

The Redwood Genome

Identifying redwood family trees sheds light on genetic variability

By [Sharon Guynup](#)

August 11, 2000

featured article

While hiking through California's Big Basin Redwoods State Park—dwarfed by the skyscraper-tall coast redwoods (*Sequoia sempervirens*) towering more than 300 feet overhead—stumbling upon Chris Brinegar and his team at work can be a rather startling experience. They carry a 20-foot pruning pole, a smoking canister of dry ice, and a ladder, their hands sheathed in latex gloves. "We scare some of the tourists," he says. "They often wonder if there's something dangerous that they should know about—or if we're cutting down the trees."

In fact, Brinegar's work is ultimately conservation-driven. He is a molecular biologist at the San José State University's Department of Biological Sciences in California who hopes that his work in coast redwood genetics will influence the preservation and management decisions of redwood lands. Conservation is a common thread among the handful of researchers studying the ancient behemoth, an awe-inspiring species that is unique in its genetic structure and reproduction—and is a valuable source of wood as well.

In the field, Brinegar collects redwood needles, stores them on dry ice at -80°C, and brings the samples back to his lab. His goal is not genetic sequencing; he is using DNA fingerprinting for "paternity testing" to discover the familial relationships among trees in redwood communities and to assess the species' degree of genetic variability.

Coast redwoods, named for the color of their bark and heartwood, forest a narrow, 450-mile strip along the Pacific Coast "fog belt" from California to southern Oregon; they once were dispersed throughout the northern hemisphere. The oldest living trees predate the birth of Christ—and are 2,200 years old.

Brinegar began sampling the trees along their entire range back in 1994. "I wasn't expecting to find much genetic variation," he says. But he did. "In groves even 50 meters apart we



Chris Brinegar retrieving redwood branchlets with a pruning pole.
Photo by R. Sundermeyer
Courtesy Chris Brinegar, Ph.D.

found great diversity. And in a current test area, we haven't found any two alike, even among neighboring trees. And though it's always great to see diversity in wild populations—it makes my job very difficult."

The scope of genetic variation was particularly surprising because of the tree's limited range. And although redwoods reproduce sexually, an individual tree sometimes sprouts several shoots from its trunk—clones. Adult redwoods are frequently arranged in circular formations known as "fairy rings," which were long thought to be clonal sprouts surrounding a long-dead parent tree. But even among these, researchers sometimes find slight genetic variations.

For use in his population and reproductive studies, Brinegar is hunting for highly repetitive DNA sequences called microsatellites, using techniques similar to the ones employed by police departments in forensic analysis. By extracting DNA from a single needle sample and using a technique called polymerase chain reaction (PCR) to amplify a specific region, he has isolated an extremely polymorphic region. This microsatellite has proven a good indicator of genetic diversity. Brinegar is now using it to determine how nearby trees are related to each other.



Chris Brinegar preparing collected needles for storage on dry ice.
Photo by R. Sundermeyer
Courtesy Chris Brinegar, Ph.D.

Brinegar also intends to use this microsatellite to compare the coast redwood with relatives like China's dawn redwood and eastern California's giant sequoia. But within its cells, the tree's chromosomal structure more closely resembles the green carpet of a back lawn than its closest cousins, says Deborah L. Rogers, of the Genetic Resources Conservation Program at University of California, Davis, who studies patterns of genetic variation. In fact, she says, it has no really close relatives, and is classified within its own genus and species.

Why? In 1948, researchers made a startling discovery: the coast redwood is a hexaploid—each of its cells containing six sets of chromosomes, with 66 chromosomes total. Its redwood cousins, like humans, are diploids, with only two sets of chromosomes. "Being a hexaploid is not unusual in the plant kingdom, but it is among trees—hexaploids tend to be grasses and non-woody plants," says Rogers. Some hardwood trees are polyploids (having multiple chromosomes), but the coast redwood is the only known hexaploid conifer.

The tree's genetic architecture may explain its incredible longevity. "If you're a hexaploid, there's the potential to harbor wider genetic diversity," says Rogers. "With six sets, you could possibly have six different genes—and gene products, proteins."

So the chance for mutation is higher, which could allow greater adaptability to changing

environmental conditions. And the coast redwood, one of the world's more ancient species, is remarkably disease-free. "You'd think that over the millions of years that they've been around, an insect or fungus would have found a way to bore into them," says Brinegar. "But very few trees are damaged this way."

Exactly how old is the coast redwood? M. Raj Ahuja, a molecular biologist at the US Department of Agriculture's Institute of Forest Genetics in Placerville, California, is trying to trace its ancestry to determine if the giant sequoia, dawn redwood, the bald cypress, or other "family members" have contributed to its evolution, or whether the ancestors of the coast redwood are extinct. "And we are also interested in finding out when the coast redwood originated as a hexaploid—whether it was during the Paleocene epoch (65 to 54 million years ago), the Eocene epoch (54 to 38 million years ago), or during a later geologic period." At the beginning of the Paleocene, the dinosaurs had just disappeared from the earth, and birds and mammals were blossoming. Conifers had appeared long before and had begun coexistence with flowering plants and modern insects. Ahuja and his team are looking at Sequoia fossil records, examining the stomata (breathing pores), that are bigger in hexaploids.



Redwoods along "Avenue of the Giants" in Humboldt Redwoods State Park.

Photo by C. Brinegar
Courtesy Chris Brinegar, Ph.D.

And the UC Davis team found yet another extraordinary trait in redwoods—their mode of inheritance. Plants have three sources of DNA: the cell nucleus, the mitochondria, and the chloroplast, which participates in photosynthesis. Some studies indicate that mitochondrial DNA comes from the mother, chloroplast DNA from the father, and nuclear DNA from both. The coast redwood was the first plant discovered that inherited both chloroplast and mitochondrial DNA from the father. "We don't know what that means in terms of ancestry or species fitness—but it's just another way that this tree is a very singular organism," says Rogers.

These redwood studies have both a curiosity element—pure scientific inquiry—and a practical element. With a burgeoning world population, "we're going to need a lot of wood, and this is a very valuable species," says UC Berkeley's redwood genetics pioneer William J. Libby. "It grows faster than any conifer on earth." He considers it an important source of pulp and wood, "and you could grow a stunning park in a hundred years."

As part of his redwood biology studies, John Kuser, of the Department of Ecology, Evolution, and Natural Resources at Rutgers University in New Brunswick, NJ, collected two seedlings from over 90 stands of old-growth trees from across their native range. He took tissue from needles to propagate shoots, rooted the cuttings, produced one clone of each, and then produced many rooted cuttings from each clone.

These trees are now being grown and studied in countries on every continent. Researchers are trying to increase the yield of this already productive species. Timber-growing land typically produces between three and four cubic meters per hectare of wood each year. Coast redwoods produce about 30 cubic meters, but Libby says a plantation in France is producing 54. "Every time we put a suitable tract of land into redwood production, we can put 10 times as much land into use as a park," says Libby.

Whether it's ultimately for the production of wood, the protection of existing forests, or the creation of new ones, researchers want to get science into the field. "It would be nice to be able to help land conservancies make sound choices, to tell them 'this grove is unique—protect this area,'" says Brinegar. And Rogers wants to impact the way harvested coast redwood lands are being reforested. And why should we care? "Very few people are in the presence of a redwood without having either a very pleasant—or a downright mystical experience," says Libby.

. . .

[Back to GNN Home Page](#)

Genome News Network is an editorially independent online publication of the J. Craig Venter Institute.
© 2000 - 2004 J. Craig Venter Institute.
All rights reserved. This material may not be published, broadcast, rewritten or redistributed.