Reviving a Fallen Giant

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by Robin Respaut

On a crisp, early morning in October, a small group of naturalists made their way down a winding trail through an isolated state forest in Derry, New Hampshire, to visit a lone American chestnut, one of only two dozen recorded in the state.

Image fromThe American Chestnut Foundation.

This healthy chestnut tree stands isolated near a still, black pond, hidden among a forest of oaks, maples, and beeches. In a region of New Hampshire once known as "Nutfield" and informally referred to as "chestnut country," few mature chestnuts have survived the chestnut blight, which has been attacking chestnuts since the early 1900s. Somehow, the Derry chestnut, for now, has escaped the deadly epidemic that killed billions of other chestnut trees.

Upon reaching the survivor, arborist Scott Davis hurled weighted ropes into the canopy above. He scaled a nearby oak, then swung himself like a human squirrel into the 60-foot chestnut, where he began snatching brown paper bags from the tips of the chestnut's branches.

The bags had hung there since earlier in the summer. In June, when the chestnut's long white flowers were blooming like holiday fireworks falling through the sky, Davis had scaled the tree and played matchmaker. He dipped each pale female blossom into a vial of blight-resistant pollen, then covered the flower with a paper bag to mark it. Now, months later, he was back to collect the fruits of this arranged union.

Back on the ground, Davis handed the bags to Kendra Gurney, New England regional science coordinator for The American Chestnut Foundation (TACF). Inside the bags, verdant spiky balls poked out, looking like wild sea urchins. Gurney later sent the seeds to a breeding orchard at the Shieling State Forest in Peterborough, New Hampshire, where they would be planted in the spring. A new generation in the lineage to breed a blight-resistant American chestnut was about to begin.

A giant is felled

A majestic tree, the American chestnut once thrived in forests from Maine southward to the Gulf States. Its straight grain and rot resistance made it a stable commodity for many nineteenth century uses, including telephone poles, railroad ties, furniture, musical instruments, fuel wood, barn beams, and even siding and shingles. Tannins from the bark were used to tan leather, and it could be pulped for paper products. In many areas in the east, the American chestnut made up 25 to 30 percent of the natural forests, though it was less dominant in the northern part of its range. In addition to using the wood, farmers relied on the nuts,

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Chestnut furniture pieces in antique shops are true relics of a past time.
Photo by Andrew Crosier

which dropped by the bushel-full from trees each fall. In rural communities, people gathered the shiny brown nuts and sold them in markets, and farmers released livestock into forested land so that the animals could browse on the sweet, carroty nuts. Chestnuts were also a favorite among bears, deer, squirrels, and turkeys.

Then the chestnut blight arrived and changed all that. Brought over inadvertently in chestnut seedlings imported from Asia in the late 1800s, the blight was first recognized in North America in 1904 after it infected a row of American chestnuts at the Bronx Zoo. It quickly radiated from the Bronx to the outer reaches of New York state, Pennsylvania, Maryland, Virginia, Massachusetts, and Maine. The blight's damage was compounded by overzealous citizens, who, in 1926, began felling remaining healthy chestnuts throughout the east coast upon orders from the U.S. Forest Service. By the 1940s, approximately four billion trees were gone.

While American chestnut trees nearly vanished, in many cases, their root systems survived. New chestnuts sprout from a resilient root base and can still be found today in old chestnut territory. A strong root system can maintain sprouts for years, though the fungus reasserts itself, usually when the sprouts are five to ten years old. Often, the root system eventually tires of the constant struggle, and the entire plant dies.

Chestnut lumber, with its straight grain and rot resistance, was a prized commodity in the nineteenth century.
Photo fromThe American Chestnut Foundation

Adolescent chestnut trees are lush, with toothed, canoe-shaped leaves. Each healthy tree trunk has a reddish-brown tone, with a sometimes greenish hue. When the blight hits, the tree glows fiery orange around wounds or cracks in the bark. If you didn't know better, you might think the orange tinge was the bright sign of health, a striking vibrancy washed through the tree. Instead, the tiny raised orange freckles are a death sentence.

In Susan Freinkel's book, *American Chestnut: The Life, Death, and Rebirth of a Perfect Tree*, she describes chestnut blight as an "efficient executioner." The fungus (*Cryphonectria parasitica*) girdles the tree, restricting the flow of water and nutrients. Even a five-foot-diameter grandfather tree, if attacked at the base of its trunk, will surrender to the blight and die within two to three years.

Initial recovery efforts

The blight left behind "ghost forests" of skeletal trees in its wake, but since then there's been a colossal effort to breed the American chestnut back to life. In 1983, a group of plant scientists and chestnut admirers formed The American Chestnut Foundation and began efforts to breed hybrid trees that could survive the blight. Their efforts hinged on the belief that blight-resistant genes from a Chinese chestnut tree could be bred into the American chestnut.

The catch here is that the Chinese chestnut is an orchard tree, not a forest tree like the American chestnut. Mature Chinese chestnuts are about the size of apple trees. Before the blight struck,

American chestnut trees grew to more than 100 feet tall, with diameters of five or six feet. So the cross-breeding program has had to be finessed to create a tree with both blight resistance and stature.

The first cross between the two species produced a hybrid chestnut with only 50 percent of the genes that carried blight resistance. These trees, called the F1 generation, grew into craggy orchard trees, some taller than the typical Chinese chestnut but definitely not a forest hardwood. When the F1 trees were six years old, TACF volunteers inoculated them with the blight fungus, monitored the trees' response, and selected the most blight-resistant trees to backcross with their American parents. The product of that backcross breeding, called BC1, and now 3/4 American, was a slightly more American-looking chestnut.

While backcrossing does not enhance blight resistance – at best, the trees can only maintain a moderate amount of blight resistance – it enhanced the hybrid's American chestnut characteristics. TACF volunteers crossed the enhanced hybrids back to pure American chestnuts two additional times, creating the BC2 (7/8 American) and BC3 (15/16) generations. Trees in the BC3 generation are no more blight resistant than their predecessors, but their appearance resembles true American chestnuts.

Boosted blight resistance came in the next generation, called BC3F2, when two BC3 trees were intercrossed in an attempt to weed out any recessive susceptible genes. Now the TACF researchers were addressing blight resistance directly and trying to identify the blight-susceptible genes. The intercrossed offspring revealed that a tree's ability to resist the fungus is transmitted on just three genes, common to all chestnut species but only expressing blight resistance in the Chinese chestnut. In approximately two percent of the intercrosses, the BC3F3 generation inherits a combination of the three blight resistance genes from each BC3 parent that creates a nearly blight-resistant tree.

Two steps forward...

When Brad Smith, a high school Latin teacher, first planted his orchard of backcross American chestnuts at the Tower Hill Botanical Garden near Boylston, Massachusetts, in 2001, he felt optimistic. His chestnuts were the fourth generation (BC3) of a breeding program that yields American-looking chestnuts with moderate blight resistance. Containing 80 adolescent trees, the plot was the first orchard in the state of Massachusetts to join TACF's 18-year old campaign to reestablish the nearly lost population of American chestnuts.

After struggling at first through a string of dry summers, the trees eventually began to flourish. "At that point, it seemed like there was nothing you could do to hurt them," Smith said. In just five seasons, his best trees grew to a height of more than 20 feet, with many averaging close to three feet of growth per year. They were a fleet of robust chestnuts, so much so that Smith admitted that he sometimes felt "a false sense of security" in the trees' future. That reassurance quickly wore thin.

After providing six years of unyielding care and nourishment to his trees, Smith transformed himself from Dr. Jekyll to Mr. Hyde: he exposed his chestnuts to their worst enemy by opening the door and inviting it in. As part of the testing program, Smith inoculated his chestnuts in the spring of 2007 with a mild strain of blight by drilling small holes into the bark and inserting the fungus. The holes were necessary because chestnut blight enters via wounds or cracks in the tree. (This was especially easy for the fungus a hundred years ago when cash crop farmers hurled rocks and sticks into tree crowns to trigger a shower of falling nuts.) Once beneath the bark, the fungus settles into the cambium, where it blocks the flow of nutrients from the tree's roots to its branches.

One of Brad Smith's seven-year-old chestnut seedlings, wracked with blight, one year after inoculation.
Photo by Robin Respaut

Smith's chestnuts responded well to the inoculation at first. They mounted a compelling defense against the blight, and Smith noted only small cankers surrounding the inoculation site. He remained quietly proud and hopeful for his trees. Later that year, the chestnuts were inoculated

with a more virulent strain of the blight. This time, the results were devastating.

Once inside a tree, the blight releases a strong acid, killing the cells caught in its grasp. As the fungus feasts on the dead tree cells, the bark above the infected area sinks, creating a hollow pocket. The tree counters the fungus by isolating the affected areas, which intensifies the blockage of nutrients. Finally, conidia, the orange fruiting bodies of the fungus, build up in fiery pustules and release spores into the wind.

By the fall, Smith's chestnuts bore sunken cankers, as if someone had smashed them with a heavy mallet. The warm glow of the blight had spread the length of the trunks. Throughout the winter, the chestnuts' bark thinned and cracked above the diminishing, famished trees.

"Now, as an orchard manager, I'm more of a mortician," Smith said sadly. This summer, TACF scientists will rank Smith's trees. As of last fall, he did not expect any of them to continue to the next round of the breeding program.

Gene splicing

The mechanics of breeding trees is crude and time consuming, because each new hybrid needs to be grown until it can produce seeds of its own (approximately four years for a well-fertilized chestnut). To the more technically advanced among us, backcross breeding can seem like the old cut-and-splice version of sound recording. And at the end of it all, purists point out that the 15/16 American chestnut is still not really an American chestnut. At a time when genetic engineers are splicing cells from tuna into tomatoes, can't they just arm the chestnut with the disease-resistant gene and be done with it?

The problem is that scientists are not entirely sure how the specific genes confer resistance in the Chinese chestnut. By applying genetic markers that act as glowing neon lights on the chestnut's DNA, scientists narrowed the location of the three blight resistance genes but weren't able to locate them exactly. "It's hard to nail down where those genes are," said Paul Sisco, TACF's Southern Appalachian regional science coordinator. He likened it to a map without enough detail. "I could get to Illinois, but not Chicago, and definitely not to the same street."

In addition, sometimes two of the three genes are "on" while the third is "off," in no particular order, greatly expanding the possible genetic combinations, of which few will confer blight resistance. If genetic engineers insert a gene into the American chestnut that they suspect confers blight resistance, they might end up with a tall, blight-resistant chestnut tree with Chinese chestnut-like leaves, bark, or nuts. The wacky combinations are endless.

Still, Sisco believes the American chestnut itself will reveal the answer to the blight-resistant gene within the next few years. When TACF scientists begin studying the final generation of their backcross breeding program, they will compare the pure American chestnut's DNA with the bred blight-resistant chestnut (15/16 American) and note the differences. The genes that express resistance in TACF's trees should stand out when compared with the original American chestnut genes.

In the meantime, other scientists are working towards genetic modification from a different angle. Bill Powell, professor of biotechnology at SUNY-ESF in Syracuse, and his colleague Chuck Maynard have spent the last decade hunched over Petri dishes, encouraging sprouts to develop in a perfectly measured environment of nutrients and hormones. The men believe that they'll soon be able to genetically manipulate the American chestnut's genome to produce a nearly pure, blight-resistant tree.

Instead of using Chinese chestnut genes, Powell and Maynard turned to common commodities on the food market where genome mapping had already been carried out. They're currently working with a gene from wheat that releases oxalate oxidase, an enzyme that neutralizes the harsh acid discharged by the chestnut blight. (The blight kills a tree by producing acid that is toxic to the tree's cells.) The enzyme raises the tree's pH, and as a result, the tree can effectively battle the blight using its natural defenses.

Last summer, Powell and Maynard inoculated their first Petri-dish-grown chestnut tree with the blight. It died, but the professors were still encouraged by the outcome. The first tree, Powell said, was "a very low expresser of the wheat gene." The blight overtook the chestnut's feeble attempt to defend itself, although the oxalate oxidase enzyme was expressed. This summer, Powell expects to inoculate a second genetically engineered chestnut sprout that is armed with a bigger dose of the enzyme.

Another branch of the chestnut restoration movement aims to change the blight itself. In Europe, the

chestnuts were saved from the full effect of chestnut blight by an indigenous virus that wrapped its spidery arms around the fungus's cytoplasm and weakened it, thereby enabling the tree to defend itself. Upon discovering the virus, referred to as "hypovirus" because it makes the chestnut blight less virulent (hypovirulent), scientists in North America became optimistic that this European virus could be beneficial for the American chestnut.

The most prominent scientist using hypovirus on chestnuts is Sandra Anagnostakis at the Connecticut Agricultural Experiment Station. Combining "a soup" of various strains of the hypovirus, Anagnostakis inoculates her trees with both the blight and the hypovirus in the hope that the chestnuts will recover. Often they do, albeit somewhat grotesquely, with swelling, tumor-like cankers where the tree has isolated the blight. The problem is that the hypovirus does not jump from tree to tree as easily as the blight does, meaning that forest trees, particularly in isolated forests, will not survive without the aid of human inoculation.

A time to plant

People who love the American chestnut claim it will someday be as desirable a tree as it was during the nineteenth century. Chestnuts can tolerate the deep, cold winters of New England and the scorching, humid summers of Georgia, evidence that it could also endure the warming climate in future centuries. A hardy tree, chestnut takes root in the harshest of soil conditions, disregarding the nuisances of stones or disruption.

An American chestnut seedling being inoculated with the chestnut blight fungus.
Photo by William Powell

"It's really a gap-filler," said Bruce Spencer, a retired forester and TACF orchard manager in New Salem, Massachusetts. Spencer spent the last few summers spreading reject breeding nuts from parent trees that had succumbed to blight to determine the best conditions for planting. "Chestnuts seem to do really well in degraded areas." Sandy, well-drained, acid soil aids chestnut germination, too.

This spring, the U.S. Forest Service will plant the first chestnut trees that the foundation believes are fully blight-resistant. If they are correct in this assumption, TACF will have completed a feat that may help the forest recover from one of the greatest environmental disasters in North America. The initial results won't be available for another five to six years, when the trees are inoculated with chestnut blight.

Kendra Gurney and Robert Spoerl examine a

Even as the last leg of TACF's breeding program begins this spring, a rosy future is not guaranteed for the chestnut. In the century that has passed since the tree once flourished, new dangers have arisen. An introduced fungal root rot from Asia (Phytophthora cinnamomi) attacks the chestnut's root system, the only remaining stronghold of the tree. Asian chestnut gall wasp, a rose-colored gall that infests the shoots of the tree, appeared in Georgia in 1974 on a crate of Japanese chestnut wood that did not go through plant quarantine and has since spread widely. Ambrosia bark beetle, gypsy moth, and two-lined chestnut borers are other insects that could easily consume a fledgling crop of chestnut trees.

Still, TACF scientists and its 6,000 members are optimistic that they've succeeded with their most recent crop of American chestnut. The true test will come in the next half-century, after the trees have been planted in the wild and begin to propagate on their own. If everything goes to TACF's plan, this time the American chestnut will be here to stay.

New Hampshire chestnut seed.
Photo by Chris Paul

How to identify a chestnut

An open chestnut bur.
Photo by The American Chestnut Foundation

How do you know you've found an American chestnut? Start by identifying the leaf. The distinctive leaf is like that of beech but larger and with a more deeply-toothed margin. Chestnut leaves are similar to those of chestnut oak, but they're more pointed. Like oak and beech, chestnut holds its leaves well into autumn.

With the leaves off, however, the twig and bark aren't as useful. Look at the twig alone, and oak or beech is a likely first guess (although chestnut buds are considerably smaller than beech buds). Chestnut saplings resemble young oaks, with perhaps a smoother, tighter bark, often with a shiny red or chestnut-brown tone. The bark on larger trees will tend toward gray-brown, with dark-hued, shallow vertical cracks.

The fact that most chestnuts are sprouts is another clue. If you think you've found one, look in the immediate vicinity to see if there are other saplings rising from the same parent root.

Chestnut blight is itself a good identifying characteristic. The distinctive orange fungus may be present and resulting cankers are generally target-shaped and nasty looking. On a more positive note, the late summer crop of burs is a dead giveaway on trees that are old enough and receive enough sun to flower.

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