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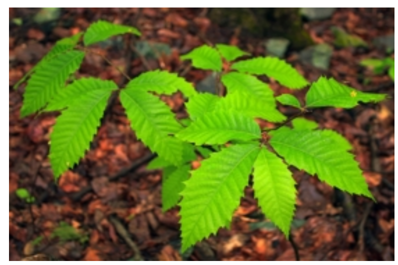
# A New Generation of American Chestnut Trees May Redefine America's Forests

Before an exotic fungus nearly wiped them out in the late 1800s, abundant chestnut trees shaped the forest ecosystem, providing food and shelter for numerous other species. In coming decades Chestnut trees engineered to battle the fungus could restore these lost relationships

By Ferris Jabr | Mar 1, 2014 | 0



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"We're just going to walk up the ridge," Don Leopold tells me, leading me along a trail through Whiskey Hollow, a 14-hectare nature reserve about 20 minutes outside Syracuse, N.Y. "It'll be a good stretch of the legs."

It's a chilly, slightly cloudy September day. Leopold and I have traveled here hoping to find a rather elusive species—one that used to be so abundant it was impossible to take a walk in these woods without seeing dozens of its kind, if not several hundred. There is no guarantee we will find the creature today, however. Although not extinct, the organism we seek has been dwarfed in size and number, maintaining an unassuming existence in the understory instead of dominating the forest as it once did.

Just under 10 minutes into our hike, however, Leopold sees something. "Oh yeah, look at that—that's a beauty," he says. "That's it right there."

We stomp off the trail, down a gentle slope and stop beneath a young skinny tree maybe 4.5 meters tall with gray bark and serrated leaves like giant arrowheads. To most people the tree would be entirely unremarkable. But to Leopold, a forest ecologist, the sapling is a rare and beautiful sight—a living descendant of the formerly mighty American chestnut.

Before the early 1900s one in every four hardwood trees in North America's eastern forests was an American chestnut. Together, chestnuts and oaks predominated in 80 million hectares of forest from Maine to Florida and west to the Ohio Valley. Every spring so many chestnut trees erupted in white blossom that, from a distance, the hills appeared to be draped in quilts of snow.

The American chestnut once provided copious food and shelter for animals and people alike. Bears, deer and all manner of small mammals and birds feasted on fallen chestnuts, which sometimes piled so high on the forest floor that people would scoop them up with shovels. Reaching heights of 40 meters and growing two meters around the middle, American chestnuts were home to squirrels, chipmunks, blue jays and scores of benign burrowing insects. People, too, constructed their lives around chestnut. Lightweight, rot-resistant, straight-grained and easy to work with, chestnut wood was used to build houses, barns, telegraph poles, railroad ties, furniture and even musical instruments.

In the late 1800s a hitchhiker that would ultimately devastate the country's chestnut forests arrived in America for the first time. A New York City nurseryman named S. B. Parsons imported Japanese chestnut trees in 1876, which he raised and sold to customers who wanted something a little exotic in their gardens. Other nurseries in New Jersey and California soon did the same. One or perhaps all of these shipments concealed the pathogenic fungus *Cryphonectria parasitica*, which chokes chestnut trees to death by wedging itself into their trunks and obstructing conduits for water and nutrients. Asian chestnut trees had long evolved resistance to *C. parasitica*, but their American relatives—which had never encountered the pathogen before—were extremely susceptible to the fungal disease known as chestnut blight.

First discovered in New York State in 1904, chestnut blight was soon spotted in New Jersey, Connecticut, Massachusetts and Pennsylvania. Within 50 years, *C. parasitica* killed nearly four billion chestnut trees. Now, few if any large trees remain in the chestnut's native range. Because the species has a resilient root system, however, the American chestnut survives here and there in the form of living stumps, which sometimes send up young, skinny treelings like the one Leopold and I found. Although a credit to the chestnut's persistence, such saplings are mere gestures at the glory and girth of their predecessors and almost always succumb to blight by their teens or 20s, never getting old enough to flower and reproduce.

Humans are both responsible for the demise of America's chestnut forests and the only species on the planet that can do something about it. Since the 1980s several generations of Leopold's colleagues at the State University of New York College of Environmental Science and Forestry (S.U.N.Y.–ESF) have toiled to restore the American chestnut to its native habitat. One semisuccessful strategy has been mating American chestnut with blight-resistant but much smaller Chinese chestnut, selectively breeding the hybrids to achieve a tree that is as genetically and physically similar to an American chestnut as possible, yet still resilient. Genetic engineering has offered another even more successful route to restoration. By taking genes from wheat, Asian chestnuts, grapes, peppers and other plants and inserting them into American chestnut trees, William Powell of S.U.N.Y.–ESF and scores of collaborators have created hundreds of transgenic trees that are almost 100 percent genetically identical wild American chestnut yet immune to *C. parasitica*. The scientists hope to get federal approval to begin planting these trees in the forest within the next five years (See “The American Chestnut’s Genetic Rebirth” in the March 2014 issue of *Scientific American*).

To predict how a new generation of American chestnut trees will modify the forest in the coming decades we need to examine how this one species defined the forest in the past. Doing so is difficult, however. *C. parasitica* wiped out nearly all mature American chestnut trees before forest ecology became the rigorous science it is today, so most of the pre-1950s data about the species comes from observational studies rather than controlled experiments. Still, by drawing on historical records and recent research on remaining chestnut trees, we can piece together a portrait of this magnificent tree’s role in the forest ecosystem. In its prime the American chestnut determined the physical structure and microclimate of the forest, creating specific and stable environmental conditions on which many other creatures depended. When the American chestnut fell, the whole forest shuddered.

The story of how the American chestnut once defined North America’s eastern forests—and how it might once again—begins in the last ice age. Between two million and 10,000 years ago, an epoch known as the Pleistocene, massive sheets of glacial ice covered Canada and the northern regions of what is today the U.S., repeatedly invading and retreating. Mammoths, mastodons, giant beavers and colossal sloths roamed New England, which at the time was a forested tundra filled with evergreen, needle-leaved conifers like spruce and pine as well as some hardwood, leaf-shedding trees such as birch, along with many grasses and shrubs. Around 10,000 years ago the ice sheets dwindled, the Gulf Stream moved north and climatic conditions much more similar to the recent past began to establish themselves. Conifers claimed the northern area of New England, hardwood species dominated its south and two kinds of trees shared its central region. A warming climate over the next 3,000 years allowed hardwoods like red maple, beech and hickory to migrate into northern New England. Between 1,500 and 2,000 years ago American chestnut followed this pattern, spreading across Connecticut and Massachusetts.

Over time North America’s forests became a dense patchwork of different sylvan communities, each characterized by a unique topography and climate. As a whole, the deciduous forest was home to many different tree species—oaks, beeches, maples, basswoods, hickories, chestnut, ashes, elms, birches and poplars—but different types of trees predominated in different regions. Between Maine and northern Georgia oaks and chestnuts prevailed.

Soon enough the eastern forests had to contend with a relentlessly invasive species with which they had never interacted before: people. Based on the latest geologic and archaeological evidence, early explorers from east Asia may have arrived in North America by water along the western coast and by land via an ice-free corridor as long as 16,000 years ago. Once settled in the east, Native Americans chopped down many trees for firewood and building materials and used fire to clear tracts of forest. Although it was by no means trivial, this first wave of human landscaping was nothing compared to what would come from across the Atlantic.

From the 1750s onward European settlers burned immense sects of forest, rapidly converting them into farmland. As much as 75 percent of forested areas became open fields. Yet this dramatic transformation was short-lived. By 1850, just before *C. parasitica* completed its journey from Asia to America, people began to abandon the vast majority of newly created farmland and move west, lured by the Louisiana Purchase, the California gold rush and improving transportation. As people left, trees moved in. Today, forest covers more than 80 percent of New England.

The American chestnut would surely have prospered as part of this renewal if only humans had not inadvertently infected the forests with a deadly fungus. Instead of reclaiming old forest sites like other tree species, the chestnuts shriveled into a meager existence, which in turn changed the whole ecosystem in which they were enmeshed. In areas where the blight had reduced a stand of chestnut trees to stumps, all available shade vanished, stunting plant species requiring shade to thrive. Sun-loving saplings, blackberries and greenbriers wrapped their nubile tendrils around the opportunity, tangling with one another in thick knots as they scaled toward the light. Oaks, maples and tulip trees became more numerous, claiming real estate that chestnut might have occupied.

These newly dominant tree species were not large enough to provide forest animals with as much food and refuge as the chestnut had once offered. Unlike oaks—which often flower too early to escape late frosts, losing what might have been a bounty of acorns to the bitter cold—chestnuts reliably bloomed after the latest frost and produced huge numbers of nuts, each of which was bigger than an acorn.

One of the most frequent diners at chez chestnut was the now extinct passenger pigeon. A swift and agile flier, highly social and twice the size of modern urban pigeons, the passenger pigeon was once the most common bird in North America. Scientists have estimated that as many as five billion passenger pigeons lived in America when Europeans first discovered the new land, comprising between 25 and 40 percent of all birds on the continent. In 1866 a cloud of 3.5 billion passenger pigeons 1.5 kilometers wide and 480 kilometers long took 14 hours to pass over southern Ontario. Such massive flocks routinely migrated from one breeding site to another, going wherever weather was most welcoming and food most plentiful. By the early 1900s, however, the passenger pigeon was pretty much nonexistent in the wild.

Although chestnut blight was not the sole or even primary cause of the passenger pigeon's downfall, the fungal disease almost certainly hastened the bird's extinction. At the same time that people were using nets, guns and pots of noxious sulfur to hunt pigeons on a massive scale for its meat and feathers, blight was knocking down the chestnut trees the birds needed to survive. Not only did the trees provide hoards of nuts, they also offered massive and sturdy branches on which the birds could safely roost and breed. Enormous flocks were notorious for breaking weaker branches with their weight.

Even the chestnut's leaves were more nourishing to many animals than those of oak. Whenever leaves fall into streams or standing water they leach all their chemicals—a slower version of what happens to tea leaves in hot water. Chestnut leaves decay much more quickly than tougher, lignin-rich oak leaves, releasing plenty of nutrients for the aquatic larvae of various insects. A 1985 study found that crane fly larvae, for instance, prefer dining on American chestnut and maple leaves to eating oak leaves.

Much more recently, Aaron Stoler of the University of Pittsburgh and his colleagues re-created miniature ecosystems resembling forest wetlands by filling kiddie pools with water, gray tree frogs, plankton, snails, insects, bacteria and leaf litter from American chestnut and a range of other tree species. His experiments confirmed that chestnuts provide more nutrients more quickly than oak, but also underscored that a wetland thrives when it has a variety of leaf types—some that decompose slowly, others quickly, rather than just one kind or the other. In one case, red maple leaves decayed so quickly and stained the water so dark that they prevented plankton from producing oxygen through photosynthesis. As oxygen levels in the water sank, the frogs began to die, which would translate to less food for snakes, birds and other larger predators in the wild. A leaf falling into a stream might seem like an insignificant event, but it sparks a complex chain of interactions between countless living things that ultimately alter an entire ecosystem.

The same is true for falling twigs and branches. Resilient chestnut branches that plopped into brooks would have created more permanent underwater shelters and hiding spots for fish than more swiftly disintegrating oak wood. J. Bruce Wallace of the University of Georgia and his team discovered that 24 percent of large woody debris that had accumulated in a southern Appalachian mountain stream by the late 1990s was from American chestnut that had perished 50 years earlier.

Chestnut trees also undoubtedly changed the very soil in which they grew. Before the 1950s mature chestnut trees in their native range lived in a variety of soils—mostly well-drained acidic dirt—but also soils made from shale, sandstone and limestone. Of course, researchers cannot directly study how those trees altered soil chemistry—but they can get close. The largest remaining stand of mature American chestnut trees grows in West Salem, Wisconsin. In the late 19th century a Wisconsin settler named Martin Hicks planted about nine chestnut trees that quickly multiplied, escaping the brunt of the chestnut blight that swept the east. *C. parasitica* eventually reached even these trees, however, perhaps on the boots of visiting New England scientists. White, red and black oaks, as well as hickory, aspen and several more of the same hardwood tree species found in the chestnut's native range grow around the stand in Wisconsin—in the same kinds of soils, too—creating a kind of eastern deciduous forest microcosm.

In 2002 Charles Rhoades of the U.S. Forest Service's Rocky Mountain Research Station traveled to West Salem and gathered dirt and leaf litter from areas surrounding 20 chestnut trees and from 20 different spots where other kinds of hardwood trees grew. Later, in the lab, he analyzed the chemistry of these samples. Chestnut leaves had more nitrogen, phosphorus, potassium and magnesium than leaves from other species, and sandy soil beneath chestnuts had as much as 17 percent more carbon and nitrogen as well as a little more moisture. In sandy soils chestnuts were returning more nutrients and life-building molecules to the earth, where they would be available to numerous other plants, animals and microorganisms.

Just a year earlier, Ryan McEwan of the University of Dayton and his colleagues also visited West Salem and harmlessly drilled into the trunks of chestnut trees and eight other species, collecting more than 100 pencil-size wood samples. Tree-ring analysis confirmed that, as many ecologists had surmised over the years, chestnuts grow faster than most other hardwood trees and that the trees are tenacious, surviving in the understory as saplings until enough light breaks through the canopy for them to grow tall.

If S.U.N.Y.–ESF's Powell and his colleagues succeed in planting young transgenic blight-resistant chestnuts in the wild, chances are good that the trees will successfully expand their domain—relatively quickly in some areas; slowly but surely in others. Over the decades this new generation of American chestnuts will change the forest from floor to canopy: Their uppermost branches will bring shade to areas that have too little; their quickly decomposing leaves will carpet the soil and drift into streams and standing water, staining the water with nutrients; their trunks will be home to billions of insects and mammals, their branches the foundations of nests; and, one day, when the trees are mature enough, they will drop scores of chestnuts for the first time in more than a century.

This past September, a day before taking a walk through the woods with Leopold in search of wild American chestnut, Powell gave me a tour of his laboratories. Linda McGuigan, one of the lab technicians, invited me to examine chestnut tree embryos under a microscope—clusters of rapidly dividing cells that have the potential to become an adult tree. In white light the embryos looked like clumps of sea salt. When Linda switched the light source to ultraviolet, some of the clusters glowed neon green. These were the transgenic embryos. Powell and his colleagues hitch the gene for blight resistance to one that makes a green fluorescent protein, so they can easily identify their successes.

Such naked embryos are not as hardy as seeds. You can't just put them in soil, spritz them with water and wait for them to sprout. Instead, Powell and his colleagues have spent 15 years developing an elaborate growing regimen that simulates what would usually happen to an embryo within the protective husk of a chestnut seed buried in the forest floor. Once the embryos are large enough the scientists transplant them to glass cubes layered with nourishing translucent gels. They treat each one with a series of plant hormone cocktails that trigger the growth of roots and shoots at different times, carefully controlling light, temperature and humidity all the while. Whereas ordinary seedlings have a thin stem and a few large, floppy leaves, the plants inside the cubes are more like baby bonsai trees, producing adult structures in miniature.

After weeks or months in a greenhouse and growth chambers that look like giant green refrigerators, the chestnuts are relocated to fields just on the edge of Syracuse. Here, fenced off from the forest, grow thousands of chestnut trees young and old. Some are Chinese chestnut; some are American-Chinese hybrids; and others are fungus-fighting transgenic American chestnut trees. Powell stoops beside a transgenic tree—one of the earliest he and his team created. He points to the base of one branch, where the bark is frayed and encircled by what looks like a band of rust. Moving our eyes along that branch, we see its leaves are yellowing and falling off. The earliest varieties of genetically engineered trees were not strong enough to fend off *C. parasitica*, but the newest transgenic trees in this field are very healthy. The risk of pollen from these trees carrying new genes to other plant species is incredibly low—the chestnut has few close relatives in its native range with which it is sexually compatible. If anything, the engineered trees might mate with wild chestnut, imbuing the latter with some much needed immunity.

Powell and his colleagues have also been comparing the transgenic trees with typical chestnuts in various ways, making sure that they both form the same kind of associations with beneficial bacteria and fungi; that the engineered trees are not in any way harmful to benign insects; and that the nut chemistry of transgenic trees matches that of ordinary ones. So far, everything syncs up.

Toward the end of our field trip, Powell, his colleague Andy Newhouse and I stop and look around. “Well, this is our program,” Powell says. “Anything else you think we should show him?”

“Not unless you want to look in the woods,” Andy says. “But the chestnuts around here are so small that there’s not a whole lot to look at. If you’re heading out with Don Leopold tomorrow, I think he’ll do a better job.”

The next day, after hiking for an hour and finding three American chestnut saplings total, Leopold and I have looped back to the beginning of the trail. He spots some wild sassafras—which was once used to flavor root beer—and cuts it so we can breathe in its spice. Before we leave, he decides to collect a few leafy American chestnut branches. We trek back to the first tree he spied.

"I want to show these to my students,” he says. “We don't cover this species in class because it hasn't really been relevant for the last 80 years. But I'm looking forward to including it again."

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