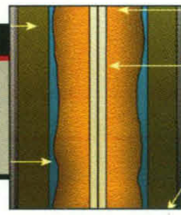

PAGE 994
Engineering more nutritious rice

995
Super-battery from super-iron

PHYLOGENY

Deep Green Rewrites Evolutionary History of Plants

ST. LOUIS—Not long ago, scientists trying to sort out the evolutionary links among plants often worked alone on secret projects, racing to scoop other labs. "It was a dog-eat-dog world," says University of California, Berkeley, botanist Brent Mishler. Fed up with this poisonous atmosphere, Mishler and several colleagues, over lunch at the Missouri Botanical Garden in 1992, hatched a plan for a botanical version of the Human Genome Project: an effort to merge molecular, fossil, and morphological data to build a family tree for all green plants. It was a "big-science solution for a field stuck in a laissez-faire mode," says Mishler.

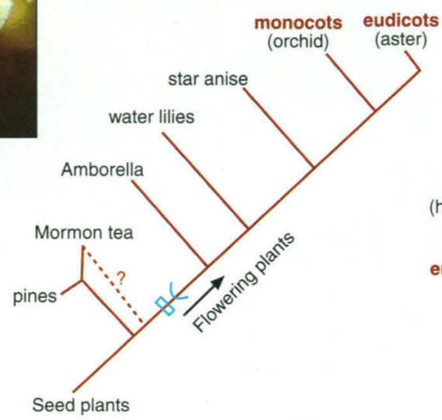
The first fruits of their 5-year effort, dubbed Deep Green, ripened in time for the 16th International Botanical Congress, held here last week. Challenging long-held notions about the relationships among species, scientists reported that plants should be divided into three kingdoms rather than one, unveiled the most primitive living flowering species, and homed in on the "Eve," or mother, of all 500,000 green plant species. Deep Green, involving 200 scientists from 12 countries, "is the biggest attempt at phylogeny ever," says Mishler.

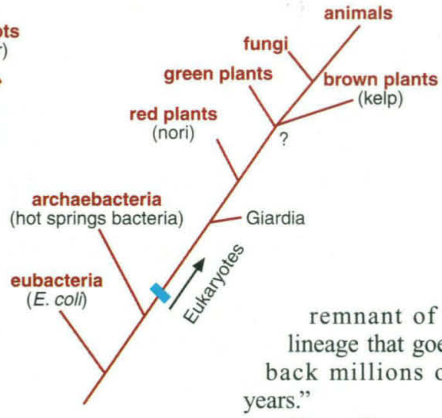
As genetic data add branches and leaves to the new family tree, biologists should be able to tap it for information on how to engineer useful traits, fight invasive species, identify organisms, and find potential medicines. Deep Green scientists intend to publish a book later this year and have established a Web site* that will become a repository for links to findings as they accumulate in the peer-reviewed literature. "If we can perfect the green plant tree, its impact will be phenomenal," says Sean Graham of the University of Alberta in Canada.

Adding one intriguing branch was the lab of botanists Pamela and Douglas Soltis of Washington State University in Pullman, a husband-and-wife team that 5 years ago set out to plumb the murky beginnings of flowering plants. How flowers arose, adding brilliant colors to a green panorama, is a question that has bedeviled biologists since Charles Darwin, who called the emergence of flowers an "abominable mystery." Studies had suggested that magnolias or water lilies—both built simply, with saucerlike flowers—could be the closest living relatives of the earliest flowering plants, or angiosperms. The Soltises, however, felt that the first flowering plants must have been even simpler—perhaps lacking either tissues that transport water efficiently or closed carpels, modified leaves that protect seeds.

To turn back the clock, the Soltises and their colleagues constructed phylogenies, or evolutionary histories, of angiosperms based on their DNA. They compared three common sequences—in the chloroplast genes *rbcL* and *atpB*, and 18*S* ribosomal DNA—from 560 species. These DNA regions mutate rapidly, making them good tools for differentiating among species. When a computer program shuffled the DNA sequences into a rough time order based on their mutations, it came up with a surprise: A rare tropical shrub called Amborella appeared at the bottom, or root. About 135 million years ago, the researchers concluded, nonflowering plants—perhaps similar to today's pines—hit an evolutionary fork in the road, with some veering off toward Amborella and later angiosperms while others continued life sans petals.

Found only on New Caledonia, an island in the South Pacific, Amborella, a diminutive plant with creamy flowers and red fruit, had gone unnoticed by most botanists, says Pamela Soltis. But as Deep Green ground on, three other research teams created flowering-plant phylogenies; each confirmed that Amborella is, indeed, the closest living relative of the first flowering plant. Such diverse support for a new phylogenetic finding is rare, says Christopher Haufler of the University of Kansas, Lawrence. Amborella, he says, "is a tiny remnant of a lineage that goes back millions of years."



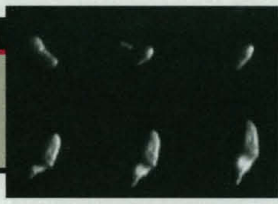


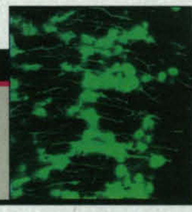
The glass slipper fits. New data point to unheralded Amborella *(inset)* as the most primitive flowering plant; new view *(right)* of plant kingdoms.

Deep Green, a \$285,000 project funded by three U.S. agencies—the National Science Foundation, the Department of Agriculture, and the Department of Energy—also threw its weight behind the idea that single-celled algae, living in the cracks of rocks and in soil along streams at least 450 million years ago, evolved into mosses that gradually crept out of the water and became the first land plants. New data from biologist Marvin Fawley of North Dakota State University in Fargo put Mesostigma, a scaly, unicellular alga, at the base of this freshwater algal line. In addition, DNA data from biologist Louise Lewis of Louisiana State University in Baton Rouge and others suggest that the Eve of the green plants that first took root on land must re-

CREDIT: (PHOTO) SANDRA FLOYD, UNIVERSITY OF COLORADO; (DIAGRAM) B. MISHLER

*ucjeps.herb.berkeley.edu/bryolab/greenplantpage.html





semble either Chara or Coleochaete algae, which still thrive in lakes and streams today.

For plant taxonomists, the new data strike a blow to the foundation of their discipline: the 250-year-old system, designed by botanist Carolus Linnaeus, which groups species by the number and arrangement of their reproductive organs, the stamens and pistils. At the meeting, a vocal band argued that the Linnaean system should be thrown out, or at least overhauled, because many plants presumed by their appearance to be closely related—such as the water lily and the lotus—are in fact quite different genetically.

In crafting a phylogenetic tree, Deep Green scientists confirmed that classic categories like monocot (one seed leaf) and dicot (two seed leaves) often fail to group plants accurately; that fungi are more closely related to animals than plants; and that some green algae are more like land plants than algae. Moreover, Mishler says, the brown, red, and green plants each arose independently from a common single-celled ancestor and thus deserve their own kingdoms. Overall, he claims, at least half the Linnaean classifications are wrong.

Mishler and others would prefer to name plants according to clade, or genetically related group—a system called the PhyloCode. For example, the herb *Prunella vulgaris* and hundreds of other plants might simply go by the name *vulgaris*, with a tag in some master directory that scientists could refer to for phylogenetic data. "When I first heard this, I thought it was crazy," says Kathleen Kron, a botanist at Wake Forest University in Winston-Salem, North Carolina. "But it's not. A plant's rank is arbitrary, and naming it by clade is a far more relevant, practical way to go."

Not everyone agrees. "The new phylogenetic information is absolutely wonderful, but renaming all these plants is going too far," says Richard Brummitt of the Royal Botanic Gardens in Kew, England. "A red oak is not a white oak, and without rank, we lose the ability to make that distinction easily." Like it or not, Brummitt concedes that the push to revamp nomenclature is gaining ground. Not too long from now, he predicts, botanists will have to cope with two systems—one Linnaean, the other cladistic.

As the green plant tree grows, scientists should be able to start to decode the genetic ciphers explaining how competitive advantages evolved in plants—for example, how mosses gained an ability to resist drought. And some Deep Green insights may offer a biomedical payoff. For example, Patrick Keeling of the University of British Columbia in Vancouver reported that Microsporidia, a parasite that can sicken people with weakened immune systems, evolved from a fungus—not an ancient, premitochondrial eukaryote, as many scientists believe. Thus, drugs that disable fungal proteins may also work against Microsporidia, Keeling says.

Although Deep Green is finished, researchers say it has sown the seeds for future collaborations. "It's taken people by surprise that botanists have been so willing to share unpublished data so we could all work together," says Pamela Soltis. Along the way, the green plant tree is sure to branch off in new directions. Says mycologist John Taylor of the University of California, Berkeley: "As more genes are added to these phylogenies, we're not going to be so smug that we've got it all figured out." —KATHRYN S. BROWN

Kathryn S. Brown is a science writer in Columbia, Missouri.

U.S. BUDGET

Tax Cut Politics Could Swallow Research Gains

An already uncertain year for science funding got even more complicated last week. In a last-minute flurry of votes before their summer recess, House and Senate lawmakers passed spending and tax cut bills that drew White House veto threats. That action/reaction is prelude to a legislative showdown when Congress returns to Washington next month that could extend beyond the start of the fiscal year on 1 October. For the major science agencies, appropriations bills now being considered by Congress fall several billion dollars short of the Administration's proposals. The critical issue will be whether that shortfall can be funded by breaking politically sensitive limits on domestic spending or diverting money from projected budget surpluses.

Unlike in past years, the current debate is fueled by the prospect of a $1 trillion surplus over the next 15 years. The Republican tax cut, passed on 6 August, would return much of the money to taxpayers. But President Clinton has vowed to veto the tax cut, which won't arrive on his desk until next month, saying the funds should be used instead to pay down the national debt and shore up retirement and medical insurance funds. Some science lobbyists worry that the partisan bickering may drown out their campaign to boost the government's $78 billion research and development budget.

White House science adviser Neal Lane has already begun beating the drums. This week Lane called a meeting of Washington science community leaders to rally opposition to the reductions by the House in a number of high-profile science programs within NASA, the National Science Foundation (NSF), and other agencies (see table). "This situation can be turned around if America's research community makes its strong voice heard," he said in a 6 August statement. Republicans say the cuts, on bills passed generally on party-line votes, are required under a 1997 budget-balancing law that imposes strict caps on spending in 2000. "The White House is blaming us for obeying the law," said one Republican House aide. In fact, neither side so far has been willing to take the political heat for suggesting that the caps be raised.

Other lawmakers, however, have called for using part of the surplus to restore the $18 billion or more that will be needed to prevent cuts in several major spending bills, including the one that funds the $16 billion National Institutes of Health (NIH), which

HOUSE BOUND

Program	Request (in millions)	House level
Advanced Technology Program (NIST)	$239	0
Earth Observing System (NASA)	663	513
Information Technology (NSF)	181	35
Spallation Neutron Source (DOE)	196	60

Swipe at science? House members, either as a whole or in committee, pruned the president's 2000 budget request for several high-profile science projects.

SOURCE: CONGRESS/OMB