MANZANITA

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Conifer Exploits in California: A Perspective from 30 Stories Up

by Jeanne Panek, PhD, Center for Forestry, University of California, Berkeley

Coast redwood (*Sequoia sempervirens*)

I would probably be intimidated by this tree if I could see the top. But I can't. It disappears hundreds of feet above me into the fog like a column disappears upwards into the shadowy vault of an ancient cathedral. I walk the enormous circle around its base, peering upwards towards the first branches jutting out from the trunk at least fifty feet above me, arms extending outward in the universal symbol of welcome. I'm about to climb to the top of this towering giant and I feel very, very small. I finally find the climbing rope hanging down amongst the deep furrows of bark, clamp my ascender onto it, take a deep breath, and start the hard work of climbing a coast redwood tree.

Gravity is not helping me. I sweat as I struggle upwards, sliding my jam-cleat up the rope. Yet gravity is the force that guides all conifers skyward and the reason they generally stand so straight. Conifers—ever serious—are driven to spend their lives constantly pushing against a force that pushes back. No doubt that's why I identify with them. Other trees—broad-leaved trees for example—give less attention to gravity and instead aim for light. The brief lifetime of a deciduous leaf urges trees like laurels, maples, and dogwoods to expand outward in many directions to exploit sunlight as quickly as possible. Not conifers. Even on the steepest slopes, you can always find "up" by finding the firs, pines, and cedars and sighting along their trunks.

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Deadline for submission of announcements and editorial material for the spring issue is February 1, 2013, for the summer issue, April 1, 2013

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The enigma

I've been invited to this redwood grove, far north on the California coast, to help Dr. Todd Dawson of the University of California, Berkeley, and his colleagues with their field research. Through their research they ask how these giant trees solve a problem that challenges even biophysicists: how to get water from roots to leaves so far above the ground. Tree leaves are supplied with water from the roots, pulled upwards through the trunk in a miniature filament of water, like a fishing line being tugged upward by a fisherman. The fisherman is actually water evaporating from the leaf surface. Gravity pulls down on the water filament like a heavy fish at the same time the fisherman pulls up, and when the tug-of-war on the filament is too much, it snaps. Theoretically, in an idealized mathematical world, the tallest water filament that can be supported before gravity wins the tug-of-war is 390 feet. Add to this the extra resistance created by the real world, such as the tortuous pathway the filament actually follows through the cells in the tree's trunk as well as all the obstacles it encounters on the way, and it turns out the filament is very difficult to reel up 390 feet without breaking.

Real-world trees rarely grow higher than 130 feet. Yet redwoods, the tallest trees in the world, routinely grow higher than 300 feet, and the tallest is more than 379 feet. How do redwoods—far removed from idealized models—get water to their highest leaves? My small task in answering that big question is to haul wires up to a computer on the redwood's trunk, 100 feet off the ground. My reward is to continue the next 200 feet to the top of the tree.

Conifer superlatives

The teasing of the ground crew tells me that I'm none too graceful ascending the rope, but their gibes fade behind me as I climb upwards. I reach the lowest branches and I'm finally alone in the arms of this ancient tree. By now I'd be at the top of a "normal" tree in New England where I grew up. But little about California conifers is "normal." Always pushing upwards, striving to be the best, California conifers are the superlatives in the world of trees, the overachievers, the Olympic athletes. The tallest tree is a coast redwood (*Sequoia sempervirens*) named Hyperion in Redwood National Park, taking that title at a towering 379.46 feet. The most massive tree is the giant sequoia (*Sequoiadendron giganteum*), winning the gold with the General Sherman tree at 6,167 tons. That same sequoia also has the largest volume of any single stem on earth. The oldest tree on the planet, aptly named Methuselah, is a bristlecone pine (*Pinus longaeva*) 4,844 years old. It grows in California's Inyo National Forest. The personification of extraordinary trees by naming them is a human tendency, but it ultimately helps foster support for their continued protection.

Coulter pine (*Pinus coulteri*) cones

The longest cones on earth are borne by California's native sugar pine (*Pinus lambertiana*). As small as the chances are of being hit by a single cone dropped in a forest of trees, I watched as a colleague—this researcher was a magnet for rotten luck—managed to get hit by a falling sugar pine cone. Sugar pine cones are not the heaviest cones, but being hit by one can ruin your whole day. The award for the heaviest cone goes to California's Coulter pine (*Pinus coulteri*). These massive cones are as close as the plant world comes to a *Tyrannosaurus rex*, with intimidating, sharp, dagger-like scales. Being hit by a falling Coulter pine cone would be more than unlucky—it could kill you.

The California landscape is shaped by these conifer superlatives. The coastal hills, the Sierra Nevada, the northern forests, and the southern arid ecosystems are defined by conifers that are the most impressive on earth.

Conifers and humans

I remind myself I have a task to do. I ascend the rope to the next whorl of branches, where a bank of instruments quietly whirs and clicks. I unpack the heavy bundle of cables from my backpack and tie them onto a rack to be installed later by one of the researchers below. They are part of a system that measures how fast water moves up through the trunk toward the leaves. It turns out that one of these trees moves more than 215 liters, or 57 gallons, of water an hour. That means they could drain your bathtub in the time it takes for you to have a nice 45-minute soak. Yet another reason to keep redwoods out of the bathroom, I note.

The human element in such an otherwise sacred and remote place seems incongruent. But then, I reflect, humans and California conifers have a connection that extends as far back as humans have been here. For thousands of years before European contact, California native peoples were intimately dependent on conifers for a wealth of forest products. Just a few examples include food (pine nuts, Douglas-fir sugar); salves/medicines (the pitch from many conifers was used on wounds and skin irritations); fuel, shelters, boats, tools, and weapons (bark, pitch and wood); and baskets (twigs, needles, and roots). The dependency was mutual, with conifers likely reliant on fires set by native people to open pitch-sealed cones, thus releasing and scattering seeds, and to create sunny forest gaps for sprouts and seedlings to grow.

European explorers relied on California conifers for centuries after mariners began to ply the California coast in the 1500s—sailors seeking out and harvesting a few individual Douglas-fir (*Pseudotsuga menziesii*) and Monterey pine (*Pinus radiata*) trees found in coastal hills for ship repair. It wasn't until later, during the California gold rush and the San Francisco earthquake, that humans would dramatically denude the California landscape of its conifers to provide straight-grained and easily-milled timber for ravenous human use. By the late 1800s, the gold rush had exploited conifer timber for use in flumes, railroads, and mines, and turned the Sierra Nevada foothill forests into a mix of cutover forests, grasslands, burned areas, and agricultural fields. Forests, particularly redwoods, along the north coast and as far south as Big Sur, were logged to provide lumber to rebuild San Francisco after the 1906 earthquake and fire.

Redwood logging, image from Ericson Collection (1999.02.0338), Humboldt State University Library

During that half century of cutting, westerners developed a different kinship with conifers, in part from the sense of loss. Among conservationists at the time, John Muir was by far the most influential, helping to craft the laws that established the National Park Service and two national parks. He was so deeply touched by the need for protection that much of his later life was devoted to protecting California forests. Muir had a special love of conifers. He describes climbing to the top of a Douglas-fir in a storm to "get my ear close to the Æolian music of its topmost needles." Modern conservationists, also, are inspired to take to the tops of trees. Julia Butterfly Hill lived for 738 days in the branches of a redwood as part of an ongoing battle to protect ancient redwood forests.

But California conifers touch even the most common of us. Giant sequoia and redwood trees attract people of all ages, from all backgrounds, and from all over the world. Visitors remark on feeling a sense of transience, fragility, and insignificance in their presence, a common feeling that draws us tiny humans closer together as a species.

Conifer adventures

I continue my journey upward. The ground disappears below me. I'm venturing into territory rarely seen by people. Humans are generally content to inhabit the thin surface of the planet. But there are entire ecosystems in the canopies of trees, just as there are under the surface of the ocean. And while the enormity of the undersea world is well-appreciated, the world 200 feet over our heads is only now being discovered. The first explorers in the world of tall California conifers include Steve Sillett, Marie Antoine, Michael Taylor, and Chris Atkins. Now there are dozens more. Some work from the ground, but many high-canopy explorers live and work in climbing harnesses, attached to a web of ropes strung up and between tree trunks and canopies. These pioneers have discovered microcosms perched in the branches of conifers and revealed new species that have evolved for hundreds to thousands of years in place, isolated in arboreal aeries, independent of any direct interaction with the ground.

While there are visionary and courageous explorers, there are also controversial characters in the adventure stories of conifers. One, Donald Currey, allegedly cut down the oldest living bristlecone pine tree to retrieve his tree-coring tool. It had become stuck in the tree while he was trying to extract a tree-ring core for his graduate field research. The tree, named Prometheus, was known to be ancient, and has since been estimated to have been at least 5,000 years old when it was cut down, making it the oldest organism ever discovered, older than even the Methuselah tree. The cutting down of Prometheus to retrieve a $250 tool was an important and alarming event in the ongoing movement to protect bristlecone pine forests. The area has since become a national park.

Solving the enigma

Finally my ascent brings me nearer to the top of the tree. Sunlight is its own reward, the fog is retreating. The branches above me become progressively shorter until I'm pushing my way through redwood foliage. It scratches my face and, smiling because I

Emerald Canary

Young bristlecone pines (*Pinus longaeva*) at Patriarch Grove, Inyo National Forest

know that means I'm near the top, I take a closer look at the leaves. The foliage isn't the familiar soft, feathery needles characteristic of the lower redwood branches. Up here, instead, are "sun leaves," leaves that form into a different shape where there is plenty of sunlight. These redwood leaves look like sharp versions of the scaly foliage of cedar trees. With excitement and relief, I poke my head above the last branches and peer out over the redwood canopy. I'm finally at the top.

The contrast between up here and down below couldn't be greater. The massive and ancient trunks that inspire such hushed awe below are absent, and absent too is the feeling of solemnity. Up here, the tree feels active and energetic. Among this newly sprouted foliage, the tree feels young. Looking out over the light green crowns of the neighboring redwoods, I reflect. If I didn't know I was 300 feet off the ground, I'd think I was in an immature redwood stand.

It's warm up here. It's humid. I look around me at the immensity of greenness, the huge number of leaves, and feel all the water transpir-

Coast redwood leaves (*Sequoia sempervirens*)

ing into the air around me. The surface area of the foliage is enormous, all of it needing water to do its job of capturing sunlight. I recall the question that is the foundation of the research going on here: How do redwoods overcome biophysical limits and get water to a height more than 300 feet above their roots, up to the leaves that now surround me?

I didn't learn the answer until over a year later. Through their research Todd Dawson and his colleagues found that redwoods don't break any biophysical limits to move water to great heights. Instead, they just tap another source of water, delivered directly to the top of the canopy where it's most needed. Fog.

The upper leaves on redwood trees comb water droplets out of the fog as it blows off the Pacific Ocean and into the redwood forests. The water is then absorbed by the upper leaves and used to keep the photosynthesis pathways within the leaves actively functioning, pathways that are necessary to feed the tree. Drought-stressed foliage shuts down, essentially starving the tree. Even though these coastal groves are shrouded in fog throughout the extended four-month summer drought that defines California's Mediterranean climate, fogwater hydration wasn't an obvious answer because water uptake by leaves wasn't a well-studied phenomenon. It was possibly an exceptional solution to a singular dilemma. So another California conifer superlative that might be added to the list that includes oldest, tallest, heaviest, largest cones, and heaviest cones: best at thinking outside of the box.

Answering one question of course raises a dozen more. Do other very tall trees, like the redwood's close cousin the giant sequoia, also absorb water in the canopy top? What about other trees that survive the dry season in the fog? Since Dawson's work, many plants of the coastal fog belt have been studied and found to take advantage of the water in the air through leaf absorption. What other surprises might be found if our assumptions are questioned?

There is still an unexplored world in conifers. To explore it, we must keep it intact. Quoting Aldo Leopold, "To keep every cog and wheel is the first precaution of intelligent tinkering." So then, as generations of humans have defined their relationship with conifers through successive eras of mutualism, exploitation, and conservation, let our generation be generous, let us keep our minds open. And let us keep all the parts.

Jeanne Panek is a forest ecology researcher at UC Berkeley, studying air pollution damage in Sierra Nevada conifer forests. The field work—when she gets to spend weeks to months in the wilderness with the trees—is her favorite part of research.

Contributions of the Regional Parks Botanic Garden *by S.W. Edwards, PhD, Garden Director*

Fall color starts to arrive in the garden in summer, as vine maples and blackfruit dogwoods flush with red.

Recently I was asked to speak to the Regional Parks board Natural and Cultural Resources Committee about historic and ongoing contributions of the garden to the Park District and the world. I was asked to do a four-hour talk in 30 minutes. As fast as I could speak, I tossed about facts and features that must have appeared to the committee like Dorothy's house, barnyard animals, and farm debris swirling up in the tornado that raged through her Kansas home. And when that whirlwind swept me, too, out of the room, what was left for them?

Following is a condensed version of my remarks before the board (plus General Manager Bob Doyle and Assistant General Manager Mike Anderson as well as other high-ranking staff).

The Regional Parks Botanic Garden is the best collection of California native plants in the world. Everything is wild collected and documented in a museum accession system. That's what makes it a botanic garden rather than just a garden, and that's one thing that makes it so valued by researchers. It is one of the most beautiful gardens in North America. Its landscapes are meticulously designed to appear naturalistic and to draw visitors irresistibly in. And it demonstrates how incredibly beautiful, interesting, and diverse a garden can be using only California native plants.

An important aspect of the garden landscape is its naturalistic bedrock outcrops and tufa troughs. Nobody builds these better than we do, and we are delighted to teach what we have learned.

The garden has a number of special collections that are second to none, for example bulbs, native grasses, manzanitas, and northern California's best display of

The garden's thriving docent program is a matter of great pride to the staff and volunteers, and it renders "wonder-full" service to the community, as evidenced by these children at the bulb bed with Carla Soracco.

California desert plants, and it is the only large garden in California that features the plants and landscapes of the Sierra Nevada. Seventy-plus years of field research and collecting have allowed us to find countless rarities and unusually good forms of many species. One can zigzag across California in early spring to see the peach-orange *Fritillaria eastwoodiae* of Butte County, the strange *F. brandegeae* of Kern, the pure yellow *F. affinis* in Napa, and the dark-chocolate bells of *F. "tristulus"* at Point Reyes, or walk around the garden and see them all in an hour, along with many of their lovely congeners.

There are paths through the woods, leading to secret places, where one can encounter such ravishments as Columbia lily (*Lilium columbianum*), erythroniums, corn lilies, and trilliums. One of the most frequent exclamations we hear is "No! Mom! This way! This way!" as a child runs ahead on her path of wonder.

The garden hosts countless group visits. When a large contingent of U.S. Forest Service staff visited, they were delighted to hear that the garden was originally made with forest service plants and that it displays more from the national forests than from any other source. When the Marble Cone Fire in Los Padres National Forest destroyed many Santa Lucia firs in the 1970s, forest personnel came to the garden to collect seed from our trees for reforestation. Just this summer we were invited to collect the recently discovered squashberry (*Viburnum edule*) in Shasta-Trinity National Forest so we could help provide insurance for the small wild population. We are already doing that with several other ultra-rare taxa from that area.

The garden is the prime training ground on native plants for local colleges as well as the best source of class material for teaching. We also have our own educational program, with the Wayne Roderick Lectures constituting one of the best natural-history series in California and our docent program now involving over 60 active volunteers. School buses are a common sight at the west gate. Our plant sales, staffed by very knowledgeable volunteers, provide both common and unusual plants at low prices, so people don't need to go to the wild and dig them up. The young mom who left a recent sale with babe in arms and baby carriage laden with plants demonstrated typical public appreciation for what we offer.

Our collection of native grasses is by far the best in the state, perhaps the best in the western U.S. Growing these plants over decades has taught us the management techniques that help perennial grasses thrive. This, with our very extensive field experience, has given us insight into grassland and wildflower ecology that has made us valuable to the park district and others as consultants in range management. I will never forget the meeting of the Society of Range Management, with the father of California range management, Harold Heady, in

Fritillaria tristulus (now included in *F. affinis*) is a partially sterile triploid that grows only on the outer point at Point Reyes. Giant chocolate fritillary would not be a bad name for it.

attendance, where we were able to move the assembly to recognize that it is really a worthy goal to manage for native plants, not just for exotic annual grass productivity and erosion control. Our work, I can say without hyperbole, played a pivotal role in helping Californians understand that livestock grazing can be a valuable tool for promoting native plants. Recognition of our efforts came in many ways, recently involving interviews for PBS at Vasco Caves and, in 2012, for the BBC at Point Reyes.

Jim Roof intended from the beginning that the garden be a haven for rare plants and that the staff do what it can to protect these plants in the wild. The legendary Alice Eastwood, visiting the garden late in life, wept when she saw that Jim had saved *Arctostaphylos franciscana* from extinction. Jim did much to save rare and endangered plants of San Francisco, and our large collection from the north peninsula is a unique and irreplaceable resource for restoration. There is a long list of Franciscan plants that barely cling to survival in or near San Francisco, and we provide insurance for many of them in the garden. Two we have reintroduced. *Arctostaphylos uva-ursi leobreweri* went extinct in the wild, and San Francisco dune tansy (*Tanacetum bipinnatum*) went extinct on San Bruno Mountain. We successfully reintroduced both on the mountain. Jim worked with the commandant of the Presidio to save *Arctostaphylos montana ravenii*, which was down to one surviving shrub in the wild, one at the University of California Botanical Garden, and a group here at the garden. According to his published records, Presidio clarkia (*Clarkia franciscana*) went extinct in San Francisco, and Jim successfully reintroduced it there from botanic garden seed.

The garden has worked to protect the Antioch Dunes since the 1960s. When the last remnants of the dunes were about to be hauled away, Walter Knight collected seed of the dunes endemic Antioch primrose (*Oenothera deltoides howellii*) and sowed it on Brannan Island and Browns Island as emergency reserves. Both populations succeeded, and they now contain genes that no longer exist at the original (type) site. Similar dunes once extended down through Oakley and hosted many unusual plants and animals. We have been helping in the effort to inform the people of Oakley about the plight of the vanishing "Contra Costa desert," perhaps most notably by working through the Park District's new Big Break Visitor Center. We have also provided for that center a long-term landscape planting plan designed to educate the local populace. Garden staff members have provided restoration assessments and planting lists all over the Park District for decades. Our staff has also frequently assisted staff of other parks as well as the Park District stewardship department in assessing botanical resources.

Presidio clarkia (*Clarkia franciscana*). Jim Roof believed he saved this species from extinction in San Francisco, at the time the only place it was known to grow.

The garden provides *ex situ* insurance for rare plants on Park District lands. Hummingbird sage (*Salvia spathacea*) from Castle Rock park, the threatened white-berried baneberry (*Actaea*) from Huckleberry Preserve, and the extremely rare oval-leaved *Viburnum* we discovered in Briones are examples. Both the *Actaea* and *Viburnum* could easily disappear in the wild. Similar efforts reach beyond the District. Leopard lily (*Lilium pardalinum*), vanishingly rare in the East Bay, disappeared from Lily Spring on East Bay Municipal Utility District (EBMUD) land east of Tilden. But we had propagated it, and for many years we provided mature plants to a grateful EBMUD for restoration. We have a very distinctive form of this species from Disappointment Slough in the delta, discovered by Wayne Roderick, that is probably now extinct in the wild, probably as a result of levee reinforcements. Perhaps we will be able to reintroduce it. Foothill penstemon (*Penstemon heterophyllus*) probably went extinct in Tilden Park in our recent drought years. We have been growing this species from nearby Siesta Valley for restoration purposes.

More wide-ranging examples include black crowberry (*Empetrum nigrum*), which is known to exist in California only at the tip of a single headland in Humboldt County that could slide into the sea in an earthquake, and is also rumored to cling to one storm-whipped sea stack a little farther north. We are trying to grow insurance for it. Coastal miterwort (*Pectiantia ovalis*, formerly *Mitella* *ovalis*) jumps from Mendocino County southward to one tiny disjunct population along Sir Francis Drake Blvd. in Marin. We grow insurance. Ditto for so many others. Vine Hill clarkia (*Clarkia imbricata*)—so utterly gorgeous—barely exists in the wild. Scadden Flat checkerbloom (*Sidalcea stipularis*), first named in our journal, *The Four Seasons*, exists only in one tiny patch near Grass Valley in Nevada County. We provide ample insurance for it. Baker's larkspur (*Delphinium bakeri*) grows only on one slope in Marin County, where a road crew nearly wiped it out. Our garden colony has provided many plants to the University of California Botanical Garden for their outplantings at the wild site. Island alumroot (*Heuchera maxima*), so prominent in our Channel Islands section, is from Catalina Island, where gardener Liz Bittner recently found that

Arctostaphylos franciscana in full bloom at the garden. Jim Roof saved this species from extinction when he dug rooted pieces in the Laurel Hill Cemetery, San Francisco, just before the bulldozers swept through, in 1947.

it is now extinct. *Ceanothus* x *vanrenselaeri* is found only along Brotherhood Way in San Francisco. We teamed with San Francisco State University and provided plants for outplanting at the type site, to be done by a local grammar school. Chinese Camp brodiaea (*Brodiaea pallida*) is known only from one tiny site in the Red Hills of Tuolumne County. Formerly it grew in Calaveras County, too. We have been asked by a consulting firm, in conjunction with the state Department of Fish and Wildlife, to propagate this species for restoration in Calaveras County. We are growing the federally endangered largeflowered fiddleneck (*Amsinckia grandiflora*) from Corral Hollow in cooperation with a consortium seeking to enhance and expand the threatened and unstable wild populations.

A number of taxa in our collection belong to the Center for Plant Conservation's national collection of endangered plants, for example the *Sidalcea* from Grass Valley, Telease's prickly pear from Bakersfield, and the Franciscan manzanita. A valuable hybrid of that manzanita was recently discovered growing wild in San Francisco, and we were asked to propagate it for insurance.

Because our plants are wild collected, the garden has fostered a great deal of research. For example, studies of our big lupines from Point Reyes resulted in the first well-documented discovery that flowers change color after pollination to inform pollinators that nectar may be depleted and other flowers should be visited. This was a discovery of global significance that was published in *Nature*. Three successive monographs on the genus *Arctostaphylos* have made intensive use of our collections. Gardener Mike Uhler is continuing manzanita research with his studies of isolated populations of Rocky Mountain-derived bearberry and other, unnamed manzanita entities in the Convict Creek–Mildred Lake area of the southeastern Sierra.

Collecting and research over the decades have led to many field discoveries of statewide significance. A few recent ones include finding Howell's tauschia (*Tauschia howelli*) for the first time in the Sierra, disjunct from the Marble Mountains; finding yerba mansa (*Anemopsis californica*) in Shasta Valley, when it was thought to grow nowhere north of the delta; and finding Canadian buffaloberry (*Shepherdia canadensis*) in the Klamath Mountains, far, far disjunct from its nearest stands in the Ruby Mountains and northeast Oregon.

In the esteemed tradition of James B. Roof, we have done our best to help protect wild areas of great botanical significance. Roof worked hard on the Antioch Dunes, San Bruno Mountain, Pine Hill in Eldorado County, the Bucks Lake Wilderness in Plumas National Forest, and many other places, with considerable success. Wayne Roderick helped save Cedar Lake and other areas in the Klamath Mountains and educated a generation of botanists and horticulturists about many threatened areas in the state. More recently, we stopped the conversion of scenic and botanically wonderful Dismal Swamp in the Warner Mountains into a strip mine and played a leading role in saving 15,000 acres of Bear Valley in Colusa County. Today, in these ever more desperate times for our wild heritage, we are doing what we can to save glorious Walker Ridge in Lake County, Corral Hollow in Alameda County, and the northern Livermore Valley.

Such is the work of a provincial botanic garden, the necessary toil of a garden devoted to displaying and protecting the native flora of its own region.

The Other Redwoods *by Glenn Keator, PhD*

Many people think that the only true redwoods are the coast redwood (*Sequoia sempervirens*) from California's coastal mountains and the giant sequoia (*Sequoiadendron giganteum*) from scattered stands in the central and southern Sierra Nevada.

Contrary to this notion, there are several other genera in the former redwood family Taxodiaceae, mostly concentrated in relict stands around the Pacific Rim. Most famous is the dawn redwood (*Metasequoia glyptostroboides*), discovered living in central China in the 1940s (it was otherwise known only from fossils), a smaller tree with buttressed trunk, soft green foliage that is shed in fall, and seed cones similar to the coast redwood.

But other genera occur as well, even if they don't bear the name "redwood." Among them are the so-called bald cypresses (*Taxodium* spp.) of the southern bayou country and the mountains of Mexico, another deciduous group that grows in swamps and along water courses, with well-developed "knees" that help roots breathe.

Emerald Canary

Dawn redwood (*Metasequoia glyptostroboides*) at Lakeside Park in Oakland

Then we have several more poorly known trees from China, Japan, Taiwan, and even Tasmania, an island off the southeastern coast of Australia. Included here is the Japanese "cedar" (*Cryptomeria japonica*), an important timber tree with brown-red bark, short, sharp needlelike leaves, and small seed cones with fringed scales; the Chinese "fir" (*Cunninghamia lanceolata*), with fibrous bark in strips, gracefully arched, narrowly lance-shaped leaves, and unusual seed cones;

Emerald Canary

Cryptomeria japonica 'Elegans' at the Blake Estate in Berleley

Emerald Canary

Cryptomeria japonica 'Elegans' texture

Cryptomeria japonica cones

Taiwania cryptomerioides (no well-established common name), a smaller tree from Taiwan with prickly, bluish needles and small cones; *Glyptostrobus pensilis*, a rare small tree from China that combines awl-shaped to needle-like leaves on the branches and has small pear-shaped cones; and finally the seldom-seen King Billy and pencil "pines" (*Athrotaxis* spp.) from the mountains of Tasmania, with foliage either resembling giant sequoia or coast redwood and bearing small redwoodlike cones.

Although most of these genera are mere botanical curiosities, the dawn redwood and Japanese cedar grow in many Bay Area gardens. The Japanese cedar has been selected for several interesting cultivars, including one with feathery evergreen foliage that turns red in the fall. If you're interested in pursuing this farther, visit the UC Botanical Garden, which grows most of these species, and the UC Santa Cruz Arboretum, which also features the Tasmanian *Athrotaxis*. And bear in mind that our California redwoods now have even more "close" relatives. Based on DNA evidence, all but one member of the former redwood family Taxodiaceae has been merged into the larger cypress family, Cupressaceae.

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Photos by the author except as noted.

Emerald Canary

Taiwania cryptomerioides at the Mendocino Coast Botanical Gardens

The Red in Redwoods: Plant Chemistry Musings about Tannins

by Margareta (Greti) Séquin, PhD

If we touch the bark of redwood trees, it does not feel sticky. The trees hardly produce any resins, even if wounded. This absence of flammable resins helps redwoods survive forest fires. (Similarly, giant sequoias have practically no resin content.) Water-repelling resins protect other conifers against water intrusion and the danger of rotting; they also keep bark beetles and other insects at bay due to the resins' stickiness. Redwoods, on the other hand, obtain protection from an exceptionally high content of tannins. In this article we'll explore what is typical of tannins and how they provide redwoods with potent defense. We will also look at some important human uses of these plant products.

Tannins are widespread in plants. They are a large and diverse family of plant pigments that provide brown, almost black, and sometimes reddish colors to woody tissues and to the bark of trees. They give the wood and bark of redwoods their red color. Tannins are also found in leaves, fruits, roots, and seeds. They are typical products that plants synthesize in elaborate steps from sugars they obtain from photosynthesis. High concentrations of tannins are generally present in conifers and oaks, also in oak galls. Some common names, like tanbark oak, redwood, bitter root (*Lewisia*), or alum root (*Heuchera*), refer to a high tannin content.

Tannins have a bitter taste and may deter potential browsers. Humans do not appreciate a high tannin level in food, either. While a low tannin level may add to the specific taste of a wine, too high a tannin content is definitely undesirable. Tannins are astringent, that is, they make our mouths pucker, something we can experience if we taste an unripe persimmon. The common name "alum root" alludes to the astringency of the tannin-rich roots of *Heuchera* species.

So, what exactly are tannins? They are complex organic plant compounds. (Organic here means that their molecules are assembled from carbon atoms linked to each other.) Tannins belong to the large family of plant pigments called flavonoids, all of them having a distinct ring system in their molecules. There is a great diversity of tannin structures. There are simple tannins, composed of relatively small molecules of only a couple of carbon atoms, and so-called condensed tannins, consisting of larger, more complex molecules.

All tannins are soluble in water to a certain extent. This is due to the fact that tannins have lots of attached OH (hydroxyl) groups that make water molecules (H_2O or HOH) easily cling to tannin molecules by forming hydrogen bonds. The hydroxyl groups surround the tannin molecules and thus dissolve them in water. This is why puddles in pine forests after heavy rains may be colored dark brown by tannins and why dead tree trunks gradually lose their brown color as the tannins are dissolved by rains and washed away. Native people who used acorns as a staple food knew to leach out the bitter tannins with water to make the seeds useful as a source of flour.

The numerous OH groups in tannin molecules can also bond to metal ions, like iron from the soil, leading to very dark substances. In former times, oak galls were used for making ink. The tannins from the galls were extracted with water. When iron salts were added to the extract, the metal ions formed strong links with the tannins and produced a black ink.

Tannins get oxidized easily, meaning they react with oxygen from the air. Old tree logs and dead snags gradually turn gray, a consequence of oxidation of tannins. Or, if we bite into an apple and leave the light-colored inner core exposed to air, it turns brown because the apple's tannins become oxidized. Tannins are antioxidants: As they react with oxygen and thus absorb it, they can interfere with the damaging oxidation of cells. So while a high tannin content in food is undesirable because it provides a bitter, astringent quality, a low dose of tannins not only gives food a distinctive taste but can also promote health.

Aside from being deterrents to browsing animals with their bitter, astringent tastes, tannins provide additional means of defense to plants. Proteins, like those that function as enzymes, form strong links with tannin molecules. This process alters the natural properties of the proteins and makes them turn solid, that is, makes them coagulate. Enzymes in the gut of a bark beetle or other animal that feeds on tannin-rich plants thus cannot work properly, to the detriment of the browser. Animal feed with a high tannin content is undesirable. Thus, tannins are sometimes called antinutrients. Tannins are strongly antifungal, a characteristic based on their reaction with proteins in the fungi. The high tannin content of redwoods makes their wood highly desirable as lumber due to its resistance to fungal rot.

The coagulating effect of tannins on proteins is used in the tanning of leather. Fresh animal hides that would spoil if left untreated are soaked with solutions of high tannin content. The tannins make the proteins in the fresh animal hides harden, thus transforming them into leather and preserving them. In past times, oaks were the source of tannins for leather-tanning baths.

In conclusion, tannins are an important part of the vast diversity of chemical defenses that plants have evolved. And for the artist's and plant lover's eye, they provide trees with a palette of many shades of browns and blacks and the characteristic reddish-brown in redwoods.

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