three or four groups:

Herbivores mostly eat plants. Examples include deer, squirrels, and wrens.

Carnivores mostly feed on animals. Frogs, owls, and ticks are carnivores.

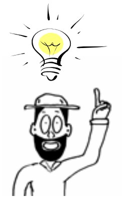
Omnivores eat both plants and animals. The raccoon is an example. As a species, humans are also considered to be omnivores.

Scavengers (detritivores) feed on dead animals or plants. Examples include turkey vultures and California condors.

Another important group of consumers is the **decomposers**. These organisms, mostly bacteria and fungi, consume dead organic matter and return the nutrients to the soil where the nutrients can then be used by plants again.

It is important to remind students that all consumers, including people, depend on the plants (producers) that form the basis of the food chain. (See below for a discussion of food chains and **food webs**.)

Teaching Idea



Have students compare their human community to a natural community such as a redwood forest. Compare the niches of organisms to the roles that people play in their community.

Food Chains and Food Webs

A "food chain" is a concept that ecologists find useful when studying ecosystems such as the redwood forest. Basically, a food chain is intended to show which organisms feed on which other organisms. For example, an insect might feed on a fern in the forest. A frog might eat the insect, and the frog might be eaten by a garter snake. The garter snake might, in turn, be eaten by a hawk. When the hawk dies, its body would be consumed by bacteria and fungi as well as a variety of insects and worms. Each of these steps is considered to be a trophic level.

Food chains are useful because they provide a simple illustration of the relationships between various organisms. However, food chains are almost always oversimplifications. The fern might have been fed upon by other types of insects, or deer, or other animals. The frog would eat a variety of insects, and the garter snake would eat other organisms, too. Although they are oversimplified, food chains can be useful in studying organisms.

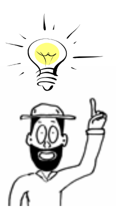
A more realistic, but more complex, concept is that of the "food web." A food web shows that most organisms eat, and are eaten by, a variety of organisms.

When people discuss or teach about food chains and food webs, they often don't emphasize the critical role of the decomposers. Without the decomposers, the raw materials needed by the producers would soon be locked up, or sequestered, in the bodies of dead organisms.

While not technically part of food chains and food webs, the physical parts of the environment, such as water, sunlight, and minerals, are also important in food chains and food webs.

The next page shows examples of food chains and a food web such as might be found in a redwood forest.

Teaching Idea



Use a transparency of the Food Chain/Food Web diagram when teaching about those concepts.

Figure 8. A Redwood Forest Food Chain

An arrow indicates that an organism is eaten by another.
For example, grass ⟶ deer
(is eaten by)

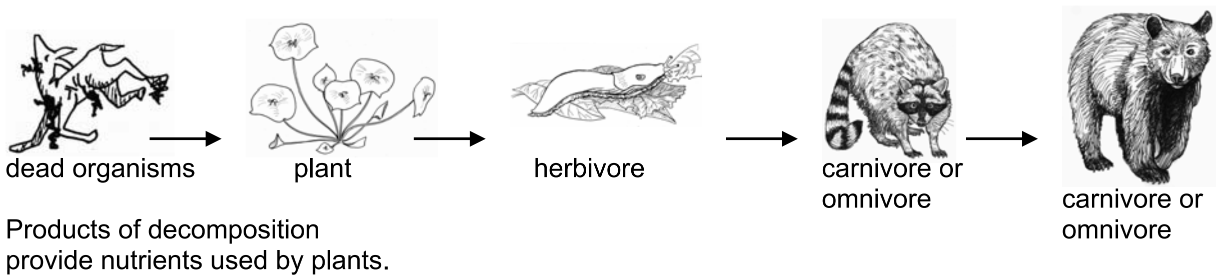
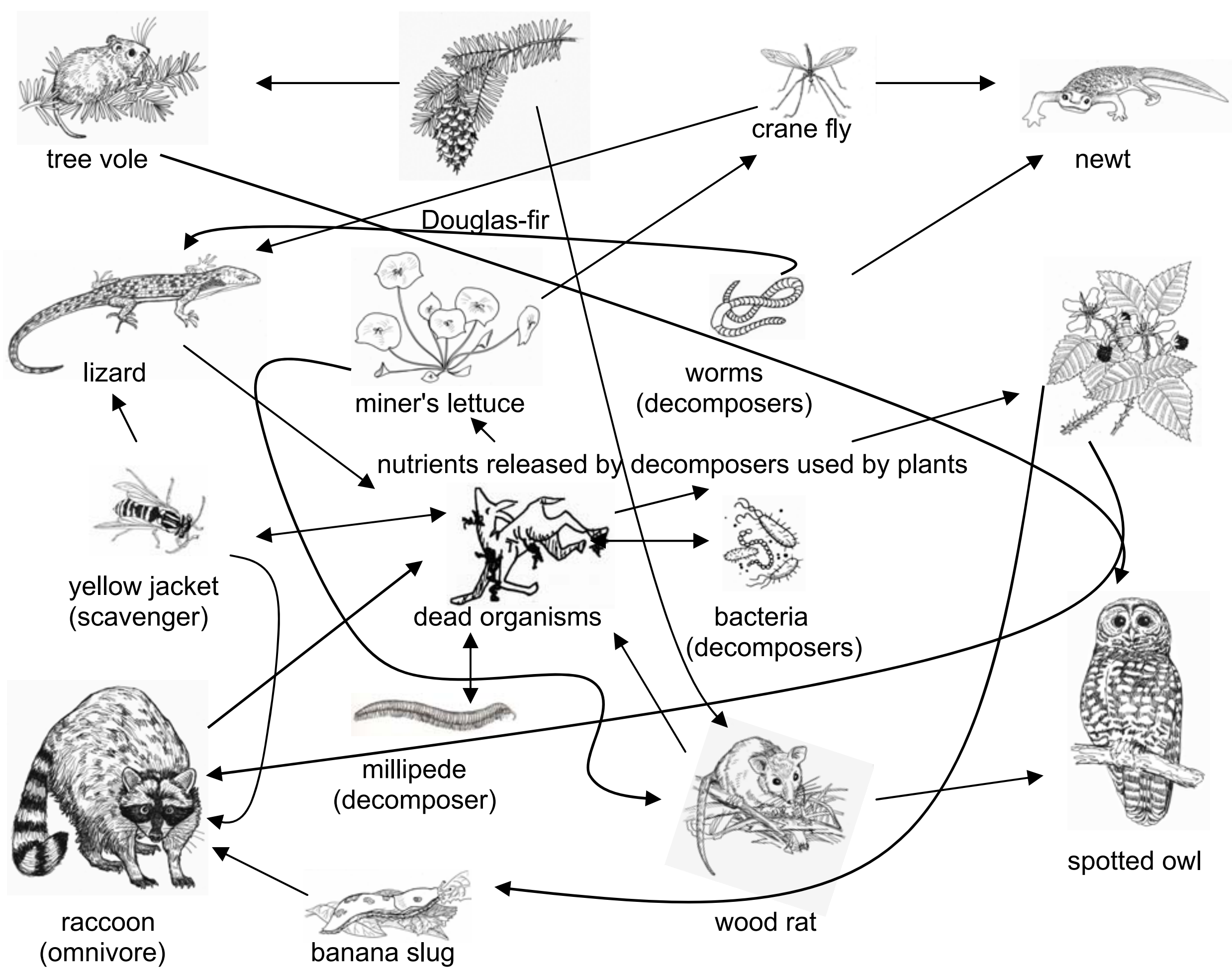


Figure 9. A Simplified Redwood Forest Food Web

Remember that the organisms depend on light (energy) from the sun, minerals and water. Even in this simplified food web, not all organisms or connections are drawn.



See the activities "We're All in This Together" and "Who's for dinner?" in Section IV.

Populations

In the science of ecology, a group of individual organisms of the same species living in a defined area is considered to be a **population**. When an ecologist discusses a population, he or she will identify both the organism and the place. One might study the population of banana slugs on a fallen redwood log, deer in and around a meadow, or coast redwoods in a **watershed**.

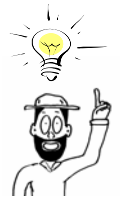
The number of individuals in a population is limited by one or more factors in the environment. Depending on the organism, the factor might be available soil nutrients, water, sunlight, food, temperature, predators, or any of a number of other factors. Whatever limits a population is called the **limiting factor**. Thus, sunlight reaching the forest floor might be the limiting factor for low-growing plants, while moisture available in the summer might be a limiting factor for coast redwood trees. Available nesting places might be a limiting factor for birds such as the marbled murrelet. Suitable food or shelter might be a limiting factor for deer or the northern spotted owl.

The number of a type of organism that can thrive in a habitat is determined by one or more limiting factors. **Carrying capacity** refers to how many of a particular organism can live in a place over a long period of time without causing damage to the environment. One could place several deer in a small meadow, but they may not do well if there were too many, i.e., if the number exceeded the carrying capacity of the meadow. The carrying capacity for deer in a meadow is much lower than the same meadow's carrying capacity for mice or grasshoppers. If there are too many of an organism for the environment to sustain, the organisms are said to have exceeded the carrying capacity of that place.

Many students have heard of **overpopulation**. To an ecologist, "overpopulation" means exceeding the carrying capacity of a place, or exceeding the number of individuals that a place can support without harm to the environment. With regards to human population, one must consider not only how many people a place (a house, a town, a state, a continent, or the Earth) can support, but also the quality of life for the people (or other organisms). Of course, the Earth can support many more people living at a subsistence level than it can support at the level of resource use that we have in the United States. Even within the United States, some people use many more resources than others. It might be useful to discuss the quality of life vs. quantity and whether we should be willing to consume less so that others can have enough to survive.

A discussion of carrying capacity can help students understand the importance of trying to minimize their negative impact on natural environments. It can also help them to understand that they can have positive impacts.

Teaching Idea

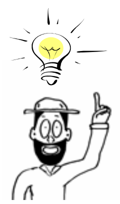


Discuss "wants" vs. "needs." Many things that most of us consider almost necessities (telephones, cars, televisions, soda pop, meat, etc.) would be considered luxuries by much of the world's population. Discuss the idea of "living simply so that others may simply live."

<u>The Pyramid of Numbers or Pyramid of Biomass</u>

As one goes "up" a food chain, there is a decrease in both numbers and the total mass of the organisms (biomass). This is because organisms are not 100% efficient in converting food to body mass. Some of the food is converted to body mass, but much of it is lost as waste. A single grasshopper, mouse, deer, bear, or human will eat many times its weight in its lifetime.

Teaching Idea



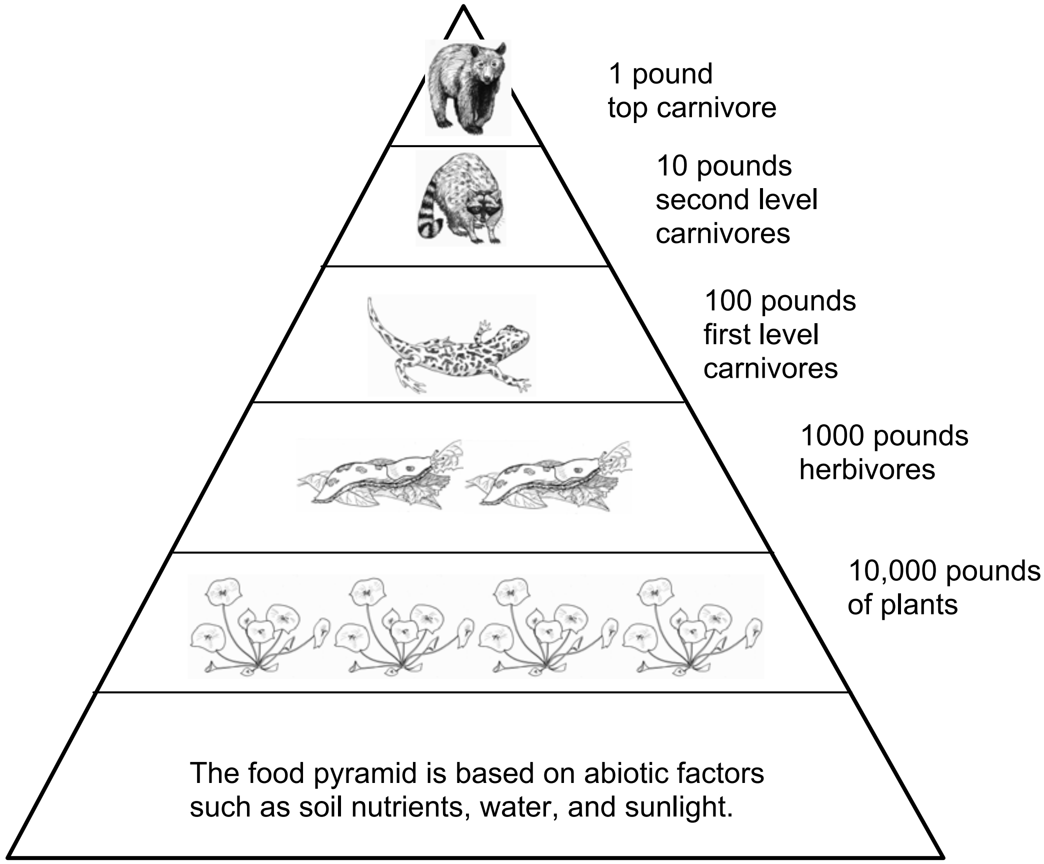
Discuss with the students what would happen if this inefficiency were not true. Ask a student to estimate how much he or she eats in a day. If they were 100 percent efficient, they would gain that amount of weight each day! Have the students calculate (and, perhaps, graph) how much weight they would gain in a week if their body added all of their food to itself. Point out that eventually all potential food matter would be "tied up" in living organisms.

In reality, of course, most of the food that we eat is not added to our bodies, even though it may seem like it as we approach middle age! Most of the food that we take in is expelled from our bodies as solid waste (feces), liquid waste (urine and perspiration), or gaseous waste (CO_2 and water vapor in our breath). While the efficiency of conversion varies among organisms, an often-used approximation is 10%. Using that estimate we can create a hypothetical **pyramid of numbers** or biomass like the one below.

An important consequence of this inefficiency is that more steps in a food chain result in fewer top consumers (such as people). A given amount of land can support more people if they eat plants such as corn, wheat, or rice than if the same amount of land is used to raise cattle for people to eat. Basically, the Earth can support more vegetarians than carnivores. For example, a field can support more mice or grasshoppers than lizards or foxes.

See the activity "The Higher the Fewer" in Section IV.

Figure 10. **A Redwood Forest Food Pyramid**



Habitat, Community, and Ecosystem

A **habitat** is a place where an organism lives. A stand of redwoods is a habitat, as is a clearing in the forest or a decomposing log. The redwood forest is not a homogeneous environment. There are various **microhabitats** such as the shaded forest floor, rotting logs, streamside (**riparian**), sunny openings, dead trees (**snags)**, and others. Studies of redwood soil organisms reveal some of the highest known diversities of soil organisms of any type of ecosystem (*Redwood, 1969?*). Even a redwood tree itself has microhabitats ranging from the bark at the base of the tree, to the crotches of branches, to the forest **canopy**. Each microhabitat will have its own set of organisms filling the various niches.

See the activity "Microhabitats" in Section IV.

The forest itself can be viewed as having different vertical layers. The soil and the organisms that live in it provide the foundation on which the forest grows. On top of the soil is the **humus**, where leaves and other organic materials are decomposing. The top part of the humus is the **duff**, consisting of more recently fallen leaves and twigs that have begun to decompose but are still recognizable as leaves. On top of the duff is the recently fallen **litter**.

Beneath the litter, duff, and humus is, of course, the soil. The nature of the soil is an important factor for all plants, including the coast redwoods. One indication of the importance of soil is the growth rates of redwoods growing in alluvial flats as compared to those growing in different soil types "upslope." In conjunction with the greater availability of water, the deeper, richer soils of the alluvial floodplains result in growth rates as much as 20 times that of the trees growing in the thinner, drier soils on some hillsides.

Growing near the ground are the ground cover plants. Shrubs are larger. Small trees form the **understory**. The canopy consists of the top branches of the taller trees.

The lower branches of a single tree or group of trees will sometimes hang down nearly to the ground, creating sort of a tent-like effect around the trunk(s). This "tent" may reduce the light and water so much that no green plants can grow underneath it. While fog drip and water from light rains may be reduced, the tent-like enclosure may actually have fairly high humidity due to transpiration. Such redwood tents are another type of microhabitat.

Forests can also be subdivided horizontally or laterally. Some organisms do best in the interior core of the forest, while others need to be near forest openings. The edge of the forest, between forest and grassland, or between redwood forest and hardwood forest, provides a greater diversity of microhabitats and, therefore, has a greater diversity of organisms. The same is true for the edge of a stream, lake, or rocky outcropping.

In an old-growth forest, there are normally gaps in the canopy due to **treefall**. Treefall can be caused by many things such as wind, a landslide above a tree, slumping of soil down slope, root rot, or erosion of the bank of a stream. These gaps provide microhabitats that allow a greater diversity of both plants and animals than one would find in an even-aged forest. Similarly, streams not only provide habitat for the aquatic and riparian organisms, but also provide access for sunlight into the nearby forest. If timber lands are managed to maintain a diversity of microhabitats, they can maintain some of the species diversity found in a natural forest. Studies have shown that pure stands of redwoods, whether in a naturally "pure" redwood forest or an area managed so that redwoods predominate, have less diversity and abundance of wildlife than stands that include a variety of types of trees (Diller, 1996).

See the activities "Creek Studies," "Duff Dwellers," and "Microhiking" in Section IV.

Each type of habitat is defined by a set of abiotic (non-living) and biotic (living) factors.

All of the organisms that live together in a habitat can be referred to as a **community**. A community is a group of interacting populations in a given geographic area. Just as our human communities have people that do different jobs, natural communities include organisms that make their living in different ways and depend on each other. A redwood community would include the redwood trees and the various other plants, animals, fungi, lichens, and bacteria that live with them. Each member of the community has a particular role or niche. Any natural community will have a diversity of organisms, *i.e.,* it will have **biodiversity**. A community with the organisms that naturally occur there is said to have **biological integrity**, *i.e.,* it is a "natural" community.

Another thing to consider regarding redwood forest communities and habitats is the spatial arrangement. One factor is the size of the "patch" of habitat. Some species will do fine if they have some logs under which to live. Others, however, require large areas. Ten 1-acre stands or patches may not support any of a particular species of bird, while one ten-acre stand may support many. Fragmentation of habitat is an important concern as forest land is developed for other uses such as houses, shopping centers, and roads.

Three types of redwood forest communities are often described. The **alluvial-flat** forest type exists along the rivers and creeks where a deep soil has been built up by periodic flooding. The temperatures are mild, summer fog persists, the soils are rich, deep, and well-drained, and moisture is plentiful. It is in the alluvial-flat redwood **stands** that the largest and most magnificent trees are usually found. Alluvial-flat stands may be almost pure redwoods, which form a dense shade-producing **overstory** or canopy, or they may include a variety of shade-tolerant species (Barbour *et al.,* 2001).

Most of the parks with which people are familiar were formed around alluvial flat groves. Since those groves contain most of the superlative trees, it was those groves that were first protected. Trees in the lowlands are typically much larger than those growing on the slopes and uplands. Alluvial flat groves, however, make up only a small fraction of the total redwood forests. The vast majority of the redwoods are found on the hillsides above the flats.

Away from the stream bottomland, redwoods often grow mixed with Douglas-fir trees. North-facing slopes may have more available moisture and may retain it longer than the south-facing slopes, which are typically shallower and retain less moisture. Tanoak and madrone may form understories, especially where the slope is more exposed. Since these upland stands of trees don't have the optimal growth conditions of the alluvial flats, the trees are generally smaller. There are exceptions, though, as the tallest known tree, the Hyperion Tree in Redwood National Park, is "upslope." These slope forest stands are, however, important in the protection of the downhill and downstream groves and watersheds.

At higher elevations, above 1000 feet, the slopes are often even steeper and the soils shallower, so even less soil is retained. In the northern part of the redwood region, redwood may dominate the overstory, but Douglas-fir or other conifers may grow with it, forming a mixed evergreen forest type. Tanoak, madrone, huckleberry, and rhododendrons may form a dense understory and shrub layer. In the southern region, a **subcanopy** layer is often formed by the tanoak.

When we combine the community of organisms with the habitat in which they live, we have an **ecosystem**. Within the ecosystem, the organisms interact with each other and with their physical environment. A community can be large, like a redwood forest covering hundreds acres and including many ridges and valleys, or smaller, like a particular stand of redwoods on a hillside or on an alluvial flat along a river, or even very small, such as the community of organisms living in and on a fallen log, or in the upper branches of a redwood tree.

Communities are not static; they continually change over time. The sequence of change from one community to another is sometimes called **succession**. The idea of succession involves a series of progressive changes in the species structure of the community. Many textbooks describe succession as a gradual and continuous replacement of one group of plants and animals with another. It is, however, rarely as simple and linear as that. Changes in the physical environment tend to favor different species, so different species dominate at different times. Species from previous or later successional stages will usually be present at several stages.

See the activity "The Only Constant is Change: Succession in Action" in Section IV.

Succession on newly formed land (primary succession), such as a lava flow or bare rock, might proceed through successional stages like this: bare rock…lichens on the rock breaking it down and trapping nutrients…mosses or small grasses growing among the lichens…small herbaceous plants growing in the accumulating soil…small grasses…bushes and shrubs…shade intolerant trees…shade tolerant trees…forest.

A common textbook example of succession occurs as a lake fills with sediments and becomes first a shallow pond and then a marshy area. As sediments continue to accumulate, the marsh may become a grassy field. Bushes and shrubs may invade the field, eventually being replaced by forest trees.

In the redwood forest, anything that creates bare soil can start a new successional process. Bare soil is commonly produced by landslides, falling trees, silt from floods, fires, clearing of land for homes or roads, or logging. The first plants that grow on the bare soil are called the **pioneer species**, and in the redwood area may include many other species, including grasses, blackberries, poison oak, coyote brush, or others, including **exotic** (non-native) species. Redwood seedlings or sprouts may be among the first plants to begin growing. In the redwoods, succession isn't so much a sequence of different plants as a change in which plants dominate.

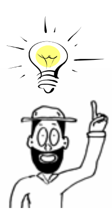
The series of communities in a successional sequence is called a **sere**, and each of the temporary communities is called a seral stage. Eventually, succession may slow down and a more or less steady state may be achieved. The "final" community is stable, tolerant of the environmental conditions that it imposes upon itself. This "final" stage has been called the **climax community**, but it is rarely, if ever, truly a final stage. While the late stages of succession are relatively stable and may last for a long time (hundreds or even thousands of years), they are not permanent. Nutrients may be tied up in vegetation, or fire, flood, landslide, or other event may set succession back. A more modern concept is that of a community reaching a state of dynamic equilibrium in which individual plants and animals are constantly dying and being replaced, resulting in a constantly changing community.

The redwood community is now considered to be a "late seral stage," but some ecologists feel that it may not be the climax community for the area. Unless something disrupts succession, the redwood forest may be replaced by a variety of other forest types including hardwoods, western hemlock, Douglas-fir, and other species. Some believe that we owe the existence of the coast redwood forests to periodic fires and floods that kill these other species. Others maintain that, since fire and flood are natural occurrences in the redwood region, redwoods should be considered the climax community type.

A 1969 study done on the Redwood National Park indicated that, if fire is kept out of the park and other methods of removing competing species aren't introduced, succession would probably result in change in the constitution of the forest, especially in the alluvial flats. It suggested that over the next 500 years, many redwoods would be replaced by hardwoods, Douglas-fir, and other species, and that the redwoods might disappear from Redwood National Park in 2000 years (Lowell, 1990).

In some areas, old-growth forests of even-aged trees suggest that natural phenomena such as fires and landslides cleared swaths of the natural forest much like **clear-cut** logging does. Clear-cutting has been compared to natural processes such as fires, landslides, and treefall, but natural disturbances rarely occur over areas as large as clear-cut areas, and the type, scale, and severity of the disturbance is usually different.

Teaching idea



Have students compare and contrast clear-cutting with fire with regards to their effect on the forest. How are they similar and how are they different? What happens to the materials in the tree when it is cut? When it is burned? What is the impact on other plants and animals? On the water and soil? How long does it take for the forest to recover?

<u>People</u>

The role of people in the redwood region is discussed in Section II, with emphasis on the timber industry. Conservation and environmental concerns are discussed in Chapter

3 of this section. Today, all but about 5% of the original coast redwood forests have been logged. Most of that 5% is in parks and reserves. Almost all logging by timber companies is done on privately-owned land that has already been logged once, or even twice, producing **second-growth** and **third-growth** redwood.

Not only has the timber industry shifted from cutting **old-growth** trees, but its methods have changed. When timber land was cheap, regulations essentially non-existent, and the redwood forests seemed infinite, an exploitative attitude of "cut out and get out" prevailed in the redwood timber industry. Today, land is relatively expensive, regulations abound, and timber companies generally manage their holdings as a long-term investment.

As California's population has increased, more people want to move into the redwood region, especially in the southern and central parts where there is less rain and fog. In those areas, an important threat to the redwood forests is from fragmentation as people purchase small parcels on which to build homes. Of course, to build homes, people cut trees for the building site, roads, and to open up the area so that they can have sun for their swimming pool, deck, and lawn. This fragmentation has a great impact on the redwood forest wildlife.

In the northern redwood region, there has been less of a population boom, but towns and cities have grown, and building has had an impact on some redwood stands. A major impact in Humboldt and Del Norte counties, where the timber industry was (and still is) most important, has been a shift from the dominance of the timber industry to a more diversified economy. This shift has been accelerated by the increase in redwood acreage protected in parks, by some population influx, as well as by mechanization, regulations, economic, attitudinal, and other changes within the timber industry.

Controversy still exists in the redwood region, though, as people seek to preserve the remaining old-growth trees, streams, and wildlife in the redwood forests and stands, even if they are owned by timber companies. Timber companies seek ways to remain profitable while managing their lands for the long term and complying with regulations.

While Section II deals with the human history of the redwoods, it might be useful to discuss here some terminology as it relates to the ongoing concern about environmental issues in the redwoods.

Even some of the terminology used to describe caring for the environment can be confusing. What is the difference between conservation, preservation, management, and stewardship of the land? In this guide, I will use the terms as follows with regards to the redwoods:

Preservation: Managing the land so that it remains, as much as possible, in a more or less natural state as it was before Europeans came to California. (It should be noted that keeping fire and flood out of redwood forests will not preserve the forests in a natural state, as both fire and flood are natural in redwood forests. How to maintain a redwood forest in its current condition – or the condition that a park was in when the park was created – is an important issue.)

Conservation: The wise use of resources so that they provide the most good for the most people. Sometimes preservation might be the best use; sometimes harvesting of lumber might be the best use. (The dictionary definition of conservation is to "preserve from loss, waste, etc.; preservation." The definition that I am using is more commonly used in resource management fields such as forestry.)

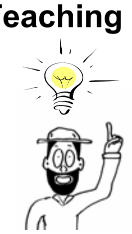
Stewardship: Caring for the land or environment, protecting it from damage.

Management: Making choices as to what happens to the forest, with specific goals in mind. A forest might be managed for recreational use, as an example of a pre-European old-growth forest, for research, or as a lumber-producing resource. A stand of trees might be managed to produce the maximum amount of timber in the short term, or to continue to produce timber over a long period of time. Management implies steps taken towards a goal, and usually includes aspects of preservation, conservation, and stewardship.

Environmentalism: Environmentalism is another term that means different things to different people. What is an "environmentalist?" The foresters and scientists of the forest products industry would consider themselves to be environmentalists, as their job is to manage the forest lands so that they can grow more trees while complying with forest practice regulations.

Preservationists would consider themselves to be environmentalists because they are trying to preserve and protect the forest environment from human impact. Some use the term "environmentalist" in a negative manner, referring to those who have interfered with business interests or who have taken actions that threaten their livelihoods. In *Redwood Ed*, I will use the term “environmentalism” to refer to concern for the environment and to environmentalists as those who have that concern.

Teaching Idea



Have the students first discuss the meanings of the terms conservation, preservation, stewardship, and management. Then have them look up the dictionary definitions. Have them try to agree on definitions that will show the differences. Discuss word roots.

A few words about "old-growth" and related terms:

Terminology can be important and confusing, as is the case with the term "old-growth." To some, old-growth redwoods are those in an area that has never been logged. To others, the term implies a certain type of forest ecosystem, while others use the term to describe trees of a certain size or age. To many, old-growth redwood forests are revered as places for spiritual renewal, while others see them as a potential but unavailable source of increasingly valuable lumber. One must also consider the difference between a stand of old-growth trees and an old-growth forest, which includes trees of varying species and ages.

Would a group of trees in an area where Native Americans felled trees using fire be considered old-growth? What about trees that are 170 years old, but growing in an area that was logged in 1830? And what about trees in a forest that has never been logged, but are only 10 years old and growing in an opening created by a fallen forest giant, root rot, fire, undercutting, flood or other causes? Are they old-growth?

In this guide, I will use the term "old-growth" to refer to redwoods that are in areas:

a. that have not been logged, other than the occasional tree felled by Native Americans…relatively undisturbed by humans
b. that are in a stand of trees or forest with diverse ages, spacing, and sizes of trees, with a multi-level canopy…structurally complex
c. with large (for the site) and/or old (for the species) trees
d. with most of the understory consisting of shade-tolerant species
e. with downed logs on the floor and some "snags," or standing dead trees

While some species can do fine in even-aged forests, the downed logs, snags, and canopies of old-growth redwood communities provide habitats for many species that do not thrive in even-aged forests. Some timber companies intentionally leave snags and other woody debris to provide old-growth-like habitats; in fact, timber management plans may require that snags and other "wildlife trees" be left during logging operations.

I will use "second-growth" to refer to trees growing in an area where the old-growth forest has been logged once, and "third-growth" to refer to trees growing where second growth forests have been logged. The term **young-growth** refers to any trees growing after the first cutting.

Coast Redwood Ecology

Factors that affect organisms are often divided into two categories—physical, or abiotic, and biological or biotic factors. These divisions are not mutually exclusive, because the physical factors affect the biological and *vice-versa*.

Physical (Abiotic) Factors

Moisture is the main limiting factor for the coast redwood. They grow best where annual precipitation is in the range of 140 inches, including **fog drip**. The climate of the redwood region can be broadly described as Mediterranean, with the majority of the rain falling in the winter, and both winter and summer temperatures being moderate.

The presence of summer fog may be the most important limiting factor, especially in the southern redwood region. Not only does fog reduce evaporation of water from the ground and reduce transpiration, but it condenses on the leaves and drips to the ground where it can soak into the soil. This fog drip is used not only by the redwoods, but by the other plants and animals in the community. In the summer, some understory plants may get nearly 100% of their moisture from fog drip, and 22-46% of the moisture available to the ecosystem may come from fog drip (Dawson, 1996). Measurements have shown that fog drip can add four or more inches of water to the soil around a tree in a single foggy summer day, and may provide up to 40% of the water that a redwood uses in the summer, and over 25% of its annual water input (Noss, 2000).

Studies have shown that redwoods, as well as other plants, can absorb water (as fog) directly through their needles. This seems to be particularly important for young trees, especially in years in which there is less rainfall than normal.

The correlation of the coast redwood's range with the fog belt of northern and central California is apparent. The coast redwood's natural range is along the coast, seldom extending beyond 35-40 miles inland. In drier areas, such as the southern range, or farther inland, the redwoods are often confined to the fog-containing valleys.

See the activity "Have a Foggy Idea" in Section IV.

Temperatures in the coast redwood region are relatively mild when compared to the areas where the other species of redwood grow. Coast redwoods grow best where the range between high and low temperatures is not very great. Temperatures rarely reach freezing or 100 degrees Fahrenheit. Not only is the annual temperature range small, but coast redwoods grow best where there is little difference between the daytime and nighttime lows. Both air and soil temperatures are important.

Light is important, of course, for photosynthesis. Different plants have different tolerances for shade, and the coast redwood is considered shade-tolerant or very shade-tolerant. While light may not be a limiting factor for survival, it is extremely important because of its effect on the growth rate of redwoods. A redwood tree growing in optimal conditions of light, moisture, and soil may add as much as 1.5-2 inches to its diameter in a year. A tree of the same age growing in the reduced light of a dense redwood forest might add less than 0.2 inches to its diameter in a year. A one-year-old sapling may grow to be two meters tall in a well-lit area, while a 100-year-old tree growing in the shade may be only 10 meters tall. Even a redwood, however, will eventually succumb if it doesn't have access to adequate light. As noted elsewhere, the redwoods with the largest diameters usually grow along rivers where they have ample light and moisture.

Anything that opens up the forest canopy can prompt a growth spurt. A large tree falling may open the forest, as might a landslide, strong wind, or even a chainsaw. A study of tree rings can show when the tree's growth was **released**, resulting in more widely spaced rings. The added light also allows trees that are less shade-tolerant species to grow. As a tree falls, it may move down slope, clearing a swath of vegetation and bringing debris to lower ground or creeks.

When a forest canopy closes in, more shade results in slower growth or suppression. In order to grow in the reduced light of a redwood forest, plants must be shade-tolerant.

See the activities "Fence Post Studies," "The Great Tree Cookie Mystery," and "Slow Growth or Fast Growth?" in Section IV.

As a tree grows taller, the lower branches receive less light. Eventually, the lower branches die and break off, a process called **natural pruning**. One consequence of natural pruning is the absence of knots in wood formed after the branch falls. Knots are formed where limbs grow from trees and are surrounded by subsequent growth. Lumber without knots is called "clear," and it is much more valuable than wood with knots. Older trees generally have much more clear wood than do young-growth trees.

The tops of most plants tend to grow towards the light. This growth towards something is called a positive **tropism**, so redwood branches and tops tend to have a strong positive **phototropism**, or grow towards light. The roots of most plants, similarly, have a strong positive **geotropism**. (Negative tropisms would, of course, be growing away from something.) Sometimes trees growing in shady areas bend towards an open space such as a creek or other clearing.

Wind is a factor in redwood ecology for a variety of reasons. Redwoods have shallow root systems for trees their size. When redwoods live in fairly dense forest situations, the trees tend to shelter each other from the strong winds that sometimes come with winter storms. If some trees are removed by logging, landslide, or other means, the remaining trees may be susceptible to being knocked down by subsequent winds. This **windthrow** or **blowdown** can have a snowball effect as the fallen trees expose the remaining trees to the winds.

While proximity to the coast provides the coast redwood with necessary moisture in the form of rain and fog, the trees don't tolerate wind-carried salt. Redwoods may live near the coast, but seldom on the coast. On the cliffs high above the ocean, however, the redwoods may grow near the water if the salt spray doesn't reach them.

Not only does wind bring salt and blow trees down, but it can remove fog, resulting in desiccation. Drying wind not only removes moisture from the leaves, increasing transpiration, but it also removes moisture from the soil.

Soil is an extremely important abiotic factor in any terrestrial community. Soil provides mineral nutrients, holds moisture, and anchors the plants. The roots of the coast redwood are relatively shallow for a tree of its size, often only 6-10 feet deep on a 200-300 foot tall tree. The roots do spread out laterally for a large distance and may even intertwine with those of neighboring trees, which can provide extra support.

The largest redwoods grow on the alluvial flats along rivers and creeks. Periodic flooding deposits silt around the trees. A coast redwood has the ability to sprout a new layer of roots from the base of its trunk when it is buried in silt. If the newly deposited sediments consist of coarse gravel, though, the roots may die because the coarse sediments don't hold moisture well.

Soil texture is important because it can facilitate or hinder absorption and retention of moisture. Redwoods do well in a wide range of soil types, but do best where the soil is continuously moist and well aerated.

For successful redwood reproduction by seeds, the soil needs to be disturbed. On an undisturbed forest floor, the layer of needles, leaves, and twigs is often too thick for the tiny seed to produce a root that can reach the soil, and the air spaces between the needles on the floor allow the developing young root to dry out. In nature, landslides, treefall, flooding, and fire prepare the soil for redwood seeds. Logging, with its concomitant soil disruption, can actually enhance the sprouting of redwood seedlings.

Sometimes a portion of a hillside slides or "slumps" downhill, resulting in a relatively flat-topped area where the slumping soil stops. This disturbed area, sometimes called a **slump-jumble** often provides a place where redwood seedlings can gain a start, along with other colonizing early-successional plants.

When a tree falls, of course, the roots pull some of the soil with them, thus creating what is called a **root-pull pit**. This pit provides exposed soil for pioneer species or redwood seedlings, as does the wad of soil attached to the root.

Flooding can be a major environmental factor, especially in the rainy north coast region. Redwoods often live on the alluvial flats, and they are more resistant to flood damage than other species such as Douglas-fir, alder, tanoak and others. Redwoods surviving a flood may eventually die, however, if the roots are unable to obtain oxygen because they are buried too deeply in sediments. As discussed above, though, many redwoods have the ability to send up new shoots into the newly deposited sediments.

Fire is a very important factor in the redwood forests. Redwood trees are relatively resistant to damage by fire, but many of the plants competing with them are more susceptible to fire damage. The trees' thick, fire resistant bark protects the living inner parts, and the wood has little resin.

The actively living part of a tree trunk is the cambium layer, which lies directly under the bark. As long as the cambium is protected, damage to the surface of the bark or the center of the trunk may not significantly hurt the tree.

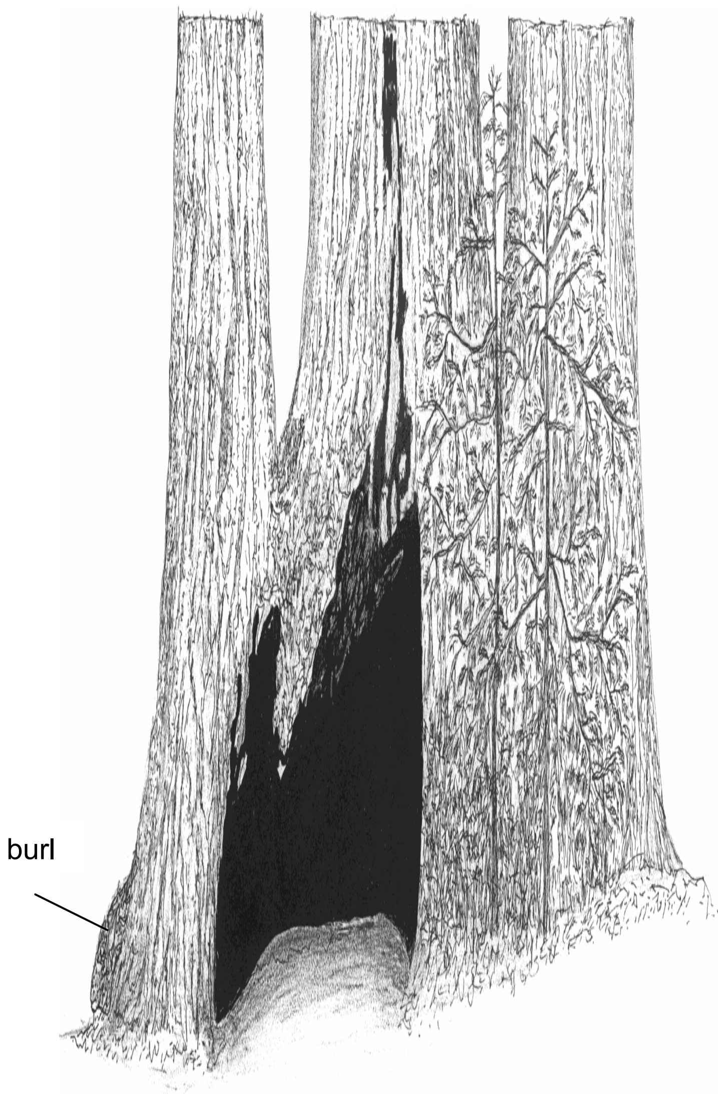
See the activity "The Anatomy of a Giant" in Section IV.

In the alluvial flat stands, fires tend to burn with low intensity. The generally moist conditions, flat terrain, and the nature of the plants near the ground all work together to reduce the intensity of the fire. The redwood's bark is resistant to fire, and even the wood itself is fire resistant because of its lack of pitch and its high water content. In a mature redwood stand, the lowest branches may be a hundred feet or more above the ground, further reducing the damage caused by fire.

In forests on hillsides, especially where other species, such as Douglas-fir and tanoak, grow along with the redwoods, fires often are much more intense. More flammable trees may even provide a ladder-like effect, allowing the fire to reach the redwood overstory. Fire is also important in maintaining the grasslands known as **prairies**. In Redwood National Park, park managers are using fire to rid the prairies of invading native and non-native species. Due to their natural resistance to fire, however, mature redwoods are seldom killed by fires.

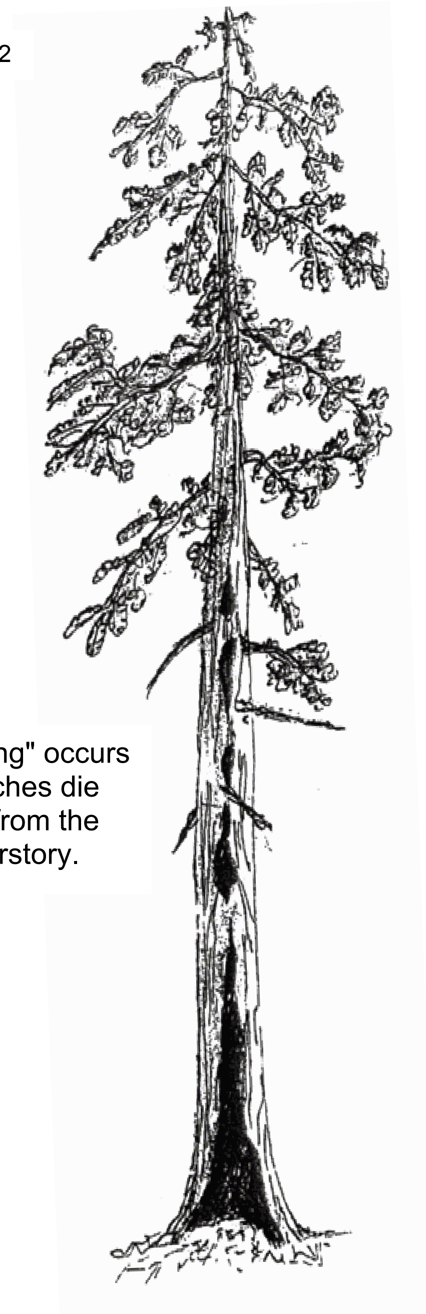
Occasionally, fire may actually penetrate the bark of a redwood and damage the wood beneath. This is most common on the upslope side of a tree where branches and litter have accumulated. Subsequent fires, along with fungal infections, may repeatedly attack the tree, resulting in a hollowed-out cavern, called a fire cavity, in the base of the tree. If enough of the sapwood is burned, the tree may be killed, but redwoods often continue to grow even if a significant portion of their base or heartwood is burned out. Early settlers supposedly used these tree-caves as pens for animals, or even living quarters, and they are often called **goosepens**. Sometimes these hollows extend well up the tree, forming a **chimney tree**. Such fire cavities provide shelter for such animals as hibernating bears and roosting bats.

Figure 11



A goosepen with a burl at the base to the left.

Figure 12



"Natural pruning" occurs as lower branches die due to shade from the canopy or overstory.

Sometimes fires will penetrate the bark and burn the heartwood, creating a "chimney tree." If the cambium and sapwood survive, the tree may continue to live for years, providing habitat for many types of organisms.

Drawings from *Life History and Ecological Guide to the Coast Redwood, Sequoia sempervirens*, by Daniel J. Miller.

Sometimes a redwood may have its branches burned off by a large fire. While the tree may be killed, sometimes the branchless **bole** (trunk) will sprout hundreds of branches, forming a "**fire column**" tree, sometimes called a **Christmas tree**, that may look like a bottle brush or pipe cleaner.

Figure 13

Crown fires sometimes burn off the limbs without killing the tree or the dormant buds beneath the bark. The buds may then sprout new branches, forming a fire column tree or "Christmas Tree."

Figure 14

Various factors such as salt spray or lack of water may kill the top of the tree, resulting in a "spike top."

Drawings from *Life History and Ecological Guide to the Coast Redwood, Sequoia sempervirens*, by Daniel J. Miller.

Fire is a natural part of the redwood forest ecosystem, and may be necessary for the survival of the redwood forest. Fires kill other species that compete with the redwoods for light and nutrients, and also return nutrients to the soil. As noted elsewhere, some studies indicate that, over the course of several centuries, a lack of fire may result in the replacement of redwoods by other species. Fires, especially large ones, are more common in the drier southern and inland parts of the redwood region. Native Americans used fire to maintain clearings in the redwood forest so that desired plants and animals would have suitable habitat. (This is discussed more thoroughly in Section II.)

In the northern redwood region, evidence of fires in moist coastal areas indicates a frequency of up to once in 500 years, while in drier inland areas significant fires occurred naturally about once in 100-200 years (Veirs, 1996). In drier southern areas, the natural fire interval was much shorter, perhaps as low as 30 to 50 years (Lanner, 1999). Native Americans may have started fires to encourage the growth of desired plants every 2-10 years.

See the activities "Fence Post Studies," "The Great Tree Cookie Mystery, and "Slow Growth or Fast Growth" in Section IV.

Biological (Biotic) Factors

Reproduction in the coast redwoods occurs in three ways: seeds, sprouting from stumps or injured trees, and sprouting from fallen branches.

Redwood trees have both male and female cones on the same tree. During the winter, the male cones produce pollen, which settles on young female cones and fertilizes the ovules within. In about six months, each ¾-inch-long female cone may develop 60 to 120 seeds. The seeds of the huge tree are tiny…it takes over 100,000 of them to weigh a pound After the seeds and cone mature, the cone opens and sheds the seeds, usually between November and February. Most of the 10 million or so seeds produced by each tree per year are not viable, but 5% to 10% are (Barbour et al., 2001).

The production of cones and seeds varies with the health of the tree and its age. Seed production begins when trees are only 5-15 years old, but trees aged 250 to 1000 years seem to produce not only the most cones, but the most viable seeds. Some trees produce few or no cones for many years. There is some evidence that this may be due to lack of stress, as stressed trees seem to produce more cones.

As noted above, if the seeds fall on accumulated forest leaf litter or duff, they are likely to dry out and die before they can extend their developing roots to the soil. Seeds falling on leaf litter are also very susceptible to infection by **damping-off** fungi. Seeds are also fed on by banana slugs and brush rabbits, as well as nematodes (round worms).

Seeds that fall on mineral soil, however, have a much better chance of germinating and surviving. Soil exposed by wildfire or deposited by flooding is often covered by forests of miniature redwoods. The soil exposed by a fallen tree's roots, a small landslide, or logging operations can provide a seed bed that also has ample sunlight.

If a quantity of redwood seedlings starts to grow, on an area of disturbed soil on a slumping hillside for example, a dense cluster of trees may form. As the trees grow, the interior portion of the cluster receives increasing amounts of shade, and the trees at the center may lose the battle for sunlight and die back. This is one way that a circle of redwoods may form.

Coast redwoods are among the fastest growing trees in the world. A 20-year-old tree may be 30 feet tall and 10 inches in diameter with a shallow network of roots extending 20 to 30 feet out. A young tree may grow two to six feet in height and an inch or more in diameter each year. A 50-year-old redwood may be 100 feet tall, and it may reach a height of 200 to 300 feet by the time it is 200 years of age. This rapid upward growth is important if the tree is to compete successfully with its shade-producing neighbors.

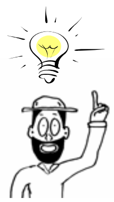
After reaching the sunlight at the height of the forest canopy, the tree slows its vertical growth and adds more wood to its trunk or bole. Thus, a 200-year-old tree may be 250 feet tall with a diameter of five feet, while a 400-year-old tree may be 275 feet with a diameter of only seven feet. By the time the tree is 700 years old and 300 feet tall, its diameter may be 15 feet. Timber companies seek an optimal growth rate and harvest cycle that produces the most wood in the shortest time.

An important form of reproduction in redwoods is its ability to sprout from its **bud collar** or **burls**. A tree may also form burls high up the side of the bole. Burls contain dormant buds, sometimes numbering in the thousands. If the tip of a seedling or tree is damaged, the dormant buds are released from dormancy and rapidly grow into shoots that are extremely vigorous in their growth. Such a sprout may grow 8 to 10 feet in its first year, and may produce a 30-inch diameter, 150-foot tall tree in 50 years. These vigorous sprouts may number more than 200 around a single stump, but competition thins them out over time. Seedlings as young as six months old have the ability to send up new sprouts if their tops are damaged. A Division of Forestry study found that within two years of logging, 90% of the stumps may sprout new saplings.

Figure 15. Burls. Note the small trees sprouting from burls at the left. (Photo courtesy of Michael Roa.)

Since the sprouts from a stump or fallen redwood have the same genetic makeup as the original tree, they are **clones** of the parent tree. Clonal rings are common in redwood stands that have been logged, as the sprouts from the cut stump often grow into a circle of trees. In fact, since the sprouts have the benefit of the original tree's extensive root system, they have a great advantage over seedlings and are an important source of "new" trees in logged areas. (These circles are sometimes called "fairy rings," but that term is probably better saved for circles of mushrooms that develop as nutrients are used up in the center of the circle.) In some areas where fires are frequent, whole groves of redwoods may consist of clusters of short, multi-trunked trees produced by stump sprouting.

Teaching Idea



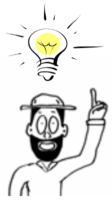
Gift shops in the redwood region sometimes sell living redwood burls that can be grown in the classroom. These burls are sometimes collected legally on private land, or from trees that have been cut for lumber. Too often, however, they are cut illegally on private land or even in parks. Thieves have been known to cut down trees in order to get at burls high up on the trunk. Caution students not to injure trees by collecting burls on their own. If you live in the redwood region, perhaps you can obtain burls from a logging company.

A discussion of burl harvesting can lead to a discussion of killing or injuring organisms for such things as fur coats, feathers, shells, and other non-essential uses. Discuss how purchasing such items supports the killing of plants and animals, often illegally. Discuss the poaching of animals in parks, not only in the U.S.A., but also elsewhere, such as Africa.

A less common form of cloning occurs when a fallen branch or tree sprouts roots from the buds on the downward side and branches or trunks on the upward side, sometimes producing a line of "new" trees along the fallen trunk. Sprouts have even emerged from harvested logs months after they were cut.

A rare type of sprout forms an "albino redwood." These trees grow from sprout burls on otherwise normal redwood trees. They don't live to be large trees, but are an interesting phenomenon. If you visit a park, you might ask the naturalist or interpreter if there are any albino trees that can be seen. Don’t be surprised if they won’t tell you of the location, though, as albino trees are rare and fragile.

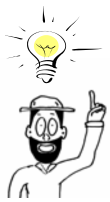
Teaching Idea



When discussing the large number of seeds produced by a single redwood cone or tree each year, also discuss how many seeds would be produced by a tree in its lifetime. (Seed production is not constant throughout a tree's life, but it is easy to see that a tree producing 10 million seeds per year may produce a billion or more seeds in a lifetime of several hundred years.) For the species to survive in its current numbers, each tree only needs to successfully produce one other tree that reaches maturity.

Discuss the idea that some seeds may produce seedlings or young trees that are more likely to survive. Help the students come up with some characteristics or adaptations that may give some seedlings an advantage in the struggle for survival. Some adaptations might include faster growing roots, faster growing stems, chemicals that make them more resistant to fungus or distasteful to animals, or better resistance to drying out. This can lead to a discussion of natural selection.

Teaching Idea



*Many students have heard of **cloning**. Discuss its advantages and disadvantages.*

Since the redwood ovum may be fertilized by pollen from another tree, reproduction from seeds provides the opportunity for a new mixture of genetic information. This results in variation, which results in the possibility of new adaptations that may give the new seedling a competitive advantage (or disadvantage). For example it has been found that trees from the southern redwood region often do not grow well in the north, and vice versa. Apparently trees in different areas have evolved somewhat different and specialized genes.

When a stump or fallen log grows a new sprout, that sprout is genetically identical to the original tree. It is a clone. It will have the same genetic characteristics, good and bad, of its "parent." Tree nurseries often take cuttings from trees with desired characteristics and use them to produce hundreds of clones with those desired genetic characteristics.

Discuss with the students what characteristics timber companies might desire. Examples include fast growth, straight trunks, horizontal branches (resulting in smaller knots), resistance to disease or insects, the ability to withstand drought, or others.

*Discuss with students the dangers of having a "crop" of trees all with the same characteristics, i.e., a **monoculture**. (All of the trees—or corn or wheat or cotton—will have the same good characteristics, but they will also all have the same "bad" characteristics; they will all be susceptible to the same diseases, environmental changes, predators, etc.)*

Discuss how nature deals with this issue…mixing of genes through sexual reproduction, natural selection, "survival of the fittest."

Then discuss how timber managers might deal with the problems of monoculture… leaving seed trees, stump sprouting producing a portion of the trees, planting a variety of clones, or using selective harvesting.

Tree growth and form are important to the redwood's survival. Much of the redwood's shape comes from adaptations that enable it to compete for the light needed for photosynthesis. Rapid growth in height, as described above, enables it to out-compete other trees when a clearing becomes available. Once a canopy forms, most other trees can't thrive in the shady understory, so competition for water and minerals is reduced.

As the tree grows taller and the canopy forms, the lower branches lose their usefulness. In a process called **natural pruning** these lower branches die and fall off. As noted elsewhere, the subsequent wood growth below the level of the branches will be free of knots, which are caused by the growth of wood around a branch. This "clear" wood produces very valuable lumber, but the young-growth trees that provide most of the lumber today produce relatively little clear wood. Conversely, the huge trees cut in the early days of logging had a lot of clear wood, so much so that the tops of the trees, which contained branches and therefore knots, were often left in the woods.

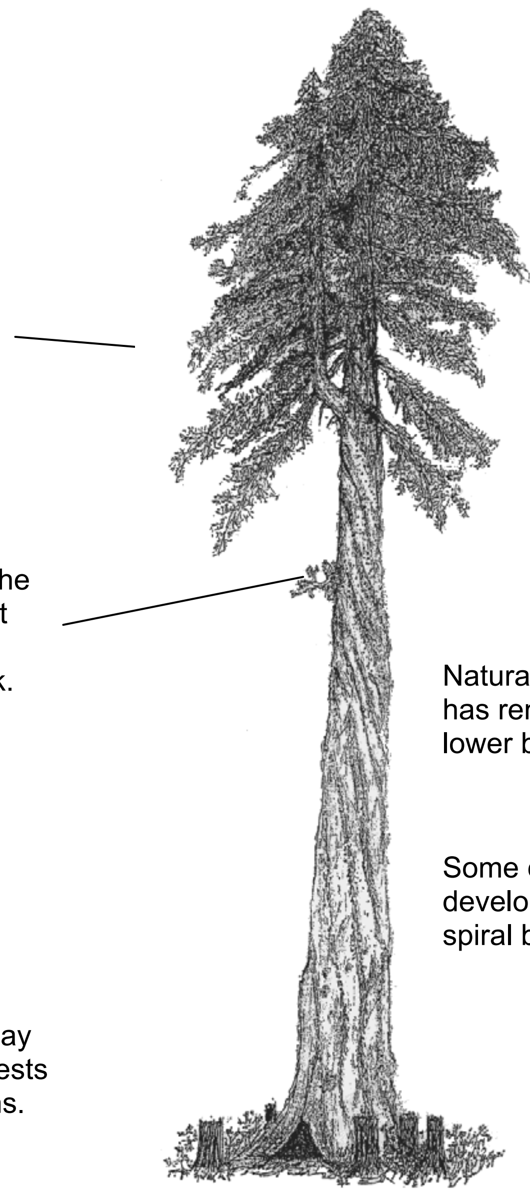
In their quest for light, trees sometimes grow **reiterated trunks** at or near the canopy level. These may grow out from the main trunk or may grow upwards from a horizontal branch. These **reiterations** are essentially like tree trunks growing from the upper parts of the tree. They can be quite large. A 156-foot tall tree in Del Norte County, aptly called the Del Norte Titan, sports a reiteration that grows from its trunk 107 feet above the ground, and has a base diameter of more than five feet. That single tree has 43 reiterated trunks growing in its crown. Another tree, called the Redwood Creek Giant, has 148 reiterated trunks (Noss, 2000). (See Figure 16.)

These reiterated trunks, along with "regular" branches, provide a complex canopy that supports a rich collection of other plants and animals. Plants that live on other plants are called **epiphytes**, and over a dozen species of epiphytes have been found in the coast redwood canopy. Although not truly an epiphytic species, a western hemlock tree 40 feet tall has been found growing in a pocket of canopy soil. (*Coast Redwood*, by Barbour *et al.,* has a nice section on the forest canopy, including photographs of reiterations.)

Sometimes when trees are under stress, the top of the tree may die, resulting in a **"spike top"** tree. (See Figure 14.) This stress may be caused by lack of water, salt spray, or other environmental factors. Such trees can often be seen along freeways.

If a redwood starts to lean, or grows on a hillside, it may develop asymmetrical growth, with the downhill or side towards which the tree leans growing faster, forming a buttress that supports the tree. Sometimes these trees are called "flatiron" trees because of their cross-sectional shape.

Figure 16.



Drawing from *Life History and Ecological Guide to the Coast Redwood, Sequoia sempervirens*, by Daniel J. Miller.

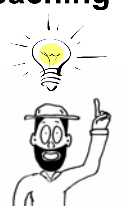
The root system of the coast redwood is also adapted to its environment. The coast redwood lacks a large **tap root**; rather, its roots extend more than 50 feet laterally and have a depth of 12 feet or less. The roots may interlock with those of neighboring trees, which provides additional stability during wind storms or floods. The roots may produce many small rootlets in the top three feet or so of soil.

Most plants have very fine **root hairs** that greatly increase the surface area of the root system and facilitate the absorption of water and minerals. The coast redwood, however, lacks root hairs. Rather, coast redwoods have a variety of strand-like fungi that grow on the roots and actually extend into the root cells. These fungi absorb water and nutrients and pass them on to the redwood cells. In turn, the fungi receive nutrients from the tree. This mutualistic association is called mycorrhizae.

See the activity "The Root of the Matter" in Section IV.

As layers of soil build up around the base of a redwood, or as the base is covered by silt from a flood, the root crown may send out new layers of roots, or the lower roots may send shoots upward. Studying these layers of roots enables biologists to study the frequency of floods. A study of root layers in the Bull Creek area of Humboldt County indicated that there were about 15 major floods in the last 1000 years, and that the floodplain was raised by more than 30 feet. (Barbour et al., 2001)

Teaching Idea



The Save-the-Redwoods League has published a very interesting booklet titled Story Told by a Fallen Redwood, by Emanuel Fritz (1995). If possible, obtain a couple of copies of this booklet for students to study, and if you are in the Richardson Grove area, visit the actual log about which the booklet is written.

Animal associations with the redwoods are important, but, other than man, it is generally the redwoods that affect the animals, as opposed to the animals affecting the redwoods. As noted above, the tannins and thick bark of the coast redwood make it unpalatable to most insects. For example, hundreds of insect species consume Douglas-fir, but only about 50 species feed on redwood. So effective are the redwood's defenses that no insect species causes economically significant damage to redwood trees.

A few mammals feed on the redwoods. Some, like woodrats, mice, deer, and elk feed on young seedlings. Elk and deer feeding on the terminal shoots of young trees or spouts can suppress the trees' growth or even kill them. Various animals, such as woodrats, squirrels, porcupines, and black bears, feed on the cambium layer beneath the bark. Black bears sometimes cause significant damage to stump sprouts or seedlings planted in logged areas as they strip the bark and feed on the cambium layer, especially in the early spring when the sap is flowing. Bears seem to prefer saplings ranging from 6-12 inches in diameter, so they are of particular concern to timber companies. A tree can be killed if a foraging bear or porcupine eats so much of the vascular tissue that the tree cannot transport materials to and from the leaves, a process called **girdling**. A variety of rodents and birds feed on redwood seeds.

Chapter 3
Environmental Concerns…conservation, sustainable management

As the human population increases, technology changes, people's expectations change, and the human impact on all ecosystems increases. Even Antarctica has been impacted by tourism and, apparently, by global warming and ozone depletion. Tropical rainforests are being logged, endangering many species of plants and animals even while the "ecotourism" business continues to grow. The fastest growing area in the U.S. is greater Las Vegas, where the water supply is far from adequate to meet the needs of the ever-increasing demand. Environmental concerns are important in the redwood region, too. Even though people have caused environmental problems, people have also taken steps to protect and conserve the environment.

Many of those concerns have been mentioned earlier in this section, and some are discussed in Section II: Human History of the Redwoods. Some of the environmental issues of the redwood region are summarized in the upcoming table.

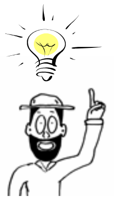
One value of field trips to natural areas such as redwood parks or forests is the increased level of environmental awareness and concern that students can develop through exposure to interesting ecosystems. While it is important not to overwhelm students with bad news about the environment, it is also important that they become aware of environmental concerns. When teaching students about environmental issues, it is essential to also teach them about ways that problems can be addressed. An important part of that is to help them to understand that there are at least two sides to every issue, and that people have learned ways to minimize or reduce negative impacts on the environment. In some cases, people are working to help areas recover from previous damage.

Students need to visit natural ecosystems to fully appreciate their beauty and importance. Merely learning about the plants and animals is not enough, though. Students should come away with not only an appreciation, but a desire and willingness to try to protect, improve, and conserve their environment. The teacher's example, not only while on a field trip, but especially in day-to-day classroom life, can be very powerful.

Discussions of "needs" vs. "wants" are important. So, too, is an understanding of the difference between quality and quantity. It is also important to help students realize the impact of population on the environment.

A detailed discussion of conservation goals and forest management can be found in *The Redwood Forest* (Noss, 2000).

Teaching Idea



Several of Aesop's Fables can be useful in such understandings. Read (or have students read) and discuss such fables as:

- *The Lioness (Quality is more important than quantity.)*
- *The Two Frogs (Think before acting.)*
- *The Two Crabs (Example is the best teacher.)*
- *The Ant and the Grasshopper (Planning ahead and conserving resources are important.)*
- *The Goose with the Golden Eggs (Conserve resources for future use.)*
- *The Crow and the Pitcher (Necessity is the mother of invention.)*
- *The Sick Lion (Don't believe everything that you hear.)*
- *The Mule (Every truth has two sides.)*
- *The Oak and the Reed (It is better to bend than to break.)*

The table of environmental issues (below) could just as well have been placed in the Human History section of *Redwood Ed*. It is placed here because of the close connection between the environmental issues and the ecological concepts discussed in this section.

Environmental Issues of the Redwood Region

Environmental Issue	What's the problem?	What can I do about it?
Lack of environmental literacy and a land stewardship ethic in both the general population and legislators	Unless people both understand the environment and care about taking care of it and using it wisely, the environment will continue to deteriorate. Since there is no "free lunch," it takes an educated and caring populace to be willing to pay the price for environmental protection, whether it is protection of redwood trees, reducing global climate change, or paying for improved sewage treatment.	Education is the key! Not only must the general population be educated, but they must care enough about the environment to influence both legislators and industry.
Lack of information…lack of baseline data	Decisions with lasting implications are made daily. How can information be gathered and interpreted prior to making decisions? Should a given piece of property be acquired for park land, or would the money be better spent on something else? How can this endangered plant or animal be protected? Is this plant or animal truly endangered? Should it be added to the endangered species list? How many of these organisms live here, and how many do we want/need to have? What would be the social or economic impact of this decision? What is the best use of this area?	Students need to comprehend the importance of understanding an issue before making decisions, if possible. If there is a controversy, they need to be willing to understand both (or all) sides of the issue. Students can be encouraged to consider careers in science or social science that may help answer some of the questions associated with decisions about land use and planning.

Environmental Issue	**What's the problem?**	**What can I do about it?**
Erosion and siltation of creeks and rivers	Landslides and erosion deposit silt and gravel sediments in creeks and rivers. Silt reduces the ability of salmon and trout to spawn. Sediments can also fill up the stream channel and change the flow of the stream, possibly resulting in flooding or erosion of the stream banks where many of the largest redwoods grow. Undercutting of banks may topple some of the largest redwoods. While natural landslides contribute to siltation of streams, improperly built roads, especially where they cross streams, are an important problem. Modern road building techniques greatly reduce the sedimentation, but old "legacy" roads and stream crossings continue to produce sediments.	Students need to understand the importance of staying on designated trails, not taking shortcuts. This helps reduce erosion. Students can be involved in trail re-routing projects that seek to reduce erosion. Modern forest management practices include efforts to protect streams. Students can be encouraged to consider careers in forestry, civil engineering, or geology so that they can help develop and institute even better practices. Students can participate in tree planting or other revegetation efforts. Students can also be encouraged to become politically active so that appropriate laws and regulations are passed and enforced.
Roads, stream crossings, and cut-over areas left over from earlier logging…"legacy issues"	Earlier logging techniques sometimes provided little, if any, environmental protection. Some of the "legacy" roads, culverts, and cut-over areas continue to result in erosion or other problems years later.	Again, students can consider careers in the natural resource sector where they can work not only to protect ecosystems but also to correct mistakes of the past. Students can be encouraged to continue their education, formally or informally, so that they can become politically active. Students can participate in tree planting or other revegetation efforts.
Compaction of soil	When people walk or drive on soil, especially if it is wet, it may become compacted. Soil compaction reduces the ability of both water and air to get into the soil. When water can't enter the soil, it runs off, causing erosion, while plants' roots are deprived of water. Roots also need air, and compacted soil may not allow enough air to reach the roots. Soil compaction may be a problem in parks and also in areas where heavy equipment drives on improperly designed roads.	In parks, people must learn to stay on designated trails and to respect boundaries such as fences and signs indicating "habitat recovery" areas. Students can be involved with trail re-routing and campsite relocation projects. They also need to learn about the impact of such things as mountain biking, off-road driving, and horses on trails.

Environmental Issue	What's the problem?	What can I do about it?
Short-rotation forestry practices	Whenever forestry (or other) equipment enters a stand of trees, plants are damaged and the soil is disrupted. When plants are damaged and soil disrupted, erosion is likely to follow. Given time, plants can regrow and once again provide protection from erosion. When equipment re-enters an area frequently, however, the plants may not have a chance to recover. Compaction may also increase. One of the main problems with soil erosion is the addition of silt to creeks, which interferes with the spawning of salmonid fishes. After a while (several years), silt can be naturally flushed from the creeks. Frequent additions of silt from soil disruption on the slopes, however, impedes this natural recovery process.	Increasing the time between the entry of heavy equipment into the forest will allow more healing and regrowth of plants that reduce erosion. Careful design of roads and compliance with regulations can also help reduce erosion.
Fragmentation of forest land	Some animals require large uninterrupted forest landscapes. For a variety of reasons, some forest tracts are becoming fragmented. Sometimes this results from roads passing through the forest, but more often it comes from timber harvests or sales of small parcels for development within the forest.	Becoming educated about local land use issues is important, but it is also important that people become politically involved. Land use planning and development must include protection of both parklands and commercial forests.
Urbanization/ development	Not only does development of forest areas break up the contiguous forest land, but urban development brings such problems as water runoff from roads and buildings (as opposed to water sinking into the forest floor), loss of habitat for native species, and the introduction of exotic species. Another issue is an urban population that does not understand forest management practices.	Not only is it important to become politically savvy and involved, but one must be willing to make personal choices with regards to such things as where one builds a home.
Overdevelopment in parks, or inappropriate development	For parks, the problem isn't just how many people want to visit. Another issue is what kind of development should be allowed. How much land should be kept in a natural state, how much should be allocated for roads, buildings, sewage treatment, campsites, or trails? Different people, of course have different ideas about what parks should be and what kinds of development are appropriate.	It is important to discuss with students what kinds of values the parks provide, and to help them appreciate those things that can only be found in natural settings. Only by spending time in nature can people appreciate and understand its value. Teachers can help students get beyond fears and discomfort to appreciate the natural world.

Environmental Issue	**What's the problem?**	**What can I do about it?**
New park land?	Some maintain that more land should be added to the existing park systems. They maintain that additional land may be required to buffer current parkland, and that an increasing population will place ever more pressure on existing parks. Many parks, for example, have no campsites available on most summer weekends. Some also point out that there are still virgin redwood stands and that much of the second-growth redwood forest has reached impressive size. Others point out that most redwood parks are little used during the rainy season, and that when timber land is removed from production, not only are jobs lost, but so are taxes and payrolls that help local communities. Also, less redwood lumber tends to drive up prices. Furthermore, modern timber companies actively manage the forests to try to prevent wildfires, erosion, and other problems. If they don't do that, the costs for doing so will have to come out of the state or federal budgets, leaving less money available for other needed park projects.	If more park land is to be acquired, or even if the goal is just to maintain and protect current park land, taxpayers need to be willing to support the California Department of Parks and Recreation, the National Park Service, county park departments, and other similar agencies. People who don't experience the parks can't very well appreciate their importance. When teachers bring students to visit parks, it is important to help students understand that the parks need their support, and to encourage parents to visit and support the parks, too.
Limited funds	As noted above, funds for managing public lands are very limited. Should available money be used to acquire new land before it is logged or developed? Should it be used to protect and conserve land already in parks? If new land is to be purchased, which land should it be, should it be developed for public use, and if so, how?	It is important that taxpayers be willing to support the park system. Organizations such as the Save-the-Redwoods League and the Sempervirens Fund raise funds to support the parks, too, and students and parents can be made aware of such groups.
Overcrowding in parks	Some redwood parks, especially those near urban areas, face problems with overuse, primarily in the summer months. Too many visitors cause soil compaction, loss of the peace and quiet that people seek in parks, law enforcement problems, demands for more development, and other environmental issues.	Discussion of why there are rules and regulations in parks can make students more willing to stay on trails, not litter, and otherwise comply with the rules. People who do not visit parks are not very likely to support efforts to purchase more park land or to develop what land is already owned. Encouraging parents and others to visit parks can help create support for parks and the efforts of organizations such as the Save-the-Redwoods League and the Sempervirens Fund.

Environmental Issue	What's the problem?	What can I do about it?
Fires…or lack of fires	Obviously, fires burn plants in the forest. People sometimes forget that fires also can kill animals, and destroy animal habitat and food. Fire is, however, a natural part of the redwood forest community. Redwoods are adapted to surviving periodic fires, and they may depend on them to reduce competition from less fire-resistant species. One problem is that fires have been kept out of the forests for so long, especially in stands that have never been logged, that there has been a buildup of fuel. This large fuel supply, if and when it burns, may be hot enough to damage or even kill redwoods that could have withstood smaller, more frequent, fires.	If fires are to be kept out of parks, some other way needs to be used to clear the understory and reduce accumulation of fuel that might turn a small fire into a conflagration. Students can participate in fuel reduction projects. Fuel reduction by hand is very expensive, as is prescribed/ controlled burning to reduce fuel accumulation. In order for taxpayers to provide funding for such efforts, they must understand the need.
Exotic species	When people think of parks, they generally envision a natural setting with plants and animals that are native to the area. Many non-native (exotic) species have been introduced to the parks and forests of the redwood region, either intentionally or accidentally. Exotic species compete, and often out-compete, with native species for space and other resources. Since natural controls may be lacking for introduced species, they may become a significant problem.	Learning to recognize introduced species and to understand the problems associated with them is the first step. This can be expanded to discussion of efforts to keep agricultural pests out of California and to check their spread within the state. Students can participate in studies of exotic species and in removal projects.
Regulation	California's Forest Practices Act and its concomitant regulations are among the strictest in the nation. Regulations generally cost forest product companies money. Over-regulation may result in companies selling forest land for development rather than maintaining it as working forest land.	Students need to understand that we need to be a balance between regulations intended to protect the long-term interests of the general public and the rights of the property owner or company. They also need to understand that regulations have economic impacts, such as higher prices for products, and jobs created or lost. Students can be encouraged to consider careers in forestry or politics so that they can have an impact on the creation and enforcement of regulations.

Environmental Issue	**What's the problem?**	**What can I do about it?**
Taxation	Like regulations, taxes can cause land owners to develop their land rather than maintain it as forest land. Rather than pay taxes on forest land while they wait for the trees to grow to a harvestable size, owners may choose to sell their land for development.	See Regulation above.
Pollution…air, water, solid waste, noise, light	With people comes all sorts of pollution. School buses or cars that bring students to visit parks also bring air pollution and noise. Litter is an issue. How is sewage to be dealt with? Should lights be installed on trails, or would that ruin the after dark park experience?	Students need to understand that their actions have many consequences. Building a culture of caring and respect in the classroom can be extended to the field. Discussion of population issues can help students understand their impact on their environment. Students can develop attitudes and habits such as recycling, being thoughtful and careful, and being willing to put up with some inconvenience for the sake of the environment.
Demand for wood products	As the human population of the world, including California and the rest of the United States, continues to increase, so does the demand for products made from wood and other resources.	Making informed choices is a key. Sometimes redwood may be the best choice because it is a renewable resource. At other times, other materials may be preferable because they will last longer. We should remember "the 3 Rs: reduce, reuse, recycle." We can reduce our use of redwood by selecting other resources, but we should keep in mind that those choices will have their own environmental consequences. We can reuse redwood. Many communities have wood recycling/reusing programs, and it may be possible to find used redwood for sale. We can recycle redwood by using sound wood for other things or by composting rotted wood.

Chapter 4
Organisms of the Redwood Forest

Some kinds of organisms are found in many different kinds of environments. Redwood forest examples of these include the raccoon, wood rat and poison oak. Some communities have organisms that are found nowhere else. Such species are called **endemic**. No truly endemic redwood forest species have been identified, i.e., plants and animals of the redwood forest can be found elsewhere, at least occasionally. There are, however, several near-endemic species whose ultimate survival may depend on the continued existence of redwood forest, as the redwoods provide 75% or more of their range. At least 42 species of redwood forest vertebrates, and 16 invertebrates, are listed as endangered, threatened, or otherwise of concern. Some of these species seem to require forests with the characteristics of old-growth forests, including diversity of tree sizes and ages, the presence of snags or downed trees, or large stands of trees.

As noted elsewhere, the focus of *Redwood Ed* is on the redwood forest itself. The aquatic ecosystems of the redwood forest are extremely important to the forest, and the redwood forest has important effects on the streams and rivers that flow through it. In *Redwood Ed* I won't discuss much about the aquatic ecosystems except to point out that the streams historically have been important breeding grounds for a variety of **salmonid** fish, *i.e.*, salmon and trout. Silt from erosion can bury the gravel or fill the deep, cool pools that these fish need to successfully live and breed. Removal of large and small trees along stream channels affects aquatic ecosystems in many ways, including increased warming because of less shade. Some studies indicate that the once plentiful decaying salmon carcasses provided an important source of minerals for the redwood forests. *The Redwood Forest* (Noss, 2000) has a fairly extensive treatment of the aquatic ecosystems of the redwood forest. Because of the susceptibility of the streams to damage, modern timber management plans must include buffer zones to try to protect the streams.

In addition to various books that are listed in the Resources section, a free CD of Education Programs for Grades K-5 is available from Muir Woods National Monument. The CD includes background information, images of some redwood forest organisms and human activities, and lessons. See MacDonald (2003).

What's in a Name?

When a child sees a new type of animal or plant, the first thing he or she usually wants to know is its name. This is true of adults, too, and it indicates a basic human desire to make a connection with an organism by knowing its name.

For most organisms, there are two names: the "common name" and the "scientific name." Our common name, for example, is "human," while our scientific name is *Homo sapiens*. There are advantages and disadvantages to both scientific and common names.

Common names are usually easier for us to understand – they're in our common language. They are often descriptive. A redwood tree does, in fact, have red-colored wood. A striped skunk does have stripes, and a rough-skinned newt has rough skin. Common names can also be confusing or misleading. The California bay tree is also known as the California laurel, the bay-laurel, and the pepperwood. Neither poison oak nor tanoak are truly oaks. Douglas-fir is not a true fir, and the same tree is sometimes called Oregon pine…and it's not a pine either.

Another disadvantage of common names is that they differ in different places. Gardeners are familiar with the pocket gopher that enjoys eating our plants. In the southeastern states there lives a tortoise called a gopher tortoise.

Also, different languages have different names for the same organism. Italians working in the mills of redwood country would call the raccoon procione, while the French would call the same animal raton laveur. A Swedish lumberjack would call it sjubb, while a German would call it der Waschbar. Russians at Fort Ross would call the raccoon eHOT (pronounced yeh en oh tea), while a Chinese laborer might call it huan xiong and a Spanish missionary might talk about the mapache. Different Native American groups had different words for raccoon: in Tolowa it's kwen-sha; in Coast Yurok it's tweg-gaw, in Pomo it's kah-doos, while the Coast Miwok would call the raccoon hoo-ma-ka. However, scientists from around the world would know the raccoon as *Procyon lotor*.

Scientific names, on the other hand, may be hard to pronounce or remember, as they are typically derived from Latin or Greek words, or "Latinized" forms of other words. They are, however, generally descriptive of the organism. The coast redwood, for example, is named *Sequoia sempervirens*: "*Sequoia*" to honor the great Native American leader and "*sempervirens*" to recognize the tree's long life. Scientists all around the world know that *Sequoia sempervirens* is the coast redwood, and that all other types of trees, even the giant Sequoia redwood of the Sierra and dawn redwood of China, have different scientific names. The giant Sequoia, also called the Sierra redwood and big tree, is *Sequoiadendron giganteum*, and the dawn redwood is *Metasequoia glyptostroboides*.

Another advantage of a scientific name is that it has two parts, the genus name and the specific epithet, which combined make the species name. The genus of an organism indicates a group of organisms that are very similar (closely related evolutionarily) to each other. The species name indicates the particular (specific) kind of organism. The genus is written first and is a capitalized proper noun, followed by the species name which is usually an adjective and not capitalized. Both genus and species are italicized or underlined. For example, a common oak in northern California is the black oak, *Quercus kelloggii*. The closely related Oregon white oak is named *Quercus garryana*. The tanoak tree, which is not a true oak, is in a different genus, and its scientific name is *Lithocarpus densiflorus*. All oaks of the genus *Quercus* are more closely related to each other than they are to *Lithocarpus*.

See the activity "Name That Plant" in Section IV.

Plants and animals were originally grouped or classified by observation of their physical structures. Some kinds of organisms from very different groups have developed similar looking and functioning structures. For example, bats and flying squirrels have adaptations that allow them to fly or glide through the air, much like birds. They aren't, of course, birds. Over time, scientists have developed a variety of methods for grouping organisms according to how closely related they are evolutionarily. Not only are physical structures examined closely, but fossil evidence, genetic studies, blood chemistry, and DNA are used to try to obtain an accurate understanding of how organisms are related. This study of how organisms are related is called **taxonomy**, and taxonomists continue to clarify organisms' relationships to each other. Some of the scientific names in *Redwood Ed* would have been different 30 years ago, and some may well change in the near future as taxonomists learn more about the evolutionary relationships of organisms. Even contemporary authors may use different scientific names for the same organisms. For example, the scientific names used by Stebbins in the *Peterson Field Guide to Reptiles and Amphibians* (2003) sometimes differ from those used by Behler and King in the Audubon Society's *Field Guide to North American Reptiles and Amphibians* (1979).

In *Redwood Ed*, I have used the "valid" names as accepted in the Integrated Taxonomic Information System (< www.itis.usda.gov >   or < http://www.cbif.gc.ca/pls/itisca/ >).

Taxonomy

When I took high school biology in the 1960s, we were taught that living things could be divided into two "kingdoms:" Plantae (plants) and Animalia (animals). Some things that didn't quite fit into either category were called protists. Currently, most taxonomists use 5 or 6 kingdoms:

1. Archaebacteria: some ancient types of bacteria; don't have a nucleus

2. Eubacteria: most bacteria; without a true nucleus or nuclear membrane; chemically different from Archaebacteria

3. Protista: organisms with a nucleus and membrane-bound organelles; includes algae

4. Plantae: green plants…mosses, ferns, grasses, flowering plants, conifers

5. Fungi: molds, mushrooms, yeasts

6. Animalia: animals

Each kingdom is divided hierarchically into smaller groups of organisms. Within each subgroup, the organisms are more closely related to each other than they are to organisms in other groups. A kingdom has several phyla (singular: phylum). Each phylum has several classes, which typically have several orders, which usually have several families, which may have several genera (singular: genus). Most genera have several **species**.

As noted above, the study of organisms and how they are related and classified is a constantly evolving science. Not only does it change as we find out more about their evolutionary relationships and discover new organisms, but names of groups change, and not all taxonomists agree on every classification.

Here is a simplified classification of the bobcat, *Lynx rufus*, which is classified in the groups indicated in **bold** below.

KINGDOM: All living things are usually classified into the 6 kingdoms listed above:

Archaebacteria	Eubacteria	Protista	Fungi	Plantae	**Animalia**

PHYLUM: Animalia is divided into different phyla, including, among others:

Porifera	Annelida	Mollusca	Arthropoda	Echinodermata	**Chordata**
(sponges)	(earthworms)	(snails, slugs)	(insects, spiders)	(sea stars, urchins)	(fish, birds, mammals)

CLASS: The Phylum Chordata is divided into different classes, incuding:

Chondrichthyes	Osteichthyes	Amphibia	Reptilia	Aves	**Mammalia**
(sharks, rays)	(trout, perch)	(frogs, newts)	(snakes, lizards)	(birds)	(mice, cats, people)

ORDER: The class Mammalia is divided into different orders, including:

Marsupialia	Lagomorpha	Rodentia	Cetacea	Artiodactyla	**Carnivora**
(opossums)	(rabbits, hares)	(mice, squirrels)	(whales, porpoises)	(deer, elk)	(skunks, cats, seals)

FAMILY: The order Carnivora is divided into different families, including:

Canidae	Ursidae	Procyonidae	Mustelidae	**Felidae**
(foxes, coyotes)	(bears)	(raccoon, ringtail)	(weasels, minks, otters, skunks)	(bobcat, mountain lion)

GENUS: The family Felidae is divided into different genera, including:

Felis	*Panthera*	***Lynx***
(mountain lion)	(lions, tigers)	(lynx, bobcat)

SPECIES: The genus *Lynx* has several species, including:

Lynx canadensis	***Lynx rufus***
(Canadian lynx)	(bobcat)

Species

Names of species are generally given as a combination of the genus (capitalized and italicized) (*Lynx*) and the species name, which is italicized but not capitalized (*rufus*).

There is one kind of animal, the bobcat, that is named *Lynx rufus*.

Sometimes species are divided into subspecies, races, or varieties.

Another way to look at the classification of the bobcat would be:

Kingdom: Animalia

- **Phylum**: Chordata
  - **Class**: Mammalia
    - **Order**: Carnivora
      - **Family**: Felidae
        - **Genus**: *Lynx*
          - **Species, epithet or trivial name**: *rufus*
            - **Scientific/species name**: *Lynx rufus*

Knowing some word roots can help make the learning, or at least understanding, of scientific names less intimidating to teacher and student alike. Learning word roots is useful for everyday reading, too. Consider the names of the groups in the classification of the bobcat, *Lynx rufus*:

Animalia: Obviously, the word root is "animal," which the bobcat is. "Animal" comes from the Latin *anima*, for living being or life. If one is animated, they are lively; computer animation seems to make things come to life.

Chordata: Animals in this group have a flexible rod-like structure called a notochord. A chord is a string of a stringed instrument, and a cord is a flexible rope-like material.

Mammalia: Mammals nurse their young with mammary glands.

Carnivora: Carnivores are meat eaters: Latin: *carnis* (meat), *vorare* (to eat). Carnivores may have a voracious appetite.

Felidae: *Felis* is Latin for cat. Feline means cat-like.

Lynx: Probably comes from the Greek *lynx*, "to shine," for the animal's shining eyes. Lynx-eyed is to have very keen sight.

rufus: From the Latin *rufus* for brownish-red or rust colored.

Some students enjoy learning about the etymology (origins) of words and word roots. Knowledge of word roots can be valuable in later schooling and elsewhere. A good source for science word roots is:

< www.biology.ualberta > (Type "word roots" in the search box.)

Another good resource for word roots is the *Dictionary of Word Roots and Combining Forms*, by D.J. Borror (1988).

What's a "species?"

By “species,” scientists typically mean organisms that are able to mate and produce fertile offspring. All kinds of domestic cats are able to mate and produce fertile offspring, and do so naturally, so all domestic cats are of the same species – *Felis domesticus.* An alley cat is the same species as a Siamese cat, as is a Persian cat. They can all successfully mate. The mountain lion (a.k.a. cougar, a.k.a. catamount, a.k.a. puma, a.k.a. panther) is classified in the same genus as the domestic cat because they have many structural similarities. It is, of course, a different species – *Felis concolor.* Both *F. domesticus* and *F. concolor* have 30 teeth. Bobcats, while they look much like domestic cats, can’t successfully mate with them and are different in other ways, such as the ratio of tail length to foot length and number of teeth (28), so they are classified as a different genus and species – *Lynx rufus.* The Canadian lynx is closely related to the bobcat (The Lynx also has 28 teeth.), so it is classified in the same genus, but as a different species – *Lynx canadensis.* Bottom line: scientific names show how organisms are related to each other, and each kind of organism has its own unique scientific name that is the same anywhere in the world.

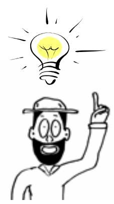
In *Redwood Ed*, both common and scientific names of organisms will be used. If the student or teacher wishes to find out more about a particular organism, I suggest using the scientific name, as it will yield more precise information. Sometimes a common name applies to more than one species. In such cases I've indicated the genus name (capitalized and italicized), followed by "spp," to indicate more than one species. For example, there are several species of oaks in the redwood region, so I might refer to them collectively or as unspecified species as *Quercus* spp.

Adaptations for Survival

Why is there such a diversity of living things on Earth, or in a particular ecosystem such as a redwood forest? What causes that diversity? The complexity of the chemical molecule named deoxyribonucleic acid (DNA), coupled with sexual reproduction and numbers of chromosomes results in a seemingly infinite variety of genetic combinations. Couple this with the mutations that constantly change the DNA and chromosomes, and the possible variations are even greater. As a result of this variation and diversity, each individual organism is slightly different from the others. Most of the differences are insignificant. However, when there is competition for resources, some individuals may survive and others may not. Those with **adaptations** that enable them to survive may pass on those adaptations to their offspring. Organisms that don't survive to reproduce can't, of course, pass on their characteristics to their offspring.

Some adaptations are structural (wings, camouflage coloration), some are physiological (the ability to grow rapidly, termite-resistant chemicals), while others are behavioral (migrating, competition for mates, tool making). When thinking about adaptations, it should be kept in mind that organisms **don't** develop adaptations in order to survive. Those that, due to natural genetic variability, **already** have certain adaptations may survive and reproduce, while those that don't have the necessary adaptations might not survive and reproduce. Thus, offspring inherit "good" adaptations from successful parents.

Teaching Idea



When I teach about the concept of adaptations, I try to emphasize the idea of diversity within a species being desirable with regards to the survival of the species. You can have "what if" discussions with your students…What if people with black hair can survive global warming better than those with blond hair? What if people with slow metabolisms survive better if there is a food shortage? Will people decide to grow black hair or change their metabolisms in order to survive? Obviously those who already have those adaptations will be the ones to survive and pass them on to their offspring. I refer to this as "pre-adaptation," and emphasize that we can't predict which adaptations will be advantageous in the future, and we can't decide to develop physical adaptations.

This discussion can also be useful in encouraging tolerance and appreciation of diversity among the students.

Every habitat (and microhabitat) has conditions that make different adaptations advantageous. Adaptations that are useful in one environment might not be useful in another. Some organisms of the redwood forest have interesting adaptations that enable them to survive in the redwood forest environment or in particular microhabitats.

Some common redwood forest organisms are described on the following pages. I've tried to point out particularly interesting, unique, or important adaptations.

A Few Words About Evolution

Some teachers are hesitant to teach about evolution, and this is understandable, as some parents reject the idea. The state of California, on the other hand, supports the teaching of the theory of evolution as a valid and important part of science education. It even uses evolution as a theme progressing through the grades, provides examples of court cases supporting education about evolution, and provides examples of evolution education in the 1990 *Science Framework for California Public Schools*.

One approach is to be clear that one is teaching evolution as a theory, and not require students to say that they accept or agree with the theory. If parents ask that their children not be taught about evolution, the child can be excused, but I recommend that you do so only after discussing it with the parent. You can point out that the child will need to understand evolution if they are to be able to counter the arguments that they will doubtless encounter later in life. Another reason that students should understand the theory of evolution, of course, is that questions about it may appear on various high school and college tests. You might also point out that many scientists are also religious and have been able to reconcile their religion with evolutionary theory.

Examination and discussion of the great diversity of life in any particular habitat provides an excellent opportunity to discuss the diversity and competition that form the basis of the theory of natural selection.

Aquatic Environments

The redwood forest ecosystem includes not only forests, but also aquatic environments such as ponds, creeks, and rivers, clearings such as the "prairies" of the hilltops in the northern redwood region, and mixed forest that includes various oaks, Douglas-fir, madrone, and other trees. Those subdivisions of the redwood forest are important, but in *Redwood Ed* I will generally limit the organisms described to those found in the redwood forest itself, along with a few other trees.

If you are interested in pursuing studies of the aquatic ecosystems, I suggest investigating resources such as the following*:*

Adopt-A-Watershed NEW Name - Earthwater	www.adopt-a-watershed.org New website – www.earthwater.org
California Classroom Aquarium Education Project (C.A.E.P.) (a.k.a. Salmonids in the Classroom, Trout in the Classroom, Salmonid Project)	www.dfg.ca.gov/oceo/caep
Project WET	www.projectwet@watereducation.org
Project WILD® – Aquatic	www.dfg.ca.gov/projectwild
Save Our Streams (Isaac Walton League)	www.iwla.org
Watershed Restoration (CA Dept of Water Resources)	www.watershedrestoration.water.ca.gov
Wetlands Protectors (CA Coastal Commission)	www.coastal.ca.gov

Some Common or Important Organisms of The Redwood Forest

The following are brief descriptions of a few of the hundreds of organisms that students might encounter on a visit to a redwood forest. This is not a complete list, of course, but it includes many of the most common or conspicuous organisms. Please see Appendix IV and V for several books that might be worthwhile additions to classroom libraries.

I have tried to include many of the kinds of organisms that visitors are likely to see. In addition, some common organisms that are not so likely to be seen are included. Some other organisms that are not common, but are important, are also described. There is some variation between the flora and fauna in the southern and northern redwood regions, so it would be a good idea to check with the interpretive staff of whatever park is going to be visited to try to obtain a local species list. The organisms described below are, of course, but a small fraction of those that one may see upon visiting a redwood forest. I highly recommend bringing with you one or more of the guides listed in the reference section. Among them are simple keys that students can use to identify many common plants and animals, as well as field guides that help with identification through the use of pictures.

Keep in mind, too, that simply memorizing names of organisms is probably not an important goal. However, knowing some organisms' names will make a visit to the redwood forest more interesting.

See the activities "Name that Plant," and "Similar, But Not the Same!" in Section IV.

Bacteria

While students won't see individual bacteria, or even populations of bacteria, it is important to remember that they play a very important role in any ecosystem. Bacteria provide food for many small organisms. Just as importantly, they serve as recyclers of dead organisms, returning nutrients to the ecosystem through the process of decomposition.

Figure 17. Bacteria take many forms.

Protista (including Algae)

Because they are generally aquatic organisms, the algae (singular: alga) and other protists are found mostly in streams and ponds. Algae may be microscopic, or they may be larger, sometimes forming stringy masses along the edges of streams and ponds.

As photosynthetic organisms, algae are classified as "producers" because they use energy from the sun to produce organic chemicals such as sugars, starches, and cellulose through the process of photosynthesis. Not only are complex chemicals produced through photosynthesis, but oxygen is also released as a waste product. This oxygen may dissolve in the water, where it is available for other organisms, or it may bubble out of the water and be released into the atmosphere.

As producers, algae form the base of the aquatic food pyramid and the beginning of aquatic food chains.

Lichens

Algae can are also important as part of the organisms called **lichens**. Lichens are actually organisms that consist of a fungus and an alga living together in a **mutualistic** relationship, i.e., one in which both organisms benefit. The alga (or sometimes a blue-green bacterium) provides nutrients for the fungus through photosynthesis. The fungus provides a sheltered environment where the alga is protected from drying out. Over 90 species of lichens have been identified in the redwood forest along the Mendocino coast alone (Noss, 1988). In many areas, the lower trunks and branches of redwoods may be coated with gray-green lichens. Other lichens may dangle from branches or cover rocks.

Fungi

Approximately 300 species of fungi have been identified in the redwood forest. (Noss, 2000) Many species are epiphytes, living in the trees, or can be found in and on decaying logs and forest floor litter (duff).

Fungi serve as important food sources for some animals, and are also important as decomposers of dead or dying organisms, returning nutrients to the environment. Fungi also kill many kinds of trees that would compete with the redwoods. Even with its tannins, the redwood is not entirely immune to attacks by fungi, but redwoods are seldom killed by fungi. Fungi also form mutualistic associations with redwood roots, helping pass dissolved nutrients to the redwood root system.

Redwoods seldom reproduce successfully by seeds unless the forest floor has been disturbed by a fire, logging, or silt deposited by flooding. Sometimes this is because the roots of the seedling dry out because they can't penetrate the thick layer of duff quickly enough. Often, though, the seeds die because of "damping off" fungus…fungus that kill the seed before it even has a chance to grow.

Plants

Hundreds of plant species are found in the redwood region, and we have space for only a few in *Redwood Ed*. I highly encourage the reader to obtain one or more of the excellent plant guides that are available, some of which are listed in Appendices IV and V.

Non-Vascular Plants:

Non-vascular plants include mosses, liverworts, and hornworts. Since they do not have specialized **vascular tissues** to carry water and other materials, they are all fairly small plants that live in moist areas such as decaying logs in shady areas and rocks along streams. In such places, they are among the first organisms in the succession sequence. The lack of vascular tissue not only limits their ability to transport materials, but it also limits their size because vascular tissues also hold up leaves in vascular plants.

Figure 18.

Mosses: Phylum Bryophyta
Various genera and species of mosses live in the cool, damp environment of the redwood region.

Look for the spore capsule on its stalk. Mosses reproduce with **spores**, as opposed to **seeds**.

Vascular Plants:
Most plants with which we are familiar are vascular plants, i.e., they have vascular tissues (**xylem** and **phloem**) that carry water and other materials throughout the plant. They have true roots, stems, and leaves.

Horsetails: Phylum Pterophyta, genus Equisetum
The horsetail, or scouring rush, is among the most primitive of vascular plants. The common name "horsetail" comes from its appearance, while "scouring rush" derives from its abrasive silica, which made it useful for scouring pots and pans. Some species of *Equisetum* have the stems surrounded by branches that stick out from the joints or nodes, while others look like a jointed spear.

Modern horsetails are very similar to giant species that lived during the time of the dinosaurs (as did the redwoods!).

The tips of young plants were sometimes boiled like asparagus, and were used as a diuretic. Too much, however, can cause illness.

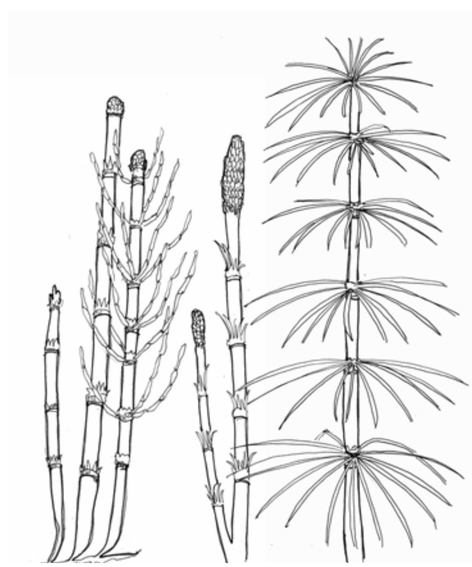


Figure 19. Horsetail (*Equisetum* spp.)

Ferns: Phylum Pterophyta
Ferns are among the most primitive of vascular plants. Unlike the "higher" plants, however, ferns reproduce with spores rather than seeds.

The spores are produced in sporangia on the undersides of the leaves. Along with leaf shape, the location, shape, and distribution of the sporangia are often used in identifying species of ferns. The *Pacific Coast Fern Finder* (Keator and Atkinson (1981), *Plants of the Coast Redwood Region* (Lyons and Cooney Lazaneo, 2003), and *Pocket Flora of the Redwood Forest* (Becking, 1982), among other resources, are useful in identifying types.

Sword Fern: *Polystichum* spp.

Look for the projection from the base of the leaflet, which somewhat resembles the hilt of a sword. Several fronds, from 2 to 4 feet in length, arise from a single base.

Sword ferns are among the most common ferns in the redwood region, sometimes forming dense clusters. They are relatively resistant to drought and do well in moist environments.

The tips of young leaves, called fiddle-heads, can be boiled and eaten. To keep fish or other food clean, Native Americans sometimes laid fronds on the dirt floors of their cooking pits.

Figure 20. Sword Fern (*Polystichum* spp.)

Bracken Fern: *Pteridium aquilinum*

The bracken fern is extremely wide-ranging, with numerous varieties living from the subarctic to tropical regions. Their triangular fronds, which may be up to four feet long, are often highly branched.

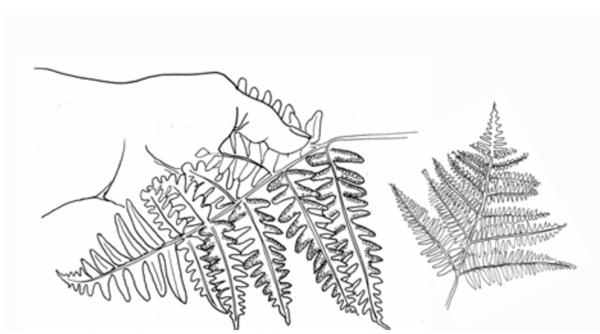


Figure 21. Bracken Fern (*Pteridium aquilinum*)

Bracken ferns may be found from shady, moist areas to relatively dry openings in the redwood forest. The fronds die back in the winter.

While the young fiddleheads can be eaten in limited quantities, large quantities, or older plants are toxic! Native Americans use the roots to create patterns in baskets.

California Maidenhair Fern: *Adiantum jordanii*

The maidenhair fern is usually found on moist rocky outcroppings. The leaflets (pinnae) are rounded and grow from short stems along a 1-2 foot dark colored central stem. The spores line the edge of the underside of the pinnae.

The dark stem was used by Native Americans, who pounded them to obtain long black strands for use in basket weaving.

Five-Finger Fern: *Adiantum pedatum*

The five-finger fern isn't necessarily five-fingered…they may have more than five segments growing out from a central area of a single frond in a finger-like fashion. These ferns are often found growing from moist crevasses in rocks and along streams. The spores are hidden on the underside of the leaf's curled margin.

Like the maidenhair fern, the five-finger fern is used in basketry.

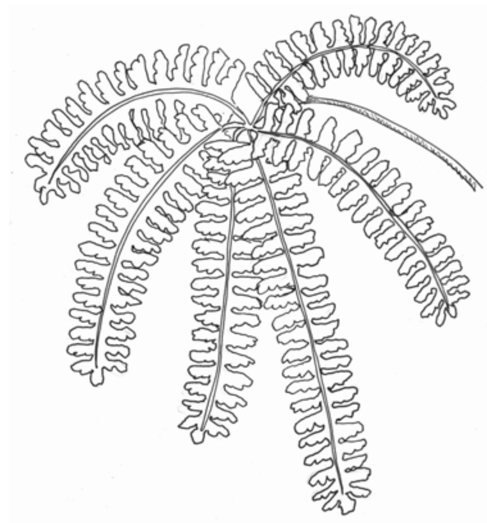


Figure 22. Five-Finger Fern (*Adiantum pedatum*)

Gymnosperms: cone-bearing trees

Coast Redwood: Sequoia sempervirens

Height to 360 feet (109 m) or more, often to over 300 feet (92 m), diameter of 10-13 feet (4 m) in alluvial flats, up to 33 feet (11 m); usually smaller on hillsides.

The thick, reddish brown bark is resistant to fire and to insect attack. The bark may be up to a foot thick, absorbs moisture readily, and is relatively free of resin, and therefore more resistant to fire.

Reproduction is often from sprouts that grow from lignotubers or basal burls that form at the base of the trunk. Forms olive-sized cones that produce tiny seeds, but the seeds often fail to grow for a variety of reasons. The male and female cones often hang in clusters and are found on the same tree. (See also Figure 2 on page 12.)

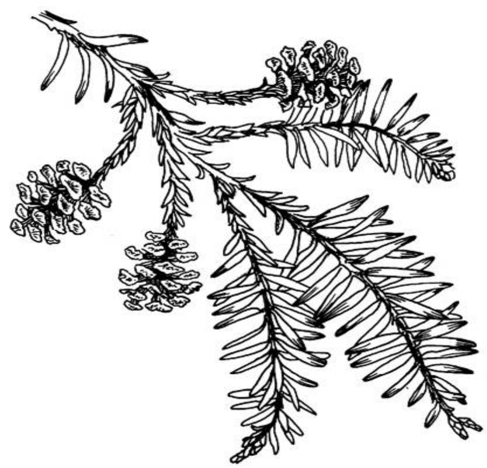


Figure 23. Coast Redwood (*Sequoia sempervirens*)

Native Americans used the strong roots for fiber, and used the wood as planks for building structures, canoes, and other uses. Redwood is now used extensively for lumber.

Redwoods are distinguished from Douglas-fir by the cones, more fibrous bark with long parallel grooves, and leaves (needles), which grow flatter from green twigs.

Douglas-fir: Pseudotsuga menziesii
Height 80-200 feet (61 m), sometimes more than 300 feet (92 m)
Diameter: usually 2-5 feet (1.5 m), occasionally over 10 feet (3 m)

"Doug-fir" commonly grow in association with redwoods, especially on hillsides or hill tops. They are the most important lumber trees from California to British Columbia.

Douglas-fir can be distinguished from the coast redwood by the cones, less fibrous bark without the long parallel grooves, and leaves (needles) that are about ¾ inch long and grow in whorls around the twigs. The cones are 3-4 inches long and have bracts with 3 points that extend out from between the rounded scales. The cones hang downward from the branches.

This tree is not a true "fir," hence the scientific genus name of *Pseudotsuga.*

Douglas-fir needles can be steeped to make a vitamin C-rich tea.

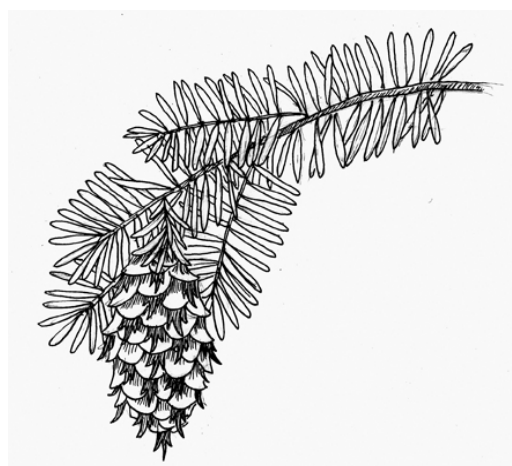


Figure 24. Douglas-fir (*Pseudotsuga menziesii*)

Coast Hemlock (Western Hemlock, Pacific Hemlock, West Coast Hemlock):*Tsuga heterophylla*
Height: to 100-200 feet (61 m)
Diameter: to 6 feet (2 m)

These trees often grow near the coast in the northern redwood region. In some cases, they tend to shield the salt spray-intolerant redwoods so that the redwoods grow closer to the coast than they otherwise might. They are more shade tolerant than Douglas-fir and may replace them in areas from which fires are excluded.

The western hemlock often grows from seeds that germinate on fallen logs, and the long roots often grow over the logs, resulting in nickname of "octopus tree." Such a "nurse log" may have several hemlocks growing along its length, resulting in a line of hemlocks growing where a log once lay.

The durable wood is used as lumber and paper pulp.

The needles are about half an inch long, growing from brown twigs, while the needles of Douglas-fir are longer. Cones about ½-1 inch long.

The wood is used for lumber and pulp. Because it is often harvested with various species of fir trees, the lumber is often marketed as "hem-fir."

Grand Fir: Abies grandis
Height: 150-200 feet ((61 m), maximum 250 feet (76 m))
Diameter: 2-3 feet (1 m), sometimes to 5 feet (1.5 m)

The Grand Fir grows from northern California to British Columbia. The needles grow out in flat sprays from the branches, more like a redwood than a Douglas-fir. The needles are ¾ to 2 inches long and have a rounded notch at the tip. The cones sit upright on the branches (as opposed to the Douglas-fir cones, which hang downward.) Like the western hemlock, grand fir are very shade tolerant and may replace Douglas-fir in areas where fire is excluded. Grand fir are not very resistant to insect and fungus attacks, so they rarely live to be over 300 years old.

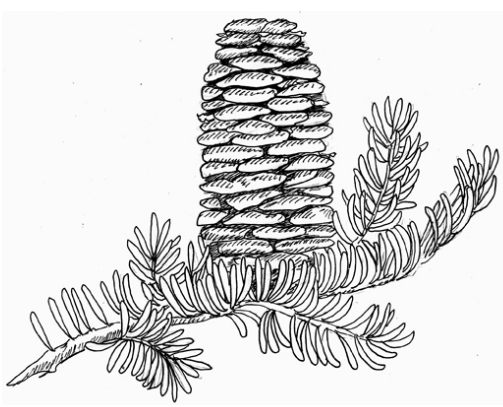


Figure 25. Grand Fir (*Abies grandis*)

The seeds of the grand fir are an important source of food for wildlife, but the lumber is not very durable so it is used mostly to make boxes.

Sitka Spruce (Coast Spruce, Tideland Spruce, Yellow Spruce): *Picea sitchensis*
Height: 100-160 feet (48 m), sometimes to 215 feet (65 m)
Diameter: 3-4 feet, rarely to 17 feet

The Sitka spruce lives in the coastal mountains from Caspar Creek in northern California to Alaska, and is rarely found more than 30 miles from the coast. Like the coast redwood, the tree seems to be dependent on coastal fog.

Their roots are exceptionally tolerant of moisture, enabling them to live in places such as Ketchikan, Alaska, with 151 inches of rain per year. The tree is often covered with mosses and ferns.

The needles are arranged spirally around the stem and are ½-1 inch in length with sharply pointed tips. The cones are 2-4 inches long and hang downward. Spruces can be distinguished from firs by the small woody pegs left on the branchlets after the needles fall off, giving the branches a very rough texture.

The sharp points of the needles provide some protection from browsing by deer and elk, which prefer the more tender hemlock and other plants.

Sitka spruce is used for lumber, plywood, and paper pulp. Sitka spruce trees from old growth forests can produce wood with narrow-spaced rings that is, pound for pound, stronger than steel. This strong wood is used for making boats, aircraft, and musical instruments.

Angiosperms: flower-bearing plants

Madrone (Pacific Madrone): *Arbutus menziesii*
Height: 25-80 feet (24 m), occasionally over 100 feet (30 m)
Diameter: 2-3 feet, sometimes to 5 feet
Blooms: early spring, with orange berries developing in late summer

Common in the mixed evergreen forests, especially on upper slopes. Madrone often grows from multiple trunks with twisted shapes formed as the branches reach for light. Smooth bark which peels off in the summer to reveal smooth light green wood, which later becomes a rich dark red-brown color.

Figure 26. Madrone (*Arbutus menziesii*)

The evergreen leaves have a thick waxy cuticle that helps prevent water loss. Madrones are well adapted for surviving fires and will readily stump sprout. Native Americans and early settlers used the leaves and berries as foods and medicines.

Oaks

There are many varieties of oaks in California, with several found in the redwood region. None live in the redwood forest *per se*, but some can be found in clearings and in mixed forests. To distinguish among the oaks, I recommend using a key such as the *Pacific Coast Tree Finder*, by Tom Watts (1973).

Male flowers develop in the spring and soon fall from the tree. The female flowers form acorns. Acorns of many varieties were a vital, major food source for Native Americans, and continue to be important for many animals, including deer and bear.

Coast Live Oak: Quercus agrifolia
Height: 30 to 50 feet (15 m), sometimes to 90 feet (27 m)
Diameter: 1-2 feet (0.6 m), sometimes to 3 feet (1 m)
Blooms: February-April

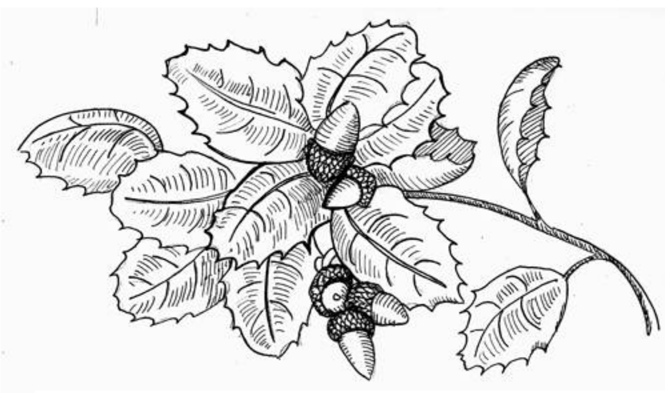


Figure 27. Coast Live Oak (*Quercus agrifolia*)

Most common of the redwood region live oaks, especially in the southern and central redwood region. When not crowded, forms a rounded crown with wide-spreading branches. The top surface of the sharply-toothed leaves is shiny dark green, while the lower surface often has a tan colored furry covering in the area where the veins join, and the leaf is deeply curved. The oblong acorn has a pointed tip.

The wood is not straight enough for lumber, but is often used as firewood.

A closely related oak, the Shreve oak, is common in the central and southern redwood regions. Some consider the Shreve oak to be a variety of the coast oak, *Quercus parvula* var. *shrevei*; others consider it to be a form of *Quercus wislizeni*; and still others classify it as a separate species, *Quercus shrevei*. Some evidence indicates that the Shreve oak is somewhat resistant to Sudden Oak Death (Dodd *et al*., 2002)

California Black Oak: *Quercus kelloggii*
Height: usually 30-75 feet (23 m), occasionally approaching 100 feet (30 m)
Diameter: 1-3 feet (1 m), sometimes to 4 feet (1.2 m)
Blooms: March-May

The black oaks grow at higher elevations, especially on the eastern slopes of the coastal mountains in the central and southern parts of the redwood region. The deeply lobed leaves have sharp points and are large, sometimes reaching almost 10 inches in length.

While most oaks are evergreen, the black oak is deciduous.

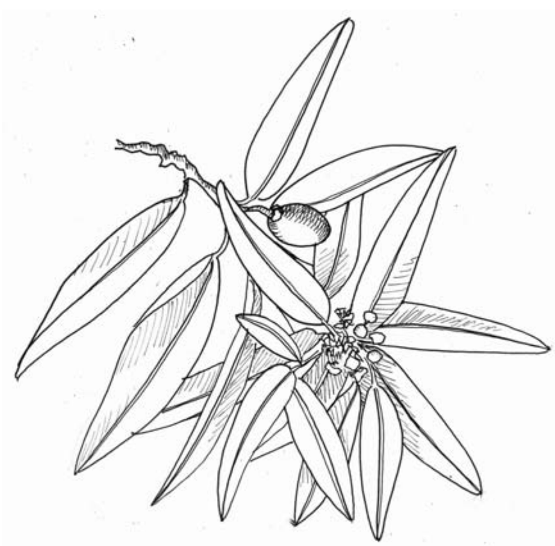
In many areas of California, the black oak's acorn was an important food source for Native Americans.

Figure 28. Black Oak (*Quercus kelloggii*)

California Bay (California Laurel, Bay-Laurel, Pepperwood, Oregon Myrtle):
Umbellularia californica
Height: 30 to 80 feet (24 m)
Diameter: 1-3 feet (1 m)
Blooms: December-April

The California Bay is common on wooded slopes in the Coast Range.

The long leaves are pointed at the tips and wedge-shaped at the base, and have a strong fragrance. They are leathery and dark green in color.



The Native Americans used the leaves to cleanse wounds and cure headaches. The leaves were also used as a flea-repellant in their dwellings. The nuts were roasted to remove the bitter taste and eaten whole or ground into flour.

Today the leaves are dried and used as a spice which is similar to the more expensive European bay leaves. The wood is often used to make bowls and other fine wood products.

Figure 29. California Bay (*Umbellularia californica*)

Alders

Red Alder: Alnus rubra (also Alnus oregona)
Height: usually 40-80 feet (24 m), occasionally to 100 feet (30 m)
Diameter: to 2.5 feet (0.8 m), occasionally to 4 feet (1.2 m)
Blooms: January-March

White Alder: Alnus rhombifolia
Height: usually 40-70 feet (18 m), occasionally to 80 feet (24 m)
Diameter: to 2 feet (0.6 m), occasionally to 4 feet (1.2 m)
Blooms: January-March

The red alder grows along coastal streams from Santa Cruz county to Alaska. The edges of the leaves are rolled under.

The white alder is more common in the southern redwood region, in more inland locations such as the eastern slopes of coastal mountains, and in the Sierra. The edges of the leaves are not rolled under.

The leaves of white alder are finely toothed, while the red alder leaves are more coarsely toothed (larger "teeth").

The bark is gray-white in color. The elongated male flowers, called catkins, release pollen in February and March. The female catkins are cone-like, to 1 inch in length, and resemble an elongated coast redwood cone.

Alders are one of the few trees that can use nitrogen from the atmosphere. They, like legumes, have nitrogen "fixing" bacteria in their roots. The bacteria are able to capture nitrogen from the air and combine it with oxygen to form compounds that plants can use.

They need a fair amount of sunlight and moisture, so they usually grow along streams. Alders grow rapidly and can grow to 40 feet tall in a decade.

Figure 30. Red Alder (*Alnus rubra*)

Native Americans used the red alder for basketry, with the roots used as a fiber and the inner bark used to produce an orange dye. The wood is used in furniture making. White alders are sometimes planted as ornamental trees.

Big-leaf Maple (Big Leaved Maple): *Acer macrophyllum*
Height: to 100 feet (30 m)
Diameter: 3-4 feet (1.2 m), rarely to 8 feet (2.4 m)
Blooms: March-May

The big-leaf maple often forms dense strands along streams and in moist areas throughout the coastal mountains.

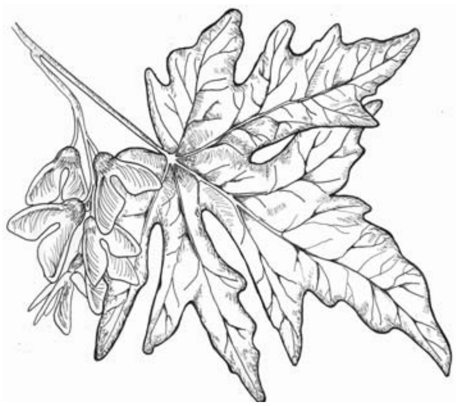


Figure 31. Big-leaf Maple (*Acer macrophyllum*)

The bark of young trees is smooth and light gray-reddish in color. As the tree grows older, the bark darkens and becomes more rough.

The leaves have a typical maple-leaf shape with deep notches. In the fall, they turn a bright yellow or orange color. The long, drooping clusters of yellow-green flowers produce double-winged fruits. The wings on the seeds enable them to be blown far from the parent tree as they fall to the ground, thus reducing competition between the seedling and the parent tree.

Maple wood is used for making furniture, paneling, and veneer. A syrup can be made from the sap.

Tanoak (Tanbark Oak): *Lithocarpus densiflorus*
Height: 50-100 feet (30 m), rarely to 150 feet (45 m)
Diameter: 1-3 feet (1 m), rarely to 6 feet (1.8 m)
Blooms: May-June

The tanoak is not a true oak tree, but its leaves, acorns, and flowers closely resemble the true oaks. It is common throughout the redwood region, especially in mixed evergreen forests.

The tree grows straight and tall and has smooth gray bark. The leaves are a glossy green on the top and are coarsely toothed along the edges.

Tannic acid was extracted from the bark of tanoak and used to tan leather. It was used in the tanning industry throughout the redwood region in the 1800s and early 1900s. (Some experiments were also done using redwood bark to tan leather.)

Because of their large size, the acorns of the tanoak were favored by native people wherever they were found.

Figure 32. Tanoak (*Lithocarpus densiflorus*)

California Hazel: (California Hazelnut): *Corylus cornuta*
Blooms: January-March

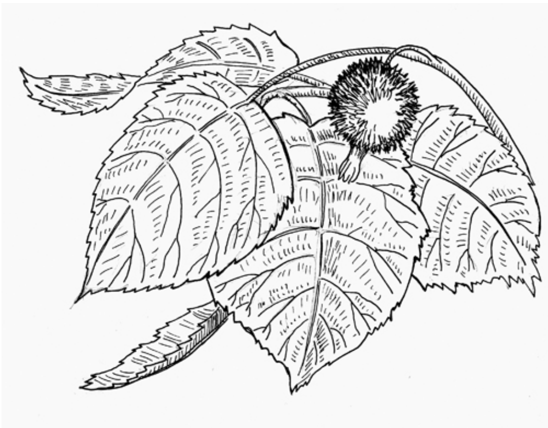


Figure 33. California Hazel (*Corylus cornuta*)

The hazel is common in various parts of the redwood region, from shaded streams to wooded slopes. The shrubs grow to 10 feet in height, with an open, spreading growth pattern. The soft leaves have pointed tips with saw-tooth edges.

Nuts, similar to filbert nuts, ripen in mid-late summer and are very tasty, although animals such as squirrels and birds often eat them before they are fully ripe. Native Americans also used the stems and young shoots in their basketry

Elderberry:
Blue Elderberry: *Sambucus mexicana*
Blooms April-June

This plant is common away from the coast along chaparral borders. Its blue berries are edible and can be made into jams and wine.

Red Elderberry: *Sambucus callicarpa*
Blooms: March-July

The berries of the red elderberry are poisonous and should not be eaten!

Stinging Nettle: *Urtica* spp.
Blooms: May-October

The stinging nettle generally grows along streams, but may be found elsewhere in the redwood region. They can grow to over five feet in height, and the plants are covered with small poison-filled hairs that inflict a very irritating sting.

Young leaves and stems can be cooked and eaten like spinach.

Figure 34. Stinging Nettle (*Urtica* spp.)

Wood Rose: *Rosa gymnocarpa*
Blooms: April-September

This small shrub may grow to four feet or more tall and produces dainty, light pink flowers that are about an inch across. The thorns are straight. As the seed matures, a "hip" is formed in the fall.

Rose hips were, and are, used to make a vitamin C-rich tea.

The California Rose, *Rosa californica*, has a somewhat larger and pinker flower, curved thorns, and the leaves are hairy on the underside.

Redwood sorrel: *Oxalis oregana*
Blooms: February-September

Redwood sorrel is very common in redwood forests, often covering the ground in a beautiful green carpet. The clover-like leaves are very sensitive to sunlight and will fold or droop down when exposed to direct sunlight. It is thought that this helps conserve water, as the stomata or openings through which water escapes the leaves are more numerous on the underside. As the flowers get older, they turn from white to a deep pink color.

The stems and leaves contain oxalic acid, which gives them a tangy, acidic taste. They can be eaten raw in moderation or cooked.

Figure 35. Redwood Sorrel (*Oxalis oregana*)

Wake Robin: (Western Trillium)
***Trillium* spp.**
Blooms: March-May

The wake robin is common in the shady redwood forest, especially in damper areas and along streams. There are three large dark green leaves atop a 5-8 inch stem. The 3-petaled flower changes from white to purple as it ages.

Figure 36. Wake Robin (*Trillium spp.)*

Poison Oak: *Toxicodendron diversilobum* (formerly *Rhus diversiloba*)
Blooms: March-May

Figure 37. Poison Oak (*Toxicodendron diversilobum*)

Poison oak is extremely common throughout the redwood region and grows in damp, shady redwood groves as well as on sunny open hillsides. It may grow as low-growing ground cover, a cluster of short sticks, a tall shrub, or even as a tree-climbing vine with thick stems over 40 feet long.

<u>To identify poison oak in the spring and summer, look for three leaves</u>. The leaves may be nearly smooth-edged, or deeply lobed, hence the name "diversilobum." In the fall, the leaves turn red and fall off.

<u>To identify poison oak in the winter</u>, look for stems that are almost pencil-thick and <u>taper</u> <u>very</u> <u>little</u> until they get to the end.

The Native Americans were apparently not very much affected by the oils of poison oak and had many uses for it. They used the stems in basketry, and obtained a juice from them to create a dark dye. The juice was also used as medicine for a variety of ailments and in a tattooing process.

California Blackberry: *Rubus ursinus*
Blooms: March-August

Blackberries are usually found in sunny areas and often form thickets in meadows and along roadways.

Like poison oak, the blackberry plant has leaflets in groups of 3, but it can be distinguished by the teeth along the edge of the leaflets (as opposed to poison oak's smooth or lobed leaves) and by the presence of many thorns. Blackberry patches often have poison oak growing among the berries, so be careful when picking berries!

Figure 38. Blackberry (*Rubus ursinus*)

White or pink rose-like flowers produce berries which ripen in late summer or fall. The closely related Himalaya blackberry (*Rubus procerus* or *R. discolor*) is replacing native blackberries in some areas and is considered an invasive plant.

Some Native Americans used the plant to make dark dye for their baskets.

Thimbleberry: *Rubus parviflorus*
Blooms: March-August

Common in the redwoods and mixed evergreen forest areas, the thimbleberry shrubs often form dense thickets 3-4 feet tall. The large leaves are very fuzzy, and the edible flowers produce tasty red berries that ripen in the summer.

The salmonberry, *Rubus spectabilis,* produces yellowish or reddish berries.

Bedstraw: *Galium* spp.
Blooms March-April

Bedstraw is a spreading vine with square stems and leaves that grow in whorls around the stems. It grows in moist shady areas where it sometimes forms dense mats. It has small hooks which enable it to climb over plants, logs, etc.

While attractive in the woods, the plant can be invasive in gardens. The small seeds cling to clothing and facilitate the spread of the plant.

Western Azalea: *Rhododendron occidentale*
Blooms: June-September

The azalea lives along streams and in moist meadows in redwood and mixed evergreen forests. The showy white or cream-colored flowers cover the bush, especially in sunny areas. The leaves are thinner than those of the related California rhododendron, *Rhododendron macrophyllum*, which has rose-purple colored flowers and doesn't need as moist an environment.

All parts of the plant are poisonous.

Elk Clover: (California Spikenard): *Aralia californica*
Blooms: July-August

Sometimes called spikenard, the elk clover is usually found along streams or in very moist areas. It can reach 10 feet in height, and the leaf stems may be as much as a foot in length. Individual leaflets can be up to 5 inches wide and 7 inches long. The small white flowers of early summer form purplish-black berries in the fall.

Miner's Lettuce: *Claytonia perfoliata* (formerly *Montia perfoliata*)
Blooms: February –May

Figure 39. Miner's Lettuce (*Claytonia perfoliata*)

Miner's lettuce often covers the ground in moist areas. It is easy to identify by its round leaves at the tips of 3-8 inch long stems. Tiny white flowers form in the center of the leaves.

Claytonia sibirica ("Indian lettuce") has more oval and pointed leaves.

Miner's lettuce can be eaten raw in salads or boiled like spinach. A tea made from the leaves works as a laxative.

California Huckleberry: *Vaccinium ovatum*
Blooms: February-June

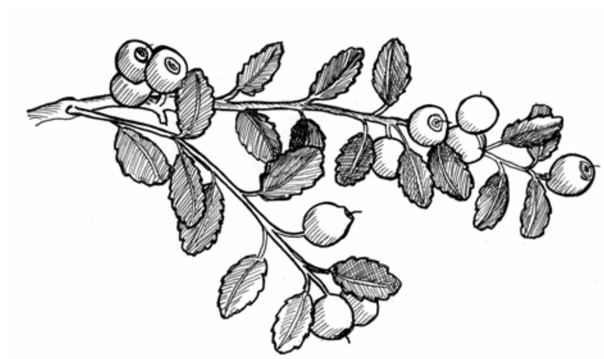


Figure 40. California Huckleberry (*Vaccinium ovatum*)

Huckleberries can be found throughout the redwood region. They are most commonly found in redwood and mixed evergreen forests, but can be found in chaparral areas, too.

The evergreen shrub often forms large thickets 3-8 feet in height. The small, white bell-shaped flowers produce deep blue colored berries in the fall. Plants in sunnier areas produce sweeter berries. The berries are similar to blueberries and can be eaten raw or cooked in pies or jams.

The red huckleberry, *Vaccinium parvifolium*, is deciduous and produces red berries in late summer.

Solomon's Seal: *Polygonatum* spp. (formerly *Smilacina* spp.)
Blooms: February-July

Both slim (star) Solomon's seal (*Smilacina stellata*) and fat (or false) Solomon's seal (*Smilacina racemsa*) live in shady areas of the mixed evergreen and redwood forests. Both have white flowers that produce berries. The slim Solomon's seal berries are greenish yellow with purple-red stripes, while those of the fat species are red, sometimes with small purple spots. Opinions vary on the edibility of the berries, so eating them is not recommended.

Trail plant: *Adenocaulon bicolor*
Blooms: May-September

Trail plants grow in mixed evergreen forests, often forming sizeable patches.

The arrowhead shaped leaves are green and smooth on top, and white and wooly on the underside. The name derives from the way that a broken leaf, with its light colored underside, points like an arrow, thus showing the path taken by a person or animal.

Redwood Violet: (Evergreen Violet): *Viola sempervirens*
Blooms: February-June

Redwood violets are common in moist areas of the redwood forests, often abundant along streams.

This low-growing plant has heart-shaped leaves and yellow flowers with purple veins on the lower three petals. Violets are related to pansies, and their flowers are somewhat similar.

Skunk Cabbage: *Lysichiton americanum*
Blooms: March-June

Skunk cabbage has a large yellow spike-like flower which is surrounded by a yellow "clasping leaf," called a spathe, which gives off a strong odor. The leaves can reach a length of four feet and a width of a foot. The plants generally grow in large patches in wet, boggy areas near springs and year-round creeks.

Exotic Species

The following plants are not native to the redwood region; they are "exotic" or "introduced" plants. They tend to be very aggressive colonizers and may displace native species of plants. They are thus described as "invasive."

Pampas Grass: *Cortaderia* spp.
Blooms: The large, showy flowers tend to remain on the plants for a long time.

Native to Argentina, pampas grass is commonly found along roadsides and abandoned fields. It is a very aggressive invader and can quickly form an impenetrable barrier with its thick, bushy growth of blades that are very sharp. They grow in clumps three to five feet wide and five feet or more high. The flowers are borne on very showy plumes, and the seeds are widely dispersed by the wind.

Brooms:
Scotch Broom: *Cytisus scoparius*
French Broom: *Genista monspessulana*
Spanish Broom: *Spartium junceum*
Blooms: March-June

The brooms are quickly invading natural areas and crowding out native vegetation throughout the coastal region. These tall shrubs have yellow flowers similar to those of pea plants and produce their seeds in pods, also like peas.

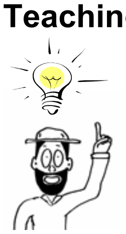
Periwinkle: *Vinca major*
Blooms: March-July

Periwinkle is commonly grown as a low-growing ornamental garden plant, but it has escaped into many natural areas. It prefers the moist shady areas of the redwood forest. The leaves are a dark and shiny green, and the flowers are 5-lobed, purple, and funnel-shaped.

Cape Ivy: *Delaireia odorata* (formerly German Ivy, *Senecio mikanioides*)

This fast-growing vine can sprout a new plant from each section or node of the stem. This ability makes is very difficult to eradicate, and enables it to spread rapidly after floods, landslides, or even removal efforts. It forms dense blankets that smother other plants up to 30 feet high. Since it often grows along streams and rivers, it threatens many sensitive riparian species. It can be distinguished from the native wild cucumber by the cape ivy's lack of tendrils, which the native wild cucumber has.

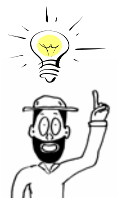
Teaching Idea



A useful brochure called Invasive Weeds of Marin and Sonoma Counties (2003) *has been produced by the Marin Sonoma Weed Management Area. This colorful and informative brochure is also useful in other counties. It can be obtained from agricultural commissioners or U.C. Cooperative Extension Services.*

The Santa Cruz County Wildlands Restoration Team has produced a booklet titled A Plague of Plants (2002, by Ken Moore) *that discusses the problem of invasive species and how people can help. Over two dozen plant species are described, and suggestions for removal, disposal, and follow-up are provided.*

Teaching Idea



Parks do not usually have the time or personnel to remove invasive plants. A group of students (or others) may be able to arrange to remove them from a given area. Because many of these species are very difficult to eradicate, you might plan to "adopt" a field, roadside, campground, or stand of trees, and revisit it for several consecutive years to remove new plants that sprout. Even if you can't commit to an ongoing project, though, park personnel may welcome your help; maybe they can find another group for next year's efforts.

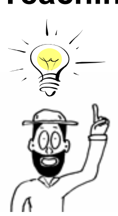
This can also be a good ongoing research project. If you establish one or more study plots, collect baseline/starting data on such things as species present, ground cover, sizes and numbers of plants, animals observed, etc., and then revisit the site periodically. The site can be photographed annually, data on numbers of plants pulled, collected, etc.

Animals

Invertebrates: animals without backbones

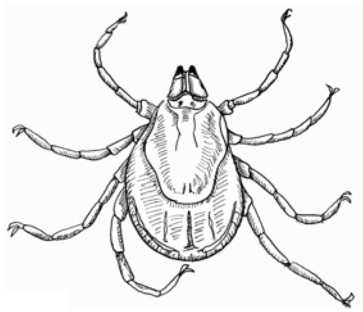
Invertebrates are extremely important in any ecosystem, including the coast redwoods. Many kinds of mites, spiders, worms, insects, and other invertebrates can be found in the soil, humus, and duff. Insects feed on animals and all parts of living plants; banana slugs, insects, and millipedes help decompose dead organisms; flies, butterflies, and bees pollinate flowers; mosquitoes and ticks feed on our blood while yellow jackets and scorpions sting. While invertebrates are very important, they are also small, and students may not notice them. I have chosen to illustrate only a few invertebrates in *Redwood Ed*, but I encourage teachers to learn more about the more common types.

Teaching Idea



The scientific names of organisms can be used to teach word roots that will be very helpful to students as they learn new vocabulary. Word roots for some of the animals described below are provided.

Tick: Phylum Arthropoda, Class Arachnida, Subclass Acarina
Ticks are classified as arachnids, which puts them in the same class as spiders and mites. Ticks have four pairs of legs and resemble watermelon seeds when not engorged. They are small (about 1/8 - <1/4 inch long) when not engorged with their blood meal, but enlarge significantly as they feed on the blood of their host. Ticks wait on a bush or other plant until an animal brushes against it. They then bury their mouth parts in their host and become engorged with their host's blood. After feeding they drop off.



Wearing light colored clothing may facilitate spotting ticks before they attach themselves. After landing on a person, ticks often crawl until they come to a barrier such as a belt line, the top of the socks, or a sleeve. The tick may stop at the constriction and burrow its head in there, so one should pay special attention to those areas. Insect repellants may help keep ticks off, and tucking shirts and pant legs in may help keep them off of the skin.

Figure 41. A non-engorged tick

Ticks carry several diseases, most notably Lyme disease, so it is important to remove them as soon as possible. They do NOT "screw themselves in," so don't try to "unscrew" them! The recommended method for removal is to use tweezers to grasp the animal as close to the skin as possible and gently but firmly pull it straight out. Hopefully, the tick will release its hold before the mouth parts break off. If parts remain after removing the body, use tweezers to remove as much as possible. In any case, the puncture wound should be treated with disinfectant.

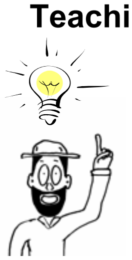
Some people recommend saving the removed tick in a small jar of alcohol or in the freezer in case one develops symptoms of a disease and identification of the tick becomes important.

Parents should be notified to watch for any sign of infection, rash, or ill feeling. If symptoms develop, the child should see a doctor as soon as possible.

Black legged ticks or deer ticks are the transmitters of the bacterium that causes Lyme disease. The adults are tiny, about the size of a sesame seed, and the larvae are even smaller. Symptoms of Lyme disease vary greatly and include such diverse and common signs as fatigue, chills, fever, headache, muscle or joint aches, and swollen lymph nodes. A "bulls-eye" rash may develop in many cases, but it doesn't always appear. When in doubt, a doctor should be consulted as soon as possible, as this disease can be very debilitating.

Wood ticks are common in the redwood region. They are larger than the deer ticks that cause Lyme disease, but they can transmit other diseases.

Teaching Idea



Before going on a field trip, have students do some research on ticks and tick-borne diseases. A useful book is Outwitting Ticks, by Susan Hauser (2001). Internet searches can yield useful information and illustrations, including descriptions of tick-borne diseases. Local veterinarians or doctors may be willing to visit the class and discuss tick-borne diseases, prevention, and treatment.

Word origins: The arthropods are animals that have jointed appendages such as legs, antennae, and mouth parts. "Arthro-" refers to joints…Arthritis is an inflammation of the joints. "-poda" refers to feet…A podiatrist is a foot doctor.

Millipede: Phylum Arthropoda, Class Diplopoda
Millipedes are sometimes mistakenly called "thousand-leggers." While they have many legs, they don't have a thousand. They are sometimes confused with centipedes but can be distinguished by having 2 legs per body segment and a more rounded body shape when viewed from the front.

Millipedes serve an important role in the redwoods as they feed on dead matter and help return the nutrients to the soil through decomposition. While not poisonous, many millipedes can excrete a smelly fluid when threatened.

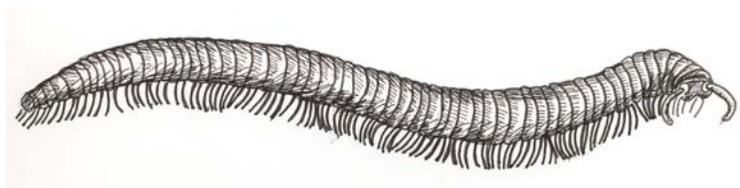


Figure 42. Millipede. Note two pairs of legs per section, rounded body shape.

Word origins: "Milli-" comes from the Latin for a thousand, and "-ped" refers to feet. A millennium is a thousand years, and a meter has a thousand millimeters. Pedestrians walk. "Di-" refers to two, as in dice, and a dichotomy is division into two parts. Again, "-pod" refers to feet.

Centipede: Phylum Arthropoda, Class Chilopoda
Centipedes are sometimes called "hundred-leggers," but they don't have a hundred legs. To distinguish centipedes from millipedes, check the number of legs per body segment: centipedes have one pair of legs per segment while millipedes have two. Also, centipedes generally are more flattened in cross section.

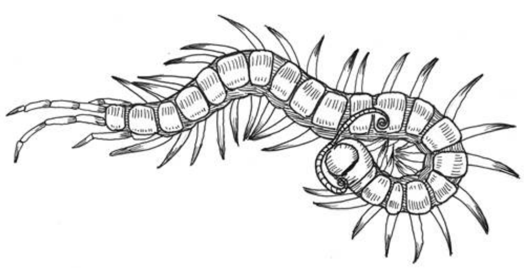


Figure 43. Centipede. Note one pair of legs per segment. The body shape is flatter than that of a millipede.

Unlike millipedes, centipedes are carnivores, using a poison claw near their mouth to kill their prey and also for defense. I have never known anybody to actually be "bitten" or stung by one, but it is best to advise students to use forceps, a leaf, a piece of paper, or other tool when picking up a centipede.

Word origins: "Centi-" refers to a hundred; there are a hundred cents in a dollar and a hundred years in a century.

Yellow jacket: Phylum Arthropoda, Class Insecta, Order Hymenoptera, Family Vespidae, Genus *Vespula*.

Yellow jackets are carnivorous wasps that build paper nests either in the ground or in trees. They can be very aggressive and should be left alone. Unlike honeybees, which die after stinging, yellow jackets can sting repeatedly. If the children are eating lunch, yellow jackets might be quite persistent in trying to get their food. Sometimes setting an open can of cat food a few yards from the lunch site can attract the yellow jackets there in stead of to the lunch table.

Figure 44. Yellow jacket (*Vespula* spp.)

Yellow jackets are very helpful in the forest as they feed on any animals that might die.

Word origins: "Hymen-" refers to a membrane and "-ptera" refers to wings. The hymenoptera have membranous wings.

Crane fly: Phylum Arthropoda, Class Insecta, Order Diptera, Family Tipulidae (and others)

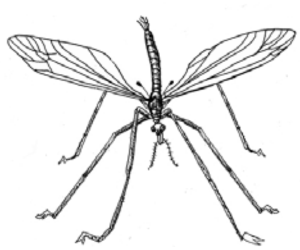


Figure 45. Crane Fly

The crane flies resemble overgrown mosquitoes, but they don't bite. Crane flies are most commonly found in areas where there is abundant vegetation and it is fairly damp. Larvae may live in water or wet soil where they feed on decaying vegetative matter. Sometimes they are called "mosquito hawks," although most species are not predacious.

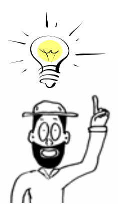
Word Origins: Flies, including crane flies, have two wings. The order name, Diptera, refers to the two (Di) wings (-ptera).

Banana slug: *Ariolimax* spp.

Banana slugs are very large relatives of the common garden slugs and snails. They get up to 6 inches long, and range in color from mustard yellow to olive gray, often with splotches of gray on a yellow body. They will eat almost anything and are very important in cleaning up dead organisms in the forest. Snails and slugs feed with a "rasping tongue," which they use to scrape pieces from their food. They have two pairs of "tentacles" projecting from the head, and the posterior (hind-most) pair have light sensing organs at their tips. The anterior (front) pair is used for feeling and smelling for food. Banana slugs are distasteful to many animals, and their yellow color may serve as a warning to potential predators.

Figure 46. Banana Slug (*Ariolimax* spp.) Color varies from pure yellow to olive green.

Teaching Idea

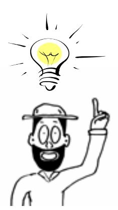


Students are often fascinated by these unusual creatures. They may be interested in the booklet The Banana Slug: A Close Look at a Giant Forest Slug of Western North America, by Alice Bryant Harper (1988).

Vertebrates: animals with backbones

The vertebrates include fish, amphibians, reptiles, birds and mammals. In *Redwood Ed*, I've chosen to illustrate a few of the more common types along with those of special interest because of their rarity or impact.

Teaching Idea



The Forest Foundation has published a nicely done booklet, called A Guide to California's Wildlife on Private Forestlands, by Adam Deem (2006). The guide includes photographs of many of the organisms listed below along with maps and other information. It, along with other materials, is available for free from the Forest Foundation. See Appendices III and IV.

Fish

Salmon, and their relatives the trout and steelhead trout (which are rainbow trout that spend part of their lives at sea), are collectively referred to as "salmonids." The main distinguishing characteristic of salmonids is a small, flexible adipose fin on the back between the dorsal fin and the tail. They also have small scales.

Salmonids may be seen in streams and rivers in the redwood region and are important to both sport and commercial fisheries. Over-fishing and habitat destruction threaten some varieties.

After laying and fertilizing eggs in shallow "nests" in gravel, adult salmon die. During this spawning period, they were once important sources of food for bears, and they brought minerals to the redwood forest from the sea. After hatching, the young fish develop in freshwater streams as they make their way back to the ocean where they spend varying lengths of time growing to adult size. As adults, salmon return to freshwater streams, usually the same one where they hatched, to breed and complete the cycle.

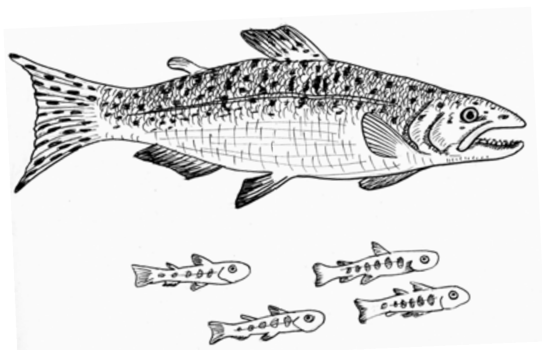


Figure 47. Salmon and young (smolt).

A healthy salmonid stream has a variety of conditions. Fast moving water and ripples help oxygen dissolve in the water. Large rocks and woody debris, such as logs, help form deep, cool pools where salmonids can hide and seek shelter from warm water at the surface. Salmonids need cool, oxygen-rich waters, and destruction of streamside vegetation can cause a deadly increase in water temperatures. Gravelly bottoms are needed for egg-laying areas. Silt can bury potential nesting sites or smother eggs. These are main reasons why timber companies are required to leave "buffer zones" along fish-bearing streams.

Several species of trout and salmon (*Oncorhynchus* spp.) are found in the coast redwood region.

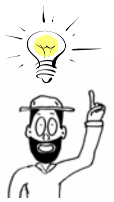
Trout spend their lives in fresh water streams, except for steelhead trout, which are rainbow trout (*Oncorhynchus mykiss,* formerly *Salmo gairdner*) that spend 1-3 years at sea before returning to fresh water to spawn. Rainbow trout are typically 6-8 inches (15-20 cm) long in small streams and may reach 16 inches (41 cm) and 1.5 pounds in rivers or lakes. Steelhead may reach 41 inches (1.1 m) in length and over 42 pounds (19.1 kg) in weight, but average 2.5-12 pounds (1.1-5.4 kg).

The Chinook or king salmon (*Oncorhynchus tshawytscha*) is the largest of the redwood region salmon, reaching almost 6 feet in length and weighing as much as 135 pounds! They average 10-15 pounds. They may travel hundreds of miles up rivers to spawn.

Populations of all species of salmon have decreased significantly since the 1940s, probably due to a combination of over-fishing, habitat degradation, and the damming of rivers.

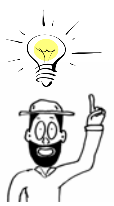
Salmon were a very important food source to Native American groups, especially in the northern redwood region.

Teaching Idea



Web of Water: Life in Redwood Creek, by Maya Khosla (1997) is a very nicely illustrated book that tells the story of life in a typical healthy creek in the redwood region.

Teaching Idea



Invite parents, commercial fishermen, or people from a local fishing club or Trout Unlimited to speak to the class about protecting fish habitat.

Amphibians

Pacific Giant Salamander: *Dicamptodon tenebrosus*, 4-7 in. long

This large salamander is generally brown or gray with black blotches on its skin, although coloration and patterning is highly variable. It feeds on insects, banana slugs or even mice and garter snakes. Loss of water-cooling and moisture-retaining stream cover, and silt from erosion, reduce population densities.

Figure 48. Pacific Giant Salamander (*Dicamptodon tenebrosus*)

Rough-Skinned Newt: *Taricha granulose*, body: 2-4 in. long

Sometimes called mud puppy or water dog, this is one of the more commonly seen salamanders. Their upper surface is dark brown, while the under side is a bright orange. Glands in their skin secrete a poisonous chemical that repels most predators. The poisonous chemicals can be found throughout the body, and newts can be highly toxic to most vertebrates, including people. Wash hands after handling a newt. In wet weather, they may wander far from streams.

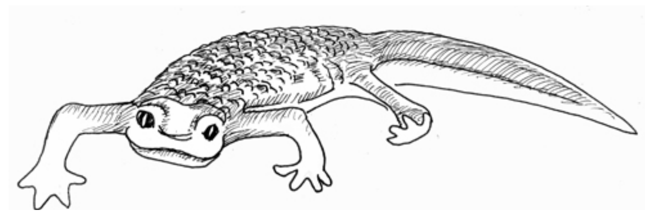


Figure 49. Rough-Skinned Newt (*Taricha granulosa*)

California Slender Salamander: *Batrachoseps attenuatus*, body: 1.5-2 in. long

These salamanders have very long, slender bodies and short legs. They are often found under bark, rotting logs, or damp leaf litter.

Red-Legged Frog: *Rana aurora*, about 5 in. long

The red-legged frog prefers slow-moving water such as ponds or lakes, as opposed to the yellow-legged frog, which prefers faster running water. Its name comes from the reddish coloring on the underside of the hind legs.

In much of its range, the population of the red-legged frog has been seriously reduced by habitat loss, pesticides, and competition with species such as the bullfrog and non-native fish. In the late 1800s and early 1900s, it was an important source of frog legs.

Pacific Treefrog: *Pseudacris regilla* (formerly *Hyla regilla*), 1-2 in.

The tree frog is often found (and heard) in bushes and small trees a considerable distance from water. The color varies from brownish-gray to black to red, to orange to bright green, and tends to resemble its habitat. It can change the shade or darkness of its color in a few minutes, changing from light to dark green, for example.

Reptiles

Western Pond Turtle: *Actinemys marmorata*, 5-8 in.
This is the only common turtle in the redwood region. Look for it basking on logs or rocks near moving water, marshes, ponds, or lakes. In much of its range, the population is in serious decline due to habitat loss and use as a food source.

Western Fence Lizard: *Sceloporus occidentalis,* 6-9 in. long
Sometimes called the "bluebelly lizard," this is a common lizard in warmer and drier areas such as gassy openings, rocky areas, wood piles, or old buildings. It is generally a grayish color with rough scales.

Figure 50. Western Fence Lizard (*Sceloporus occidentalis*)

Western Skink: *Eumeces skiltonianus*, 6-9.5 in. long
This beautiful lizard has smooth scales with light and dark stripes down the sides. The tails of the young are a beautiful blue color, as are regenerating tails of adults. Like fence lizards, skinks prefer warmer and drier areas of the redwood region.

Alligator Lizard: *Elgaria* spp., 8-13 in. long

Generally a lighter green-brown color than the fence lizard, with smoother scales. It is more commonly found in the forest itself than the fence lizard. When captured, they will often try to bite, and large specimens may bite hard enough to break the skin.

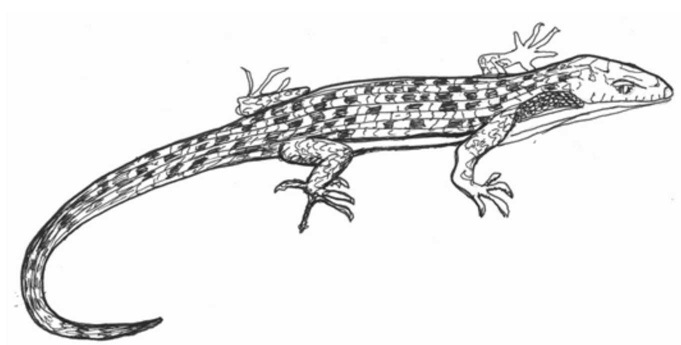
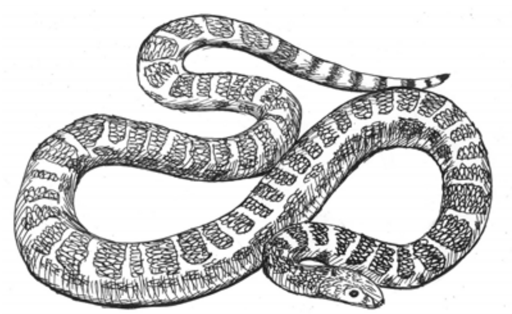


Figure 51. Alligator Lizard (*Elgaria* spp.)

Ringneck Snake: *Diadophis punctatus*, 10-22 in. long
The upper body of this snake is a uniform blue-gray or dark gray color, with a yellow, orange, or red ring around the neck and a similar colored belly. These pretty snakes are usually found under leaves or other debris.

Gopher Snake: *Pituophis catenifer*, to 6 feet in. length



This well-camouflaged snake is common in woodland and grassy areas. Distinguish it from the rattlesnake by the head, which is narrower than the body. The gopher snake will sometimes vibrate its tail in dry grass or leaves, making a sound somewhat like a rattlesnake. These snakes help keep the rodent population in check.

Figure 52. Gopher Snake (*Pituophis catenifer*)

Rattlesnake: *Crotalus* spp., to 5 feet in. length

Rattlesnakes of various species can be found in the drier parts of the redwood region, and children should be cautioned to look before stepping over logs or rocks. Their color ranges from brownish to dark green, and they may look like gopher snakes. Distinguish it from a gopher snake by its head, which is triangular and wider than the body. Babies may have only a single "button" for a rattle and, therefore, may not be able to produce a warning rattling sound. Like gopher snakes, rattlesnakes help keep the rodent population in check.

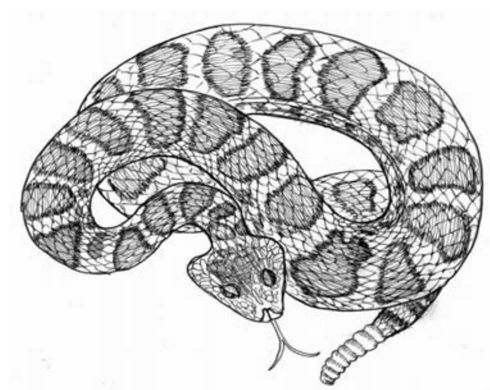


Figure 53. (Rattlesnake: *Crotalus* spp.)

Garter Snake: *Thamnophis* spp., to 4 feet in length
Several species or subspecies of garter snakes inhabit the redwood region. Most have light colored stripes running the length of the body. Some types are often found in and around water, while others prefer areas such as meadows, but not really dry areas. Some tend to strike out in self-defense, and they will often secrete a foul-smelling fluid if picked up.

Figure 54. Garter Snake (*Thamnophis* spp.)

Birds

Acorn woodpecker: *Melanerpes formicivorus*, about 9 in. long

The acorn woodpecker is a striking black and white bird with a red cap and white patch on its outstretched wing. Common where there are oaks, these birds often store acorns by pecking storage holes in snags, bark, or even fence posts or the walls of buildings. Such granary trees may be used for many years by a colony of acorn woodpeckers. They also feed on insects during the spring and summer months.

Figure 55. Acorn woodpecker (*Melanerpes formicivorus*)

Steller's Jay: *Cyanocitta stelleri*, 11-13.5 inches long

This large blue bird with a dark gray-blue head is easily identified by the pointed crest on its head. Their natural food includes insects and conifer seeds. They can often be seen around picnic areas, noisily searching for scraps of food. Children should be discouraged from feeding them, as human food can be harmful to them.

Steller's jays have been known to drive marbled murrelets from their nests by making a hawk-like call. The jays then feed on the young or the eggs.

Figure 56. Steller's Jay (*Cyanocitta stelleri*)

Varied Thrush: *Ixoreus naevius*, 8-10 in. long

Similar in appearance to a robin, but with a black or gray band across its breast and orangeish bars on its wings. It feeds on various arthropods such as millipedes and sow bugs, earthworms, fruits and acorns and other seeds.

Winter Wren: *Troglodytes troglodytes*, 3.25-4 in. long

With a very short tail, this small bird can sometimes be seen bobbing its head in thick undergrowth in the redwood region.

Northern Spotted Owl: *Strix occidentalis*, length to 16 in, wingspan to 42 in.

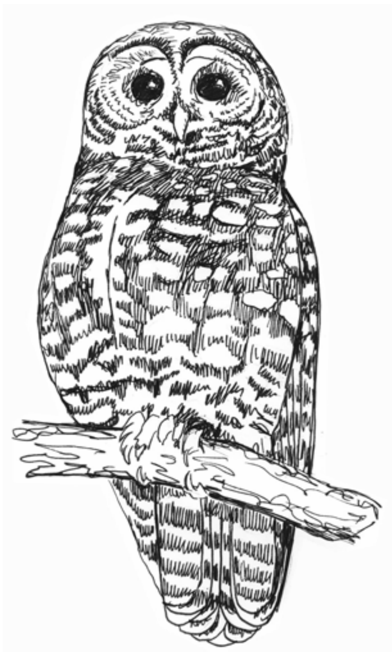


Figure 58. Northern Spotted Owl (*Strix occidentalis*)

There are at least four recognized subspecies. The northern spotted owl is apparently more common in northern California than in some other parts of its range. Considered an endangered species, it has been the subject of much controversy because its presence severely restricts logging due to protection afforded by the endangered species act. Yocom and Dasmann (1965) refer it as "resident and fairly common in the region," while Robbins *et al.* (1966) say that it is "rare." While some books say that it requires old growth forests, recent studies indicate that it is often found in older young-growth forests (Noss, 2000), even reported as commonly found in 30-40 year-old stands of redwoods (Diller, 1996). Spotted owls seem to need older trees and snags for nesting and may be found in younger stands either because of remnants of old trees left there, because of the rapid growth of redwoods, or because they enter the young-growth from surrounding stands of older trees and snags to forage for food.

A favorite prey for the spotted owl is the flying squirrel, but where the flying squirrel populations are low, they feed on the dusky-footed woodrat and voles. They also eat insects such as large beetles and crickets.

According to the *Field Guide to the Birds of North America* (1999), there is some hybridizing between the spotted owl and the barred owl, *Strix varia*.

Great horned owls and barred owls will feed on the spotted owls, and barred owls seem to be encroaching on the spotted owls' range from the east. Some stands of old growth (or at least a diversity of forest types) seem to provide corridors for spotted owl dispersal as they provide some protection from predation by other species (Noss, 2000).

Some biologists have developed the ability to imitate their call and have good success attracting the owls. Sometimes mice are used to attract the owls as the biologists complete their surveys prior to timber harvesting.

Information, pictures, range maps, and even sound recordings can be found on the Internet at <Owling.com>.

Marbled Murrelet: *Brachyramphus marmoratus*, about 8-9.5 in. long
In the summer, the marbled murrelet is sooty-brown with lighter mottling on the belly and relatively solid brown coloration on the back. In winter, the back gets darker and the belly lighter, with a white band between the wing and the back.

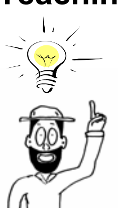
This endangered species feeds in the ocean, returning to nests on large branches high in large trees by flying up coastal rivers and streams. They seem to have a strong preference for streamside redwood forests with a high density of old growth cover (Miller and Ralph, 2005). Murrelets seem to require a high amount of canopy cover. They don't build nests *per se*, but rather use a large branch covered with moss and lichens as a nesting site.

Figure 59. Marbled Murrelet (*Brachyramphus marmoratus*)

In California, nests are almost always in redwoods, although murrelets have been found to nest in Douglas-fir and hemlocks. Steller's jays will sometimes attack the young in the nest.

Today's marbled murrelet population is only about 10% of its historical number of about 60,000. Habitat loss from logging and development continue to reduce its population. The bird is listed as threatened in Washington, Oregon and California by the federal government, and as endangered by the California Fish and Game Commission (Noss, 2000).

Teaching Idea



Marbled murrelets can sometimes be seen in the pre-dawn hours at the parking lot at the Prairie Creek Redwoods State Park Visitor Center. It takes a while to learn to spot the birds as they zoom out of the forest and fly around above the grassy areas, but after a while one can learn to not only see them, but also identify their calls.

Mammals

Opossum: *Didelphis marsupialis*, total length: 27-33 in., tail: 12-14 in.

Figure 60. Opossum (*Didelphis marsupialis*)

The opossum is not native to California; it was introduced from the eastern part of the U.S. As a marsupial, it is more closely related to kangaroos and other marsupials of Central and South America, than to other U.S. animals. While the opossum's tail is strong and prehensile, they seldom actually use it to hang from branches. "Possums" are slow moving and commonly killed by cars on the road. They are omnivorous, feeding on invertebrates, small vertebrates, plants, and carrion.

Big Brown Bat: *Eptesicus fuscus*, 3.5-5.5 in. long with wingspread to 13 in.
This is one of the more commonly seen bats, usually the first out in the evening. It easily adapts to parks and buildings as well as the forest environment. The Big Brown Bat generally feeds on beetles and hoppers, which they generally catch while flying within 30 feet of the ground at dusk or dawn.

Several species of bats are found in the redwood forest, where they often roost in burned-out redwood trees.

Chipmunk: *Tamias* spp., 9-11 in. long with tail length: 3.5-5 in.
Light colored lines on the side of the face distinguish chipmunks from squirrels. Various species may build nests in burrows or tree cavities. Generally ground-dwelling, they feed on seeds, nuts, berries, and mushrooms. They often learn to "beg" from humans, but children should be discouraged from feeding them because many human foods are not good for them, and if they get too tame they may get careless around cars or pets. According to Eder (2005), where several species of chipmunks inhabit the same area, the different species develop different calls.

Northern Flying Squirrel: *Glaucomys sabrinus,* 9.75-15 in. long with tail length: 4.25-7 in.
The nocturnal flying squirrels don't actually fly; they jump from high in a tree and glide to their destination. Furred skin "glide membranes" extending down the length of the body between the front and hind legs enable these aerialists to glide over 100 yards. The flying squirrel's diet is mostly lichens and fungi, but it will also eat buds, berries, seeds, and even some arthropods, bird eggs, and

nestlings. They generally nest in lichen and grass-lined tree cavities or in nests built of twigs and strips of bark, including redwood bark, in a large tree fork. Flying squirrels are a favorite food of the northern spotted owl.

Douglas' Squirrel: *Tamiasciurus douglasii,* 11-14 in. with tail length: 3.75-6.25 in.

Sometimes called the chickaree, this noisy squirrel scolds humans who dare enter its domain, chattering, stamping its feet and flicking its tail. They cut conifer cones, letting them fall to the ground, then collecting them for storage in caches under fallen logs or beside tree stumps. When they consume the seeds from the cones, they typically carry the cone(s) to a tree branch and drop the scales and cores, so you may locate them by looking for piles of recently discarded scales. They will also feed on green plants, young trees, berries, and mushrooms.

Figure 61. Douglas' Squirrel (*Tamiasciurus douglasii*)

The similar-appearing Western Gray Squirrel, *Sciurus griseus*, is larger and grayer, having a lighter colored belly than the Douglas' Squirrel, which has a rust-colored belly.

Western Red-backed Vole: *Clethrionomys californicus*, 5.5-6.5 in. long with tail length: 1.75-2.25 in.

The voles are mouse-like animals, and the red-backed vole scurries about under leaf litter and logs in the forest. They primarily eat green plants, but they may also feed on seeds and fruits. They build nests of lichens and other soft vegetation, using abandoned burrows of other animals or cavities under logs or rocks.

Figure 62. Vole

Sonoma Tree Vole: *Arborimus pomo*, 6.25-7 in. long with tail length: 2.5-3 in.

The tree vole generally lives high in large Douglas-fir trees. Nests are built 5-115 feet off the ground, mainly of twigs and needles. Nests may be up to 3 feet in diameter and are often used by several generations.

These animals are an important food source for spotted owls. Habitat loss is their greatest threat.

These voles are sometimes classified in the genus *Phenacomys*.

Dusky-footed Woodrat: *Neotoma fuscipes*, 13-19 in. long with tail length: 6.25-9 in.

The woodrat builds a nest of sticks, bark and plants, either on the ground or in trees, sometimes as much as 50 feet off the ground. In redwood forests, they may use fire cavities or sprout clumps for nesting sites. These nests may be used for many generations and may be quite large, and provide homes for many other animals. The dusky-footed woodrat is notorious for stashing a wide variety of objects in its nest, earning it the name "packrat." They mostly feed on green plants, but may also eat seeds, fruits, nuts, and fungi. Where flying squirrels are scarce, they are an important food source for the northern spotted owl.

Figure 63. Dusky-Footed Woodrat (*Neotoma fuscipes*)

Striped Skunk: *Mephitis mephitis*, 21.5-31.5 in. long with tail length: 8-14 in.

More often smelled than seen, the striped skunk is omnivorous, feeding on insects, bird eggs, amphibians, grains, green vegetation, fruits, berries, and many other foods, including road kill. They usually nest in an underground burrow lined with dried leaves and grasses. They can spray their famously smelly fluid about 20 feet, and are accurate to about 10 feet.

Figure 64. Striped Skunk (*Mephitis mephitis*)

Black Bear: *Ursus americanus*, 4.5-6 ft. long, shoulder height: 3-4 ft., weight: 88-600 lb.

The black bear's coat ranges from black to brown to honey colored. They are excellent climbers. Their dens are used mostly in the winter and may be in a cave, hollow tree, under a fallen log or any other protected area. They don't truly hibernate; rather, they enter a sound sleep, and they may actually leave their dens on mild winter days.

While often thought of as being carnivores, bears are very omnivorous; up to 95% of their diet may be plant material. They can be problematic near human habitation, as they will raid garbage containers, cars, and food caches. They sometimes do significant damage to young redwood and Douglas-fir trees as they strip the bark to feed on sweet sap in the spring.

Figure 65. Black Bear (*Ursus americanus*)

Raccoon: *Procyon lotor*, 26-38 in. long with tail length: 7.5-16 in., weight: 12-31 lb.

Raccoons often use hollow trees for their dens, but will also nest in rock crevices and even beneath abandoned buildings. They often become quite used to people and become pests of cabins, campsites, and garbage cans. In places where people live, they can be garden pests and will steal pet food left outside at night.

Figure 66. Raccoon: (*Procyon lotor*)

Raccoons often follow streams, and their hand-like footprints are among the most commonly seen. They often "wash" their food in water to remove bits of inedible material. (The name "raccoon" is derived from the Algonquian name for the animal which translates to "he scratches with his hands," and the Latin scientific name *lotor* means "washer" (Eder, 2005)).

Black-tailed Deer: *Odocoileus hemionus*, 4.5-5.5 ft. long, shoulder height: 35-41 in., weight: 68-470 lb.

Also known as mule deer, these animals range throughout western North America. There are several subspecies; the redwood region subspecies is the Columbian black-tailed deer. They generally avoid the deep forest, preferring grassy meadows or mixed woodland. These animals have managed to adapt quite well to human invasion of their habitat, so much so that they are commonly garden pests and frequently killed on the highways. They often feed at dusk, dawn and into the night. They can do damage to young trees, especially in the winter, but generally prefer grasses and shrubs. Look for deer tracks along creeks and rivers.

Figure 67. Black-tailed Deer (*Odocoileus hemionus*)

Deer may become quite tame near parks, but children should be discouraged from feeding or attempting to pet them. Human food is generally not good for the animals, and they can (and do!) strike out surprisingly quickly with sharp hooves or antlers.

Roosevelt Elk: *Cervus elaphus*, 6.5-8.5 ft. long, shoulder height: 4-5 ft., weight: 400-1,000 lb

Elk, also known as wapiti, once roamed throughout the Pacific coast states and even into Arizona and New Mexico. Extensive hunting during the 19th century reduced the population of elk to pockets scattered throughout its original range.

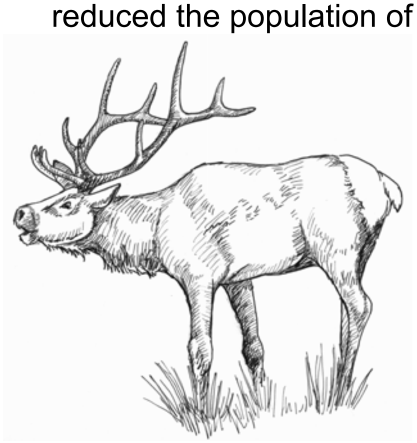


Figure 68. Roosevelt Elk (*Cervus elaphus*)

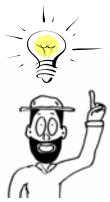
The Roosevelt elk is a subspecies found in the coastal mountains of northern California. Unlike the mule deer, they were often found in the dense forests. Other species include the tule elk of central and southern California and the Rocky Mountain elk, which inhabits parts of Shasta and Kern Counties.

A male or bull elk may have several females in his "harem," and he will defend his mating rights by fiercely fighting with other males. Only the males have antlers, which are shed in the winter and regrown in the spring.

Elk can often be seen in Prairie Creek Redwoods State Park, feeding on the abundant grasses and sedges along Highway 101.

Elk were an important source of food for the Native Americans, and their antlers were used for a variety of tools, including wedges for splitting redwood into planks.

Teaching Idea



Many parks have museums with illustrations, samples, models, historical artifacts and other displays that can be of interest to the students. Most have specimens of animals that students may or may not see alive. Prior to bringing groups to visit the park, teachers should visit the park and associated museums to find out about what resources are available. Prepare a scavenger hunt or other activity to encourage students to spend some time exploring the museum exhibits. Find out if a park interpreter or docent may be available to help guide the students' explorations.

NOTES