

# arnoldia

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*Front cover:* Pine tree tent supports at Hama Rikyu, Tokyo, Japan, photographed by Marc Treib.

*Inside front cover:* The first illustration of *Magnolia* x *thompsoniana*, from *Curtis's Botanical Magazine*, 1820. Library of the Arnold Arboretum.

*Inside back cover:* Yellow-throated vireo drawn and published by John James Audubon in *Birds of America*, vol. iv, 1844.

*Back cover:* Eastern red-back salamander *(Plethodon cinereus)* photographed by Brooks Mathewson.

COURTESY OF JANET HEYWOOD, MOUNT AUBURN CEMETERY

RICHARD B. PRIMACK

# Using Photographs to Show the Effects of Climate Change on Flowering Times

*Richard B. Primack, Abraham J. Miller-Rushing, Daniel Primack, and Sharda Mukunda*

There are many indications that global warming is affecting natural processes around the world. Glaciers are melting and many species are shifting their ranges poleward and up mountain slopes while others are becoming extinct. Changes in the timing of phenological events like the flowering of plants and the arrival of migratory birds are among the most sensitive indicators of global warming's effect on biological systems. In England, plants now flower up to a month earlier than they did fifty years ago. Across Europe, leaves emerge an average of six days earlier than they did thirty years ago. In Massachusetts, we have observed earlier flowering, earlier bird migrations, and earlier frog reproduction in recent warmer years.

Clearly, current changes in plant phenology will have widespread impacts on critical ecosystem processes such as carbon dioxide storage in plants, interactions between land and atmosphere, and relationships among species. In the Netherlands, for example, dramatic declines in some populations of pied flycatchers *(Ficedula hypoleuca)* have been attributed to changes in the time-sensitive relationships between oak tree leaf-out, caterpillar emergence, and bird breeding times: earlier leaf-out, linked to warmer temperatures, causes the caterpillars to finish their lifecycle earlier, thereby depriving later-arriving birds of the caterpillars required to feed their nestlings.

The fundamental questions being asked by scientists are: How is the timing of phenological events changing? And how will continued climate change affect this timing in the future? Most studies documenting the impact of climate change on phenological events have relied on long-term written records. Although many such records have been found and analyzed in Europe, they are too rare in the United States and elsewhere to help answer these questions. To expand our information base to more species and more geographic locations, scientists must therefore seek out reliable data from other kinds of records.

In an earlier *Arnoldia* (vol. 63, no. 4), we described how herbarium specimens collected over many years could be used with a single baseline season of field observations to provide data about changes in plant flowering times. Since then, we have discovered that like herbarium specimens, dated photographs of plants in flower can also inform us about those changes. These photographs are far more common than herbarium specimens or written records: collections can be found in many museums, libraries, universities, and private holdings. Scientists in other fields have used photographic records to document changes in soil and vegetation and to calculate the rate of glacier retreat. Recently, Tim Sparks and colleagues used dated photographs to document changes in plant development in response to weather conditions in particular years.

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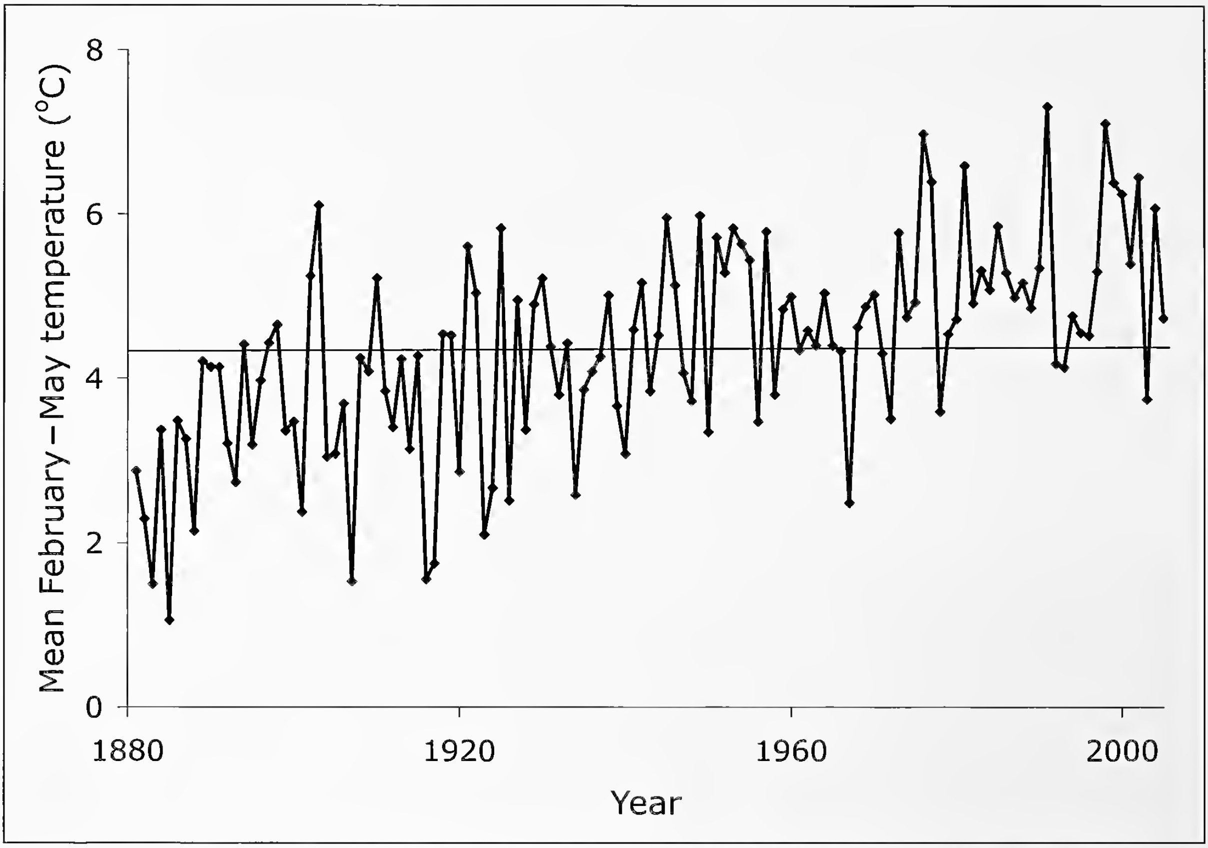
*The photos (facing page top and bottom) show leaf-out at the Lowell, Massachusetts, Cemetery. Leaves are conspicuously missing on Memorial Day in this 1868 photograph by an unknown photographer.*

*In the bottom photo, taken on Memorial Day, 2005, at least two of the large, bare trees seen in the 1868 photo are alive and fully leafed out. They appear directly above the two large plinths at the far left and far right. Mean February-through-May temperature in 1868 was 35 degrees F (1.9 degrees C), whereas in 2005 it was 40 degrees F (4.7 degrees C).*




*Mean temperatures in February, March, April, and May from 1881 to 2004 as recorded at Blue Hill Meteorological Observatory in Milton, Massachusetts. The horizontal line represents the long-term mean February–May temperature, 40 degrees Fahrenheit (4.4 degrees C).*

To test the value of photographs in our own phenological research, we examined two collections of dated photographs of flowering plants and a single, very unusual photograph of trees taken at the Lowell, Massachusetts, Cemetery.

**The Test: Methodology**

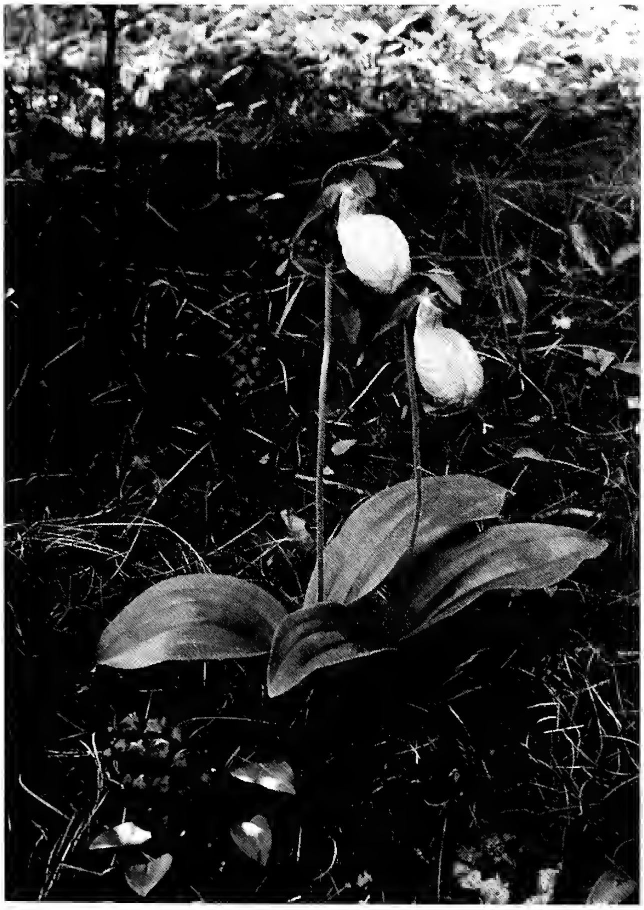
Our first step was to obtain temperature data from Blue Hill Meteorological Observatory in Milton, Massachusetts. The Blue Hill Observatory, located approximately five miles (8 km) south of the Arnold Arboretum and twenty miles (33 km) southeast of Concord, Massachusetts, has one of the longest continuous records of weather observations in the United States. These records allowed us to correlate temperatures with plant flowering times. From 1881 to 2004, mean February–May temperatures at the site warmed 4.5 degrees F (2.5 degrees C)—an increase in metropolitan Boston that is nearly as great as those predicted for western Massachusetts and beyond over the next fifty to one hundred years. About three-quarters of the increase at Blue Hill has been attributed to the urban heat island effect, that is, the warming associated with more buildings, streets, parking lots, and other human modifications. Urban areas, being in the vanguard of climate change, can therefore provide useful information about the ecological changes that will occur elsewhere, though somewhat later, as a result of global warming.

Our photographic data came from two collections of photographs. The first consisted of 251 dated images of 48 species of cultivated woody plants in flower at the Arnold Arboretum between 1904 and 2004. They had been taken by staff photographers as well as by other staff members and amateur photographers. In general, the individual plants shown in the photographs were not recorded, but the species were either recorded or clearly identifiable.

We examined the photographs taken at the Arnold Arboretum first, assuming that on average the photographs represented the mean flowering time of a species in a particular year. (We had previously confirmed a similar assumption during our study of herbarium specimens.) For each photograph, we calculated how much earlier or later a plant had flowered in the year it was photographed than it did in the benchmark year of 2003, when we observed the flowering times on the grounds. We then used statistical techniques to estimate the rate at which flowering dates changed over time and to relate that change to mean temperatures from February through May. We validated the magnitude of these changes by comparing them to the ones revealed by our herbarium-based study.

The second collection contained 34 dated photographs of 17 species of wild plants in flower in Concord, Massachusetts. Most were images of wildflowers, with a few of trees and shrubs as well. These photographs, spanning the years from 1900 to 1921, were taken by the landscape photographer Herbert Wendell Gleason, who was focusing on plants and places mentioned in the journals of Henry David Thoreau.

To demonstrate the general usefulness of the approach, in 2005 we analyzed the collection of flowering wild plants in Concord. By comparing the dates of the photographs to the mean

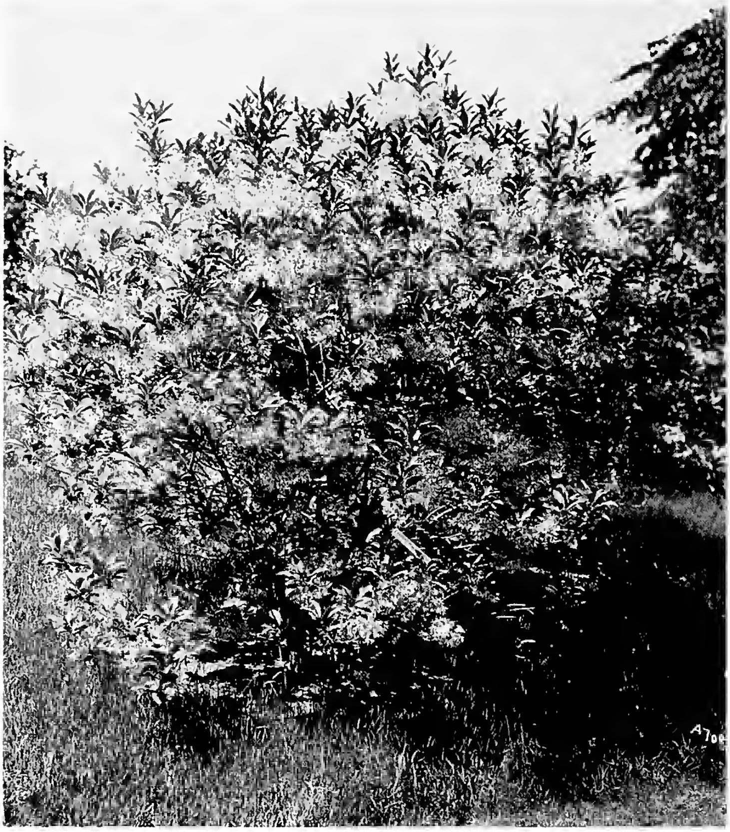


H. W. GLEASON. COURTESY OF THE CONCORD FREE LIBRARY

A. J. MILLER-RUSHING

*Wild specimens of pink lady's slipper (Cypripedium acaule) in Concord, Massachusetts, flowered six weeks later in 1917, on June 22, than in 2005, when they were in flower on May 17. Mean February–May temperature in 1917 was 35 degrees F (1.8 degrees C) and in 2005, 40 degrees F (4.7 degrees C).*

E. H. WILSON, ARCHIVES OF THE ARNOLD ARBORETUM



ROBERT G. MAYER

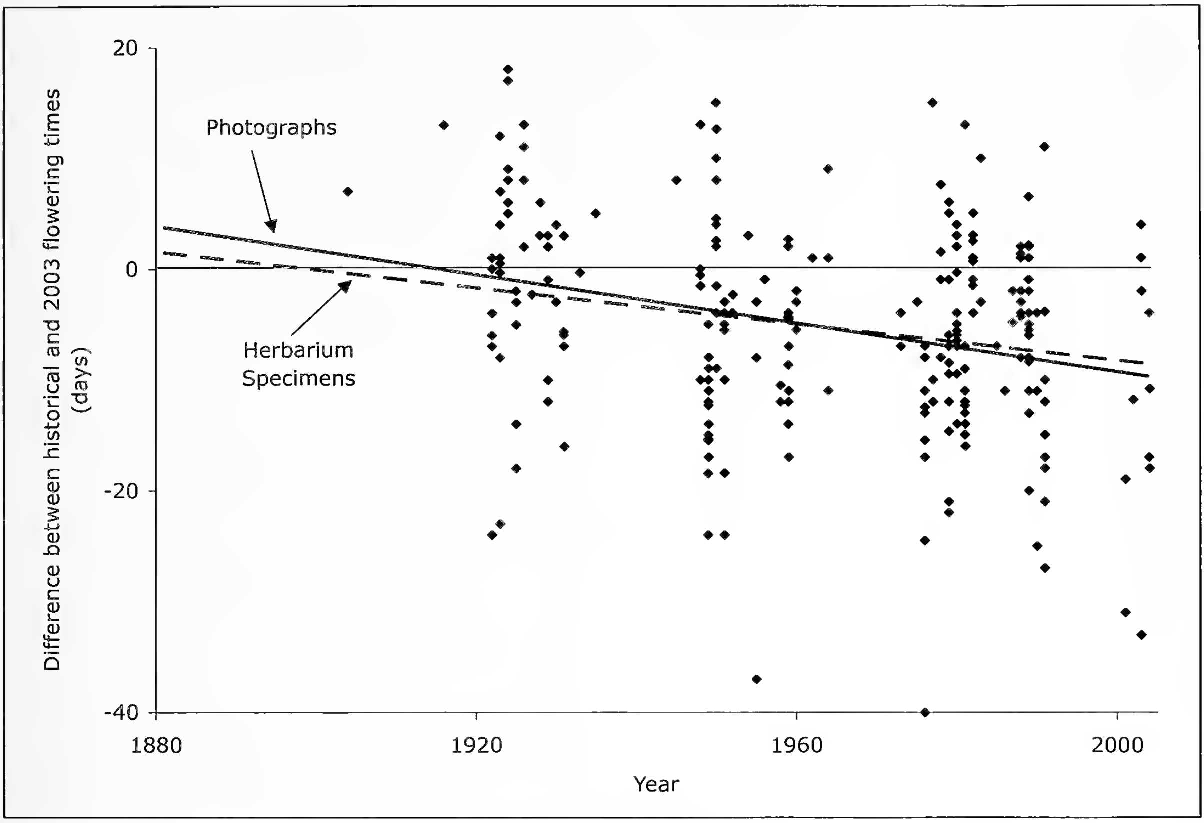
*Another representative comparison of historical and recent photographs is this pair of native fringetrees* (Chionanthus virginicus) *photographed at the Arnold Arboretum on June 20, 1926, and again in 2003, on May 7, when they flowered seven weeks earlier.*

plant flowering times of the same species that we found in our Concord field observations, we were able to calculate how much earlier or later a plant species had flowered in the year of the photograph than it did in the benchmark year of 2005. Again, we used statistical techniques to derive an average rate of change for all the photographed species in relation to mean temperatures from February through May. In this case, we validated our results by comparing them to trends shown by 13 of the same species in observations made by the botanist Alfred Hosmer in Concord each year from 1888 to 1902.

**Findings**

Our study of the photographs from the Arnold Arboretum indicated that plants are flowering about eleven days earlier on average than they were a century ago. The rate of change was 3.9 days for each increase of one degree Centigrade (.5556 degree F) in mean February–May temperatures—in other words, plants were flowering earlier because the temperatures in the months before flowering were getting warmer over time. On average, mean February–May temperatures at Blue Hill Observatory warmed 2.1 degrees C (just over one degree F) from 1904 to 2004. In the particularly cold springs of 1916, 1923, 1924, and 1926 (mean February–May temperatures less than 37 degrees F [3 degrees C]), plants flowered nine days later than average. In the particularly warm springs of 1976, 1977, 1981, 1991, 2002, and 2004 (mean February–May temperatures greater than 43 degrees F [6.0 degrees C]), they flowered two days earlier. This rate closely matched the response to temperature change that we had found in our previous study, using herbarium specimens and the living plants at the Arnold Arboretum.

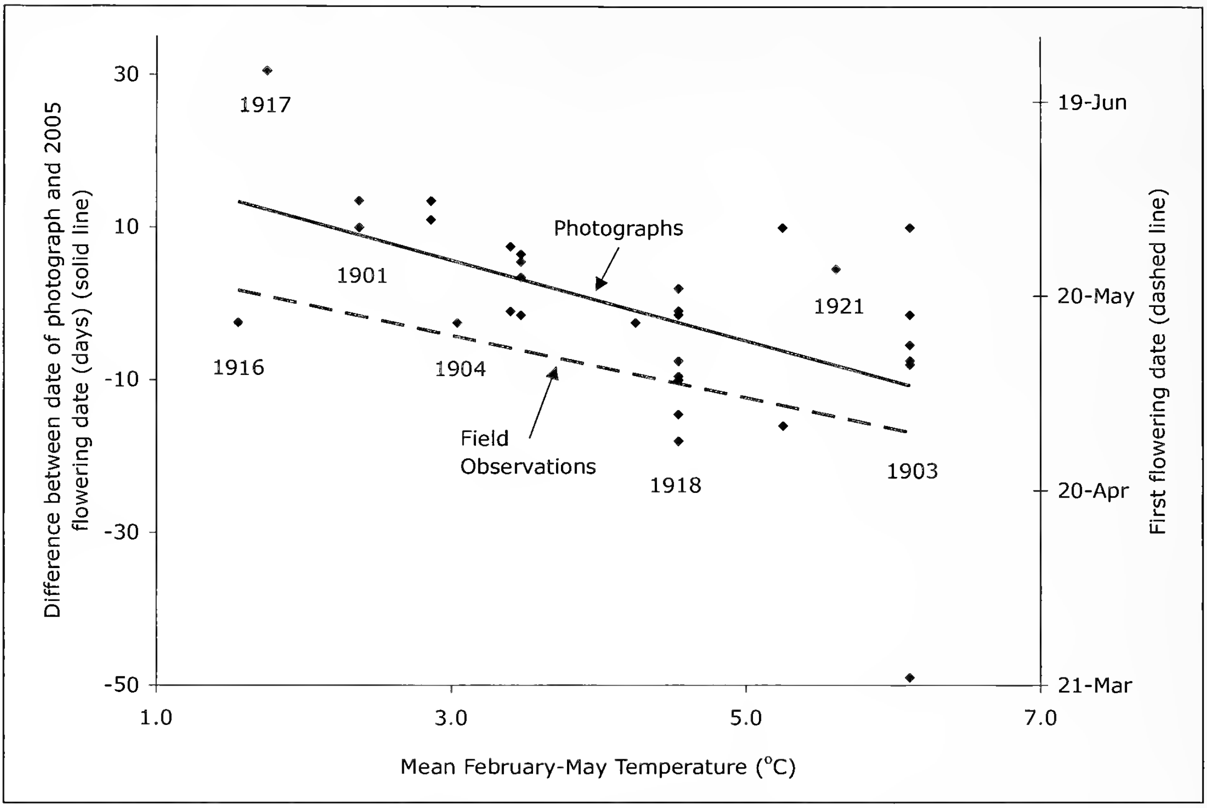
These findings were confirmed by the study of wild species in Concord. Flowering times as recorded in the Concord photographs were the same in 1921 as




*Changes in flowering times of woody plants at the Arnold Arboretum of Harvard University in Boston for the period 1904–2004. Each point represents the difference between the date a historical photograph showed a specimen in flower and the date that the same species was in flower in 2003 (historical date–2003 date). Negative values indicate historical flowering times that were earlier than flowering times in 2003. The line represents the best fit to the data. For comparison, the dashed line represents the same relationship using herbarium specimens but without individual points being shown. It is readily apparent that both dated photographs and herbarium specimens indicate that plants are flowering earlier during this hundred-year period.*

they had been in 1900; this was to be expected since temperatures at Blue Hill Observatory did not on average increase between those years. However, during these years the photographic record showed plants flowering 5.3 days earlier for each single degree Centigrade increase in spring temperatures. In warm years, such as 1903, plants flowered earlier than in cool years, such as 1916. In the particularly cold springs of 1901, 1916, 1917, and 1920 (mean February–May temperatures less than 37 degrees F [3.0 degrees C]), plants flowered eight days later than average. In the particularly warm spring of 1903 (mean February–May temperature more than 43 degrees F [6.0 degrees C]), they flowered eight days earlier.

We verified these findings by comparing them to the evidence in a set of unpublished observations of flowering times in Concord made by Alfred Hosmer from 1888 to 1902. Hosmer apparently carried out these observations as a continuation of similar observations begun by Thoreau in the 1850s. His observations indicated that the same species flowered 4.8 days earlier for each degree Centigrade warming. The results from the two sets of photographs and from Hosmer's observations are statistically indistinguishable. The results also reflect the disparity in dates: Hosmer recorded first flowering dates, whereas Gleason photographed plants on their peak flowering dates. Hosmer's observations are therefore




*Changes in flowering times in response to changes in mean spring (February–May) temperatures for wild plants in Concord, Massachusetts, for the period 1900–1921. Each point represents the difference between the date a historical photograph showed a specimen in flower and the date that same species was in flower in 2005 (historical date–2005 date). Negative values indicate historical flowering times that were earlier than flowering times in 2005. Solid line represents the best fit to the data.*

*The dashed line represents independent data from field observations of first flowering dates collected by A. W. Hosmer between 1888 and 1902 but without the individual data points. The slopes of the lines are indistinguishable, indicating that they both show the same relationship between climate and flowering times; plants flower earlier in warm years than in cold years. The line using photographs is higher in the graphs because photographs are usually taken when plants are in full flower, which occurs several days after plants are in first flower, which is what Hosmer was recording.*

dated several days earlier than Gleason's photographs.

We also noted an example of how photographs can be used to document changes in the timing of leaf-out as well as flowering. The striking photograph at the top of page 2 was taken in the Lowell Cemetery in Lowell, Massachusetts, on Memorial Day, 30 May 1868. In the photo, the trees have not yet leafed out, despite the late date, and people are wearing heavy clothing. The photograph below it, taken on the same date in 2005 at the same location, shows the trees fully leafed out. At least two of the large, leafless trees in the 1868 photo are still alive and had fully leafed out in 2005. An exceptionally cold spring probably caused the delayed leaf-out in 1868; the mean temperature from February to May of that year was 4 degrees F (2.2 degrees C) lower than the average over the past 150 years and nearly 5 degrees F (2.7 degrees C) colder than February to May 2005.

**The Advantages and Problems of Using Photographs**

Our study showed that photographs provide reliable estimates of the date of peak flowering and can be used to calculate rates of change in flowering times that are comparable to the rates determined from independently collected data sets, including direct field observations. Moreover, these results hold true for both wild and cultivated plants.

Because photographs are far more abundant than are scientists' field observations, they can dramatically increase the amount of reliable data available for studying the times not only of flowering but also of leaf-out, bird migration, the emergence in spring of hibernating animals, and other seasonal events. And even though the photographs may have been taken over several days or even several weeks, the flowering dates they reveal can be accurately correlated with temperatures as long as enough photographs are used and if analysis of the photographs is combined with studies in the field.

As noted, the analysis of a photograph collection may need to take account of the tendency of some people to photograph plants as soon as they start to flower while others photograph them when more flowers are open. These limitations did not substantially affect the results of our study, as demonstrated by the validation from independently collected data.

Researchers should also be aware of a problem inherent in using photographs of multiple species to calculate a single rate of change. In our study, we assumed for the sake of simplicity that the flowering times of all the plants we observed changed at similar rates in response to warming, even though we knew this is not the case. These differences added variation to our results, making them less reliable than if we had examined changes in the flowering times of individual species. Nevertheless, the indications are that on average, plants are flowering earlier now than in the past because of warmer temperatures.

Even though these alternative sources of information—herbarium specimens and photographs—can be used to show phenological responses to climate change, botanical gardens remain a particularly valuable source of long-term data. We hope that regular observations of key events such as leaf bud burst, flowering, fruiting, and leaf senescence will be recorded. At the same time, however, analysis of additional photograph collections could dramatically increase our understanding of how climate change affects a wide range of species at many previously unexamined localities. If you know of any such collections, please get in touch with us.

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# *Magnolia* x *thompsoniana* 'Cairn Croft'

*Peter Del Tredici*

*Magnolia* x *thompsoniana* 'Cairn Croft' is the reincarnation of a very old hybrid. Indeed, the sweetly scented *M.* x *thompsoniana* was the first hybrid magnolia to be described in the Western horticultural literature, in 1820, beating *M.* x *soulangeana* into press by seven years. The original *M.* x *thompsoniana* selection was discovered in 1808 by Archibald Thomson among a flat of normal seedlings of the sweetbay, *M. virginiana,* which had germinated at his Mile End nursery in London, most likely from seed he collected from a plant growing in England. John Sims, writing in *Curtis' Botanical Magazine* twelve years later, described the plant as a robust, large-flowered variety of the sweetbay, to which he gave the name *M. glauca* var. *major,* and published a full-color illustration of its leaves and blossom (see inside front cover). In 1838, J. C. Loudon, in his monumental *Arboretum et Fructicetum Britannicum,* followed Sims' lead in classifying the plant as a variety of sweetbay magnolia "enlarged in all its parts," but changed its specific name to *thompsoniana.* He speculated that the plant might be a hybrid between *M. virginiana* and *M. tripetala* but left the question open. Thirty-eight years later a Dutch botanist, C. de Vos, followed up on Loudon's suggestion and formally reclassified the plant as the hybrid between *M. virginiana* and *M. tripetala,* retaining *M.* x *thompsoniana* as the name.

Despite its large, deliciously fragrant flowers, *Magnolia* x *thompsoniana* has achieved only modest popularity in European gardens since its introduction. This is partly because of its ungainly habit of growth, which makes it difficult to use in small or medium-sized gardens, and partly because it does not seem to perform all that well under typical growing conditions. In the United States, the plant is less widely grown than it is in Europe, mainly because of its lack of winter hardiness. Indeed, the Arnold Arboretum's first director, C. S. Sargent, writing in *Garden and Forest* in 1888, noted that "it is a curious fact that it [*M.* x *thompsoniana*] is much less hardy and much less vigorous than either of its supposed parents, suffering here always, unless carefully protected in winter, and rarely rising above the size of a small bush."

PHOTOS BY THE AUTHOR

*The fully opened flower of* Magnolia *x* thompsoniana *'Cairn Croft', roughly six inches across.*

In 1960, J. C. McDaniel, the well-known horticulturist and magnolia breeder at the University of Illinois, attempted to remedy the hardiness problem by recreating the hybrid using *Magnolia virginiana* parents that were hardier than the one that the original plant came from. His work culminated in 1966 with the introduction of 'Urbana', which had the greatest ornamental potential of all of the seedlings he raised and was hardy to minus-15 degrees F. Like its predecessor, however, 'Urbana' has never achieved anything other than limited distribution, and most nursery people who have grown the plant consider it a poor performer. In 2004 a third *M.* x *thompsoniana* cultivar, 'Olmenhof', was found growing in a public park in Belgium and was named and registered by Koen Camelbeke, Jef Van Meulder, and Wim Peeters. It is reported to have a better growth habit and earlier and larger flowers than the 1808 selection (Boland, 2005).

*The flowers of* Magnolia x thompsoniana *'Cairn Croft' (left) next to those of a "sibling"* M. virginiana *(right).*

**'Cairn Croft'**

*Magnolia* x *thompsoniana* 'Cairn Croft' is the fourth reincarnation of this unusual hybrid. The plant was discovered on a private estate in Westwood, Massachusetts, about ten miles southwest of the Arboretum. It was one of a group of about a dozen specimens of sweetbay magnolia that had been purchased around 1989 from a nursery identified only as "southern." On June 22, 1998, the gardener for the estate, Kevin Doyle, stopped by the Arboretum's Dana Greenhouses with some cuttings (with flowers) of one of the seedlings that was strikingly different from its supposed siblings. One quick look was all it took to recognize the plant as a *M.* x *thompsoniana* hybrid, which I knew from the literature but had never seen.

Research in the library confirmed my initial diagnosis, and I immediately set about propagating the plant from the cuttings that Kevin had brought in by dipping the lower portion of their stems in an aqueous solution of K-IBA (5,000 parts per million) for five seconds and then placing them under fog and intermittent mist. Some six out of sixty-three cuttings were well rooted by the following April, two of which are now growing on the Arboretum's grounds (AA #174-98). The mother plant remains alive and well in its original Westwood home.

'Cairn Croft'—the name Kevin selected—produces flowers with a sweet, lemony fragrance that are two to three times larger than those of the *Magnolia virginiana* seedlings that came in the same 1989 shipment. The plant is fully hardy in USDA zone 6 (minus-10 degrees F), where it has been growing without winter protection or damage since 1989. It is a fully deciduous plant, with pale green winter twigs and buds, not unlike those of *M. virginiana.* It produces relatively large, elliptical leaves, six to eight inches (16–21 cm) long by two to three-and-a-third inches (5–8.5 cm) wide with slightly undulating margins; they are a bright, shining green above and, due to a covering of fine hairs, silvery-white underneath. Like the original clone of *M.* x *thompsoniana,* the pith of its young twigs is incompletely septate while that of *M. virginiana* is completely septate and that of *M. tripetala* is continuous (Spongberg, 1976).

'Cairn Croft' produces flowers from mid June through July that stand erect on the ends of the branchlets on relatively stout, glaucous pedicels, not unlike those of its *Magnolia tripetala* parent. Typically the flowers have eleven tepals: the three outer ones are greenish-white in color, spatulate in shape, and reflex back as the flower opens. The eight inner tepals are thicker than the outer tepals, creamy white in color and oblong-ovate in shape. They are three to three-and-a-quarter-inch (7–9 cm) long and

*The original plant of 'Cairn Croft' with its discoverer, Kevin Doyle, in 2002. It was fifteen feet tall, with a spread of seventeen feet.*

less than an inch by an inch-and-a-third (2.2–3.5 cm) wide, and fade as they age to a "rusty yellow," to use John Sims' phrase. The flowers of 'Cairn Croft' are intermediate in size between its two parents, being roughly twice the size of *M. virginiana* and three-quarters the size of *M. tripetala*. Fortunately, in fragrance all of the *M.* x *thompsoniana* selections favor their sweetbay mothers rather than their "ill-scented" fathers.

The original 'Cairn Croft' is a vigorous grower, having reached a height of fifteen feet (4.6 m) with a spread of seventeen feet (5.2 m) by 2002, in the absence of any pruning. Despite its proximity to flowering specimens of *Magnolia virginiana*, 'Cairn Croft' does not set viable seed. No doubt it suffers from same case of pollen sterility that was reported for the original *M.* x *thompsoniana* clone by Frank Santamour in 1966.

It is my hope that in 'Cairn Croft' we at last have a "home-grown" *Magnolia* x *thompsoniana* selection that can stand up to the rigors of the North American climate. For now I am assuming that 'Cairn Croft' originated from open-pollinated seed collected from a plant of *M. virginiana* and was the only hybrid among a group of seedlings that was true to its maternal parent. How accurate this assumption is awaits the results of DNA-testing, which is planned for later this year. Scions of 'Cairn Croft' were distributed to Pat McCracken (McCracken's Nursery) and Dick Jaynes (Broken Arrow Nursery) in March of last year and, with luck, should be commercially available within a year or two.

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# Plant Prosthetics: Artifice in Support of Nature

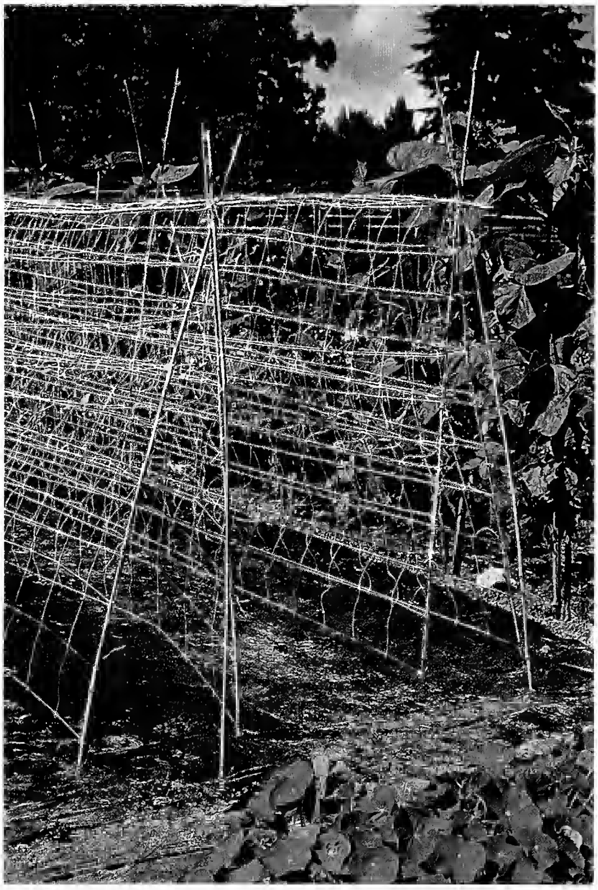
*Marc Treib*

In the wild, trees seem to do rather well all by themselves. That is, some of them do rather well; you know, Darwin and all that. But in constructed settings, urban or suburban, they seem to need some help just to get by. So we irrigate them, protect them from getting gnawed, buffer them from being bumped, spray them against insects and rot—and we prop them up. The debate still rages whether staking is a good thing (aiding the tree in its struggles to withstand the attacks of wind and vandals during their adolescence) or a bad thing (creating a dependence on the artificial support that hampers the development of the tree's own natural systems). Whichever side of the argument you land on, the fact remains that staking accompanies the planting of almost all trees. And like it or not—except perhaps within the realms of those sufficiently wealthy to purchase large and mature specimens—for many years the visual impact of the stake will dominate that of the tree. The French landscape architect Alexandre Chemetoff understood this and used it to aesthetic advantage in his hillside plantations for a motorway intersection near Toulouse. Rather than deny their presence, Chemetoff painted the stakes a bright blue; paired with the colored polyethylene used to retard erosion and weeds, the strong diagonals of the staking arranged on a grid became the principal features of the design [figure 1].

Supports may be delicate and almost diaphanous or stout and sturdy. The schools of staking vary from the single—whether vertical or diagonal—the paired, and the tripod and quadrupod. And how the supports connect with each other and with the tree varies from a manner that accepts sway and movement as a part of growth and one that ranks stolid rigidity above all else. The selection of form appears to depend on the budget, the size of the tree, and the number and degree of hazardous conditions [figure 2].

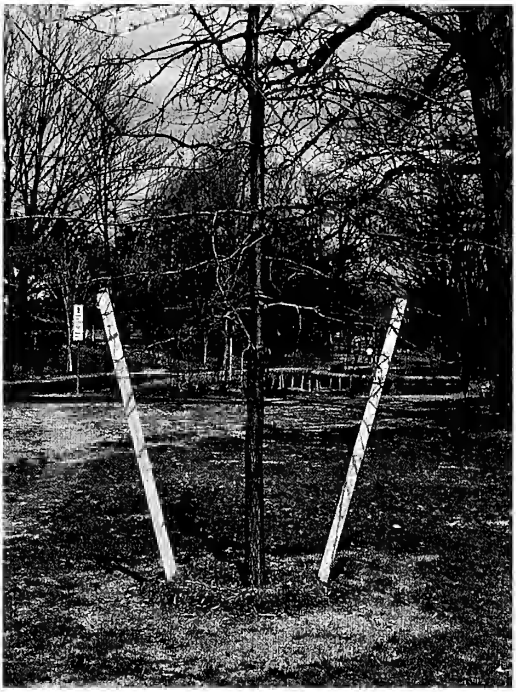
ALEXANDRE CHEMETOFF

*1: Single stake, diagonal, blue paint. Roca de Est Junction, Toulouse, France, circa 1989. Design by Alexandre Chemetoff.*



ALL PHOTOS BY THE AUTHOR EXCEPT WHERE INDICATED OTHERWISE

*2: Vine supports. Gravetye Manor, Essex, England, 2005.*



*3–6: clockwise from upper left: Two stakes, wood with rope. Viken, Sweden, 2002; Two stakes, wood, sturdy. Tokyo, Japan, 1988; Two stakes, wood, multiples. Museu Serralves, Porto, Portugal, 2003; Two stakes, diagonal. Boston, Massachusetts, 1999.*

The single stake represents an optimistic gesture; one encounters many a fallen, broken, or missing stake that accompanies—or accompanied—many a fallen, broken, or missing tree. Dual staking, with rubber-covered leads, bolsters the trunk just as two friends support a drunkard [figures 3–6]. It is strong along one axis, but weak when faced with perpendicular forces. Certainly it is no match for an errant automobile or the nonchalance of an inattentive garbage-truck driver. Schools of application range from the sturdy vertical to the angled and more tensile.

The tripod configuration starts getting serious in locations like Tokyo and other urban areas where the edge between sidewalk and road is barely apparent [figures 7–9]. These tend to be constructed of stout wooden poles, wired

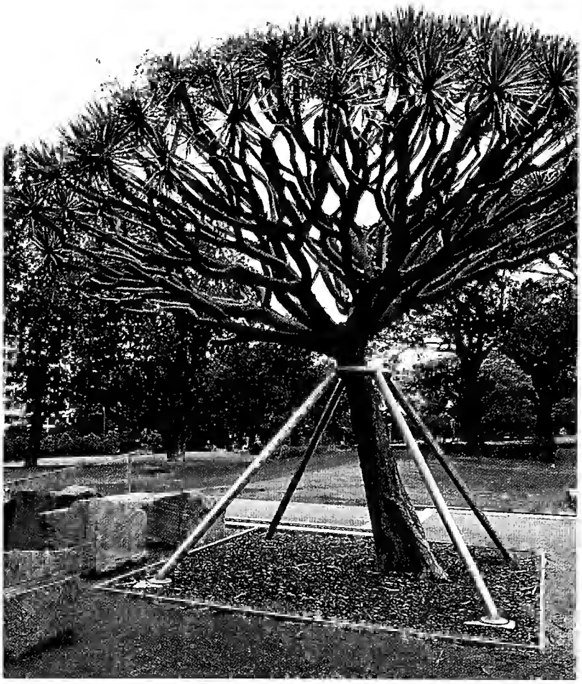


*7–9: Tripod, large scale, wood. Mito, Japan, 2006; Tripod, small scale, re-bar. Awaji Island, Japan, 2005; Tripod, superscale, metal: staking as gateway. Summer Palace, Beijing, China, 2005.*

or nailed together, with no pretense of naturalness. But they are also made of metal, some of them so tall that they double as spatial markers and entryways. Like the crutch and the knee-brace these are prosthetic devices that use the artificial to improve the natural. The quadruped is the heavy duty, industrial-strength version of the tripod, exceeded in muscle and effect only, perhaps, by devices of stainless steel that give no quarter to any oncoming vehicle [figure 10]. Darwin and all that, you understand.

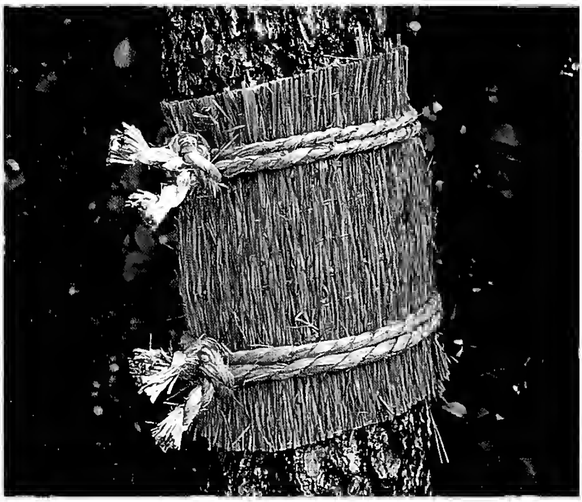
Arboreal prosthetics address a variety of needs: to support the tree during its early years, often to counter problems incurred by the demand for quick growth; as compensation for a structural weakness, perhaps caused by mannered horticultural practices; in periods of decline; and as life-support in advanced age, countering senility in the twilight years. Staking is most commonly practiced during early adolescence, however, suggesting the parents' handholding of the child, or their protecting it from cold, hunger, and the elements. Props also compensate for weakness due to infirmity, for example re-erecting a tree fallen in a storm or one undermined by insects or erosion.

Then there are the prosthetics necessary to certain horticultural practices—Japan is the great example here. Cultural norms coerce the Japanese gardener and arborist to treat the vertical mass of the tree as a series of masses horizontally defined. To accomplish this look, branches are trained and pruned, needles thinned and shaped. The resulting sub-masses of the trees are exposed and inherently frail, a limitation multiplied enormously when applied to the



*10: Quadrapod, steel. Sydney, Australia, 2006.*

*11: Pine tree tent supports, caps. Hama Rikyu, Tokyo, Japan, 1988.*



*12: Tree wrapping, straw. Koraku-en, Okayama, Japan, 2005.*

*13: Cycad wrapping, straw. Tokyo, Japan, 1971.*

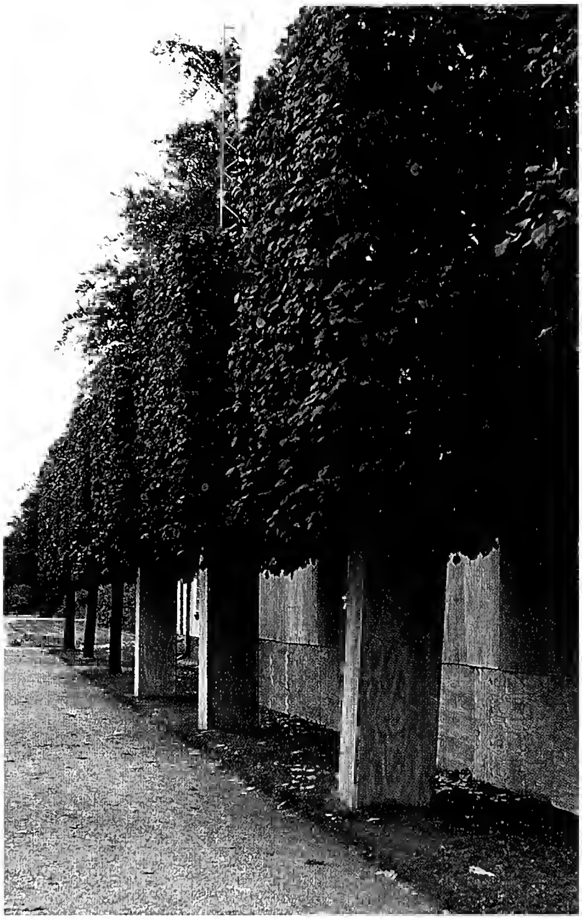
*14: Cycad wrapping, straw, base. Hama Rikyu, Tokyo, Japan, 1988.*

pine family. Unlike the denuded branches of deciduous trees, in winter the clumps of evergreen pine needles catch and clutch volumes of snow, and their accumulated weight threatens to snap the branches from their trunks. To thwart this threat elaborate laceworks of (traditionally) rice-straw ropes support the branches from a central pole or trunk [figure 11]. The resulting structure is visually splendid, a carousel-like tent whose tawny hue contrasts eloquently with the deep green of the pine needles.

Coats made of rice-straw matting complete the winter garments worn by Japanese trees [figure 12]. Around the base of the trunks the mats serve double duty: protecting the trunk from bumps and scrapes and—it is claimed by Japanese gardeners—tempting boring insects with a more easily penetrated target. At season's end, these are removed and tossed away, vermin included. Matting also protects the tender tops of cycads whose fronds are cut back each winter to protect them from frost [figures 13, 14]. The logic of these multi-layered constructions is verified by their parallels with the structures constructed by termites in humid

*15: Trunk protection, bamboo. Koyasan, Japan, 2005.*

*17: Canopy protection, plastic mesh. Tokyo, Japan, 1988.*



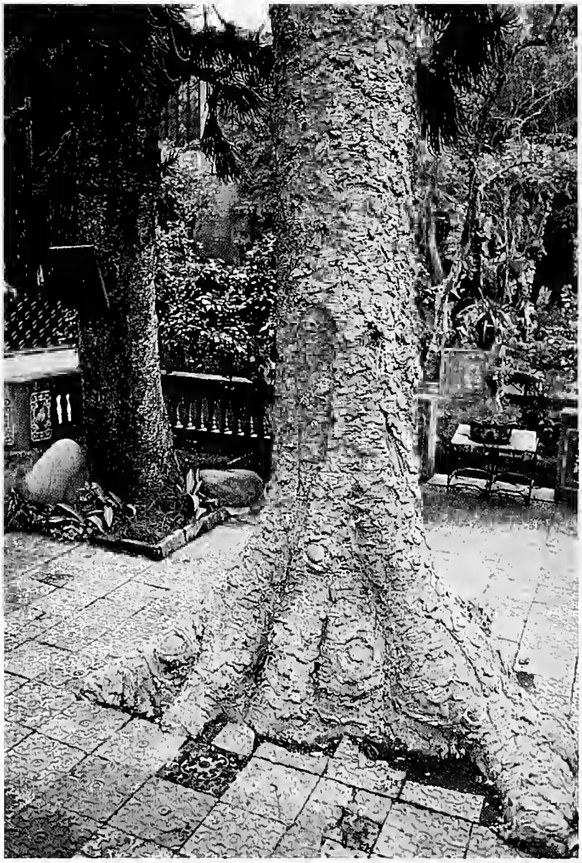
*16: Trunk protection, plywood. Fredensborgslothave [Fredensborg Castle Garden], Denmark, 2003.*

climates with heavy rainfall: the stacked roofs continually eject the water and prevent it from running down the full length of the mat and into the tree, which may cause rot.

Against heavy vehicular or pedestrian traffic or during construction, existing vegetation requires protection for it to survive. Prosthetic appliances protect the trunk, the canopy, or both. Plywood boxes guard the trunks against unintended thuds from forklifts and bulldozers, while pervious sheets of plastic mesh defend leaves and branches from the knocks of cranes or careless workmen [figures 15–17]. Each produces its own aesthetic, an aesthetic at times verging on the threshold of art, whether the minimal "specific objects" of Donald Judd or the wrapped landscapes of Christo and Jeanne-Claude.

Mature trees in their sunset years often require supports in order to endure, like the pensioner requiring the aid of a walker or a cane. Perhaps the trunk has been attacked by borers or fungus, perhaps key branches have been lost to lightning or to encroaching development, perhaps the depleted circulation system no longer keeps the trunk and branches sufficiently turgid. Support is required. And in cultures that venerate longevity—China and Japan, for example—the tree is treated as an honorable member of the family. In these situations one often encounters the wooden or metal post. But one also finds the cultural urge to disguise the prosthetic effort, as if the tree would be embarrassed by such reinforcement. Or is it an attempt to make the unnatural appear natural? In any event, in these situations one may encounter a field of posts, each directly reacting to the drooping force of gravity, in some ways a ghost duplicating the field of tree trunks themselves.

*18: Tree support, concrete. Ming Tombs, Dingling, China, 2005.*



*19: Tree support,* Araucaria cunninghamia, *concrete. Yu Yin Shan Fang garden, Panyu, Guangzhou, China, 2005.*

Wrapped up in this nursing of weakness, then, is the relation of the natural to the artificial. Most prosthetics make no bones about being constructions. In material and in form they stand apart, functionalist in approach and vocabulary. They stand to serve, not to blend, and there is little question as to which is the tree and which is the structural addition. In China, however, detecting which is which may be difficult. For some reason, posts of concrete are modeled or cast to emulate the pine trunks they support [figure 18]. So realistically are they modeled that after years in place, colored by layers of dirt and discoloration, they look exactly the same as the real trunks. There develops a second forest of concrete trunks that shadows the living forest of brown bark and green needles: a forest of the artisans' efforts rather nature's. The results can be almost unnerving. In the Yu Yin Shan Fang garden in Panyu, near Guangzhou, the post supporting an aged *Araucaria cunninghamia* was so realistic that it was easy to confuse the living with the made [figure 19]. Perhaps this is the ultimate prosthetic effect—a creation so authentic in its guise that it becomes indistinguishable from its host. More than prosthetic, construction is akin to what plastic surgery is to the human face or body—an artificial creation that appears to be natural and real. Real, without a doubt; natural, not really.

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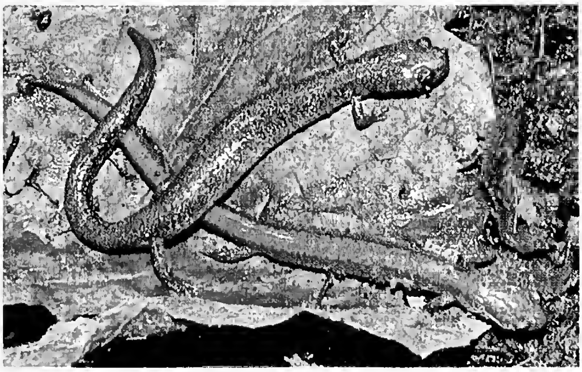
# Salamanders in a Changing Environment on Hemlock Hill

*Brooks Mathewson*

One way ecologists measure changes in the environment is by monitoring animal populations over long periods. Over the past five years, for example, Robert G. Mayer has documented 126 bird species at the Arnold Arboretum, including 46 confirmed breeders and another five probable breeders. Using data from several earlier studies, Mayer was able to document the absence of at least 27 species that had once bred successfully at the Arboretum over the past century and the occurrence of seven new breeding species. In 2004 researchers at the Harvard Forest extended their studies of salamander populations in New England to the Arboretum's Hemlock Hill. No studies of salamanders at the Arboretum existed, but we have now compiled baseline data on species composition and abundance for use in future monitoring of this ecologically important group.



PHOTOS BY THE AUTHOR

*Red-back salamanders occur most commonly in two color morphs, the leadback morph and the striped morph. The percentage of leadback morphs in red-back salamander populations increases with warmer temperatures.*

**Salamanders of Massachusetts**

Of the 4,600 known species of amphibians in the world, approximately 400 are salamanders, of which 127 are found in the United States and Canada. Salamanders are morphologically distinct from the other two amphibian orders, Anura (frogs and toads) and Gymnophiona (caecilians), in that they possess tails. They are also characterized by four toes on their front feet and five on the back. Like other amphibians they are ectotherms (cold-blooded) and have no epidermal structures, such as scales, feathers, or hair.

Ten salamander species from three families are found naturally in Massachusetts. (In addition, one species from a fourth family, the mudpuppy *(Necturus maculosus)*, was introduced into the Connecticut River, probably late in the nineteenth century.) Perhaps the most familiar salamander family is the mole salamanders, Ambystomatidae. Four representatives of this family are found in the state: the Jefferson salamander *(Ambystoma jeffersonianum)*, the blue-spotted salamander *(A. laterale)*, the marbled salamander *(A. opacum)*, and the spotted salamander *(A. maculatum)*. They spend the majority of their lives in underground burrows in upland woods surrounding the ephemeral vernal pools in which they breed. The largest and most common is the spotted salamander. Adults of this species measure between six and ten inches and are very distinctive in appearance, with two rows of bright yellow spots prominently displayed on their black backs. On the first warm rainy night of the year, when the temperature approaches roughly 50 degrees F (10 degrees C), these animals migrate up to half a mile from upland woods to vernal pools to breed in a dramatic event that has been dubbed "The Big Night" by naturalists and conservationists.

*During their terrestrial juvenile—or "red eft"—phase, eastern red-spotted newts are ten times more toxic than during their aquatic adult phase. They are often seen foraging in forests adjacent to breeding ponds.*

Another commonly observed species in Massachusetts is the eastern red-spotted newt *(Notophthalmus viridescens)*, the state's lone representative of Salamandridae. While this species is aquatic both as larva and adult, it also has a terrestrial juvenile, or "red eft," phase that lasts from two to seven years. As a deterrent to potential predators, red efts are equipped with toxic chemicals in their skin similar to those produced by puffer fish. Consequently, on days that are wet enough to keep their skin moist, they are able to forage in the open without fear of predation—often in such abundance as to make hikers fear stepping on one by accident.

The fourth family of salamanders occurring in Massachusetts, the plethodontids, or lungless salamanders, are considered especially valuable indicators of environmental health, thanks to their position in the middle of the food web, their great abundance, and their relatively stable population size. Plethodontidae is the largest family of salamanders in the world, consisting of 240 species in 27 genera. The five representatives found in Massachusetts are the northern two-lined salamander *(Eurycea bislineata)*, the dusky salamander *(Desmognathus fuscus)*, the spring salamander *(Gyrinophilus porphyriticus)*, the four-toed salamander *(Hemidactylium punctatus)*, and the eastern red-backed salamander *(Plethodon cinereus)*.

The eastern red-backed salamander is the only one of these that is a fully terrestrial breeder. Since amphibian eggs do not have calcareous shells, they are vulnerable to desiccation; therefore, most species deposit their eggs in aquatic environments where they pass through a gill-bearing larval stage that is not present in other vertebrates. Red-backed salamanders are an exception to this rule, laying their eggs in moist locations under logs and rocks on the forest floor and completing the larval stage within the egg. Incubation of the eggs by the mother and sometimes the father over a six-week period helps prevent the gelatinous egg mass of three to fourteen eggs from drying out.

Since red-backs do not need to be near aquatic breeding habitats, they are far more ubiquitous than other salamander species. At Hubbard Brook Experimental Forest, a northern hardwood forest in the White Mountains of New Hampshire, red-back densities were estimated to be 0.25 individuals per square meter. In fact, the biomass of plethodontid salamanders at the Forest—of which red-backs contributed 95 percent—was found to be double the breeding bird biomass and equal to the biomass of all small mammals. Similar high densities have been found in other parts of its range.

Red-backs are small and slender, measuring only three to five inches in length and weighing about a gram—less than half a penny. Their legs are short relative to their body size, and they have 18 to 20 grooves along the side of the body. In most populations red-backs occur in two forms, a striped morph, with a red stripe on a black back and a darkly mottled stomach, and a lead-backed morph, which lacks the red stripe. In New England, where the striped is the more common morph, a 1977 study by Fred Lotter and N. J. Scott found that the frequency of lead-back color morphs was positively correlated with warmer climates. In contrast to red efts, which are often seen on the surface of the forest floor during the day, red-backs are rarely seen, spending most of their lives in the soil or under such cover objects as decaying logs on the forest floor and emerging only on warm, rainy nights in the summer.

**The Ecological Role of Salamanders**

Salamanders are an important link in the food web between small soil fauna on which they prey and the larger vertebrates that prey on them, such as American robin *(Turdus migratorius),* hermit thrush *(Hylocichla mustelina),* wild turkey *(Meleagris gallopavo),* and garter snakes *(Thamnophis sirtalis).* As ectotherms with low metabolic demands, salamanders convert newly ingested material into biomass very efficiently. In addition, salamanders have high protein content, making them attractive prey items.

The diet of the red-back salamander consists primarily of invertebrates that live in the soil—adult and larval beetles, adult and larval two-winged flies, mites, ants, centipedes, millipedes, snails, slugs, and spiders. Yearly consumption of these invertebrates by red-backs can exceed five times the total biomass of these organisms living at any one point in time. The soil invertebrates are important to the process of leaf decomposition since they fragment the leaves for the primary decomposers, bacteria and fungi. As leaf litter decomposes, an important greenhouse gas, $CO^2$, is emitted into the atmosphere. Consequently, a change in decomposition rates may lead to changes in the global carbon budget.

A study conducted by Richard Wyman in 1998 found that decomposition rates were between 11 and 17 percent lower in artificial enclosures installed in the field that contained salamanders versus enclosures without salamanders. Wyman also found, not surprisingly, a significant decrease in the numbers of invertebrates in the enclosures containing salamanders. He speculates that salamanders indirectly reduce decomposition rates by reducing the abundance of leaf litter fragmenters and, subsequently, the surface area of leaf litter available to bacteria and fungi.

*Red-backs are lungless and breathe through their skin, which must remain moist for efficient gas exchange. The required moisture appears as a film on the red-back's skin.*

In addition to being extremely abundant and positioned in the middle of the food web, plethodontid salamanders are good indicators of overall ecosystem health because populations do not fluctuate greatly from one year to the next. An extensive survey of time series data gleaned by monitoring a number of taxonomic groups found that annual counts of plethodontid salamanders varied less than counts of passerine birds, small mammals, and butterflies, as well as other amphibians. This population stability is thought to be partially explained by salamanders' site fidelity and the small size of their home territories.

Since plethodontid abundance does not fluctuate dramatically under normal conditions, when changes do occur they could provide valuable warnings of the impacts of global stresses caused by human activity. For example, acid rain resulting from nitrous oxide and sulphur dioxide being emitted into the atmosphere and reacting with water vapor to produce nitric and sulphuric acids can lower soil pH to levels that may prevent red-backed salamanders from occupying them. In Albany County, New York, eastern red-backed salamanders are far less abundant where the soil pH is below 3.7. In fourteen eastern hemlock-dominated forests in north-central Massachusetts, where the average soil pH was 3.7, red-back abundance was negatively correlated with soil pH. Warmer temperatures on the forest floor as a result of global climate change could also have a negative impact on red-back abundance. As mentioned above, plethodontid salamanders are lungless and breathe through their skin and the linings in their mouth. To respire efficiently they must remain moist. In fourteen hardwood stands in north-central Massachusetts, the most important predictor of red-back abundance is the temperature on the surface of the forest floor, with abundance decreasing as the temperature rises.

*As top-level predators of soil fauna, red-backs are believed to regulate biodiversity in the soil community by reducing the number of leaf litter fragmenters, chiefly adult and larval beetles and larval two-winged flies. By reducing their numbers the salamanders indirectly lower the rate of decomposition of the leaf litter on the forest floor.*

**Hemlock Hill in Transition**

The Arnold Arboretum provides important habitat for many wildlife species. It is a critical time to be conducting this study on Hemlock Hill as the area is undergoing significant changes. The hemlock woolly adelgid (*Adelges tsugae*, or HWA), an invasive insect pest that causes mortality within four to ten years of infestation, was discovered on Hemlock Hill in 1997. Native to Japan, HWA is believed to have been introduced into Virginia in the 1950s and since then has been spreading throughout eastern hemlock's range. Currently, fifty percent of eastern hemlock-dominated stands in Massachusetts are infested with HWA, and no failproof way has been found to treat the affected trees or eliminate the pest.

Eastern hemlock-dominated stands are structurally distinct in having dense canopies and little understory. Being shade tolerant, hemlocks retain their lower branches, creating a cool, dark microenvironment on the forest floor that provides habitat for many species of wildlife that require mature forests for their growth and/or reproduction. Among the migratory breeding birds found to be strongly associated with this forest type are black-throated green warblers *(Dendroica virens)*, blackburnian warblers *(D. fuscus)*, and solitary vireos *(Vireo solitarius)*; full-year residents include black-capped chickadees *(Parus atricapillus)* and red-breasted nuthatches *(Sitta canadensis)*. In addition, 23 of the 32 small mammal species and thirteen of the fourteen large mammalian carnivore species occurring in New England use this forest type, as do white-tailed deer *(Odocoileus virginianus)*, especially in winter when these

*Left to right, the black-throated green warbler, blackburnian warbler, and red-bellied nuthatch drawn and published by John James Audubon in* Birds of America, *vol. ii, 1841, and vol. iv, 1844.*

forests have less snow cover than hardwood stands. In my 2003–2004 study conducted at the Harvard Forest I found higher red-back salamander abundance in eastern hemlock-dominated stands than in hardwood stands. A follow-up study conducted throughout north-central Massachusetts found no difference in red-back abundance in the two forest types, but the populations in hemlock-dominated forests did contain a higher percentage of larger individuals than populations in hardwood stands.

The potential loss of eastern hemlock from this region provides an opportunity to study how the loss of a dominant tree species changes the forest ecosystem. Researchers at the Harvard Forest, who are conducting several studies to assess ecosystem changes and wildlife response to the loss of eastern hemlock are interested in further exploring some of their results, which suggested that pre-logging of hemlock stands to prevent the spread of HWA causes much more abrupt changes than does the gradual loss of hemlock to HWA infestation when left alone. Hemlock Hill provides an opportunity to explore this hypothesis and to examine the impacts of the loss of a hemlock-dominated forest in an urban environment.

Currently, seventy percent of the trees on Hemlock Hill are infested with HWA and are in severe decline. While the trees at the base of the hill can be reached with a spray truck and treated with horticultural oil, the remaining trees are inaccessible and are expected to die over the next two to ten years. The Arnold Arboretum's management plan calls for removal of hazardous trees as needed while encouraging the regeneration of native species such as red oak *(Quercus rubra)*, red maple *(Acer rubrum)*, black birch *(Betula lenta)*, sugar maple *(Acer saccharum)*, and white pine *(Pinus strobus)*. Since 2004 researchers from the Arboretum and the Harvard Forest have been monitoring nutrient cycling and microenvironmental changes as well as vegetative succession in three experimental plots totaling roughly 2,000 square meters (one-half acre) on Hemlock Hill. In February and March of 2005 all eastern hemlocks were removed from two of the three experimental plots, with the third plot left unchanged as the control.

In the summer of 2004, before trees were removed from the two experimental plots, I initiated a study of red-back salamander abundance on Hemlock Hill. With the help of

Richard Schulhof and Peter Del Tredici I set out 8 one-inch-thick eastern hemlock boards measuring 36 by 12 inches to serve as artificial cover objects (ACOs, used to avoid disturbing natural cover objects) in each of the three study plots. I made 5 observations of each ACO from mid August 2004 to the end of October 2004 and 12 observations from early April 2005 to the middle of November 2005. Previous studies have found that differences in salamander abundance on the surface of the forest floor correlate directly with differences in total abundance, including in the soil.

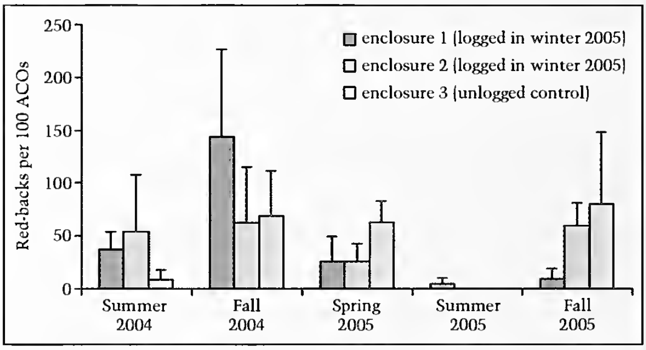
## Reptiles and Salamanders Found on Hemlock Hill

During the course of the study, I recorded 139 observations of eastern red-backed salamander, twelve of American toad, three of northern dusky salamander, and one garter snake. Forty percent of the red-backs observed were lead-back morphs and sixty percent were striped. This is a higher percentage of lead-back morphs than in any of the fifty populations observed in Lotter and Scott's 1977 New England study although comparable to populations found in Pennsylvania, Maryland, and Ohio.

The three observations of northern dusky salamanders occurred under the same ACO in successive visits, suggesting that all were of the same individual. Northern dusky salamanders are slightly longer and weigh about three times as much as red-backs, and like most stream-breeding plethodontids, their tails are laterally compressed, in contrast to the round tails of terrestrial species.

A recent study by Mike Bank and colleagues (2006) found northern dusky salamanders in only one of the 37 streams surveyed (out of 41 total streams) in Acadia National Park, Bar Harbor, Maine, between 2000 and 2003. Amphibian surveys conducted in the 1950s found that northern dusky salamanders were widely distributed in streams throughout Acadia. The exact cause of this decline is unknown, but regular acidification of Acadia's streams, causing toxic aluminum and mercury to leach, may be part of the explanation. Further monitoring efforts along Bussey Brook at the base of Hemlock Hill, where northern dusky salamanders may be breeding, would be worthwhile.

The two non-salamander species I observed, the American toad and the garter snake, are widespread, occurring in diverse habitats ranging from gardens and suburban yards to moist upland woods. American toads belong to Bufonidae, one of the four families in the order Anura that occur in New England. Like salamanders, they prey on terrestrial invertebrates such as insects, sowbugs, spiders, centipedes, millipedes, slugs, and earthworms. One of their most important predators, the garter snake, also preys on both species of salamander observed on Hemlock Hill; indeed, red-back salamanders have been found to contribute as much as 38 percent of the diet of garter snakes.




*Eastern red-back salamander relative abundance over five seasons in three enclosures (each containing 4 stations consisting of paired 3ft x 1ft hemlock boards which were used as artificial cover objects (ACOs)) on Hemlock Hill at the Arnold Arboretum.*

Given the lack of ponds or vernal pools near Hemlock Hill, I was not surprised to find neither red efts or mole salamanders. The three ponds surrounding the Bradley Collection of Rosaceous Plants may provide breeding habitat, however, and these species might be found in the woods to the west of the ponds. Another species not found on Hemlock Hill that could be present in other areas of the Arboretum is the northern two-lined salamander, a plethodontid, like the red-backed. This common species occurs in and near streams and may inhabit either Bussey Brook or the stream running through The Meadow. The other two plethodontid species that occur in Massachusetts, the four-toed salamander and the northern spring salamander, are uncommon-to-rare and are unlikely to be found at the Arboretum. Four-toed salamanders prefer acidic, wet woodlands and bogs with sphagnum moss, and spring salamanders are found in and near clear, cold streams and seeps.

**The Impact of Logging on Red-back Salamander Abundance**

In the spring of 2004, immediately following logging, red-backed salamander abundance declined significantly, dropping 83 percent in Plot 1 and 63 percent in Plot 2. Meanwhile, abundance changed little in the unlogged control plot (minus-9 percent). Temperature measurements on ACO observation days show that in the logged plots the average temperature was 10.3 degrees F (5.7 degrees C) warmer on the surface of the forest floor and 2.3 degrees F (1.2 degrees C) warmer two inches beneath the surface than it was in the control plot. In addition, the average relative humidity was 3.4 percent lower in the logged plots than in the unlogged plot. The large drop in red-back abundance in the logged plots is likely due to these microclimatic differences.

While red-back abundance declined substantially in both logged plots in the spring following logging, by fall of 2005 it had nearly recovered in plot 2, where observations were only 8 percent fewer than in the pre-logging fall of 2004. In plot 1, by contrast, abundance had declined even farther, by 94 percent of the pre-logging number. In fall 2005, plot 1, which is more exposed than plot 2 and seems to get more direct sunlight, was found to have higher average air and soil temperatures as well as lower average relative humidity than plot 1. These results suggest that the effect of logging on red-back abundance is site-specific.

The large number of red-back salamanders on Hemlock Hill suggests that relatively small forest fragments within the larger urban landscape can sustain healthy populations of this ecologically important animal. Hemlock Hill is likely to change significantly over the next decade, however, as declining eastern hemlocks are replaced by hardwood species. This study establishes a baseline that can be used to track population changes in these ecologically important organisms as the ecological conditions at the Arboretum change.

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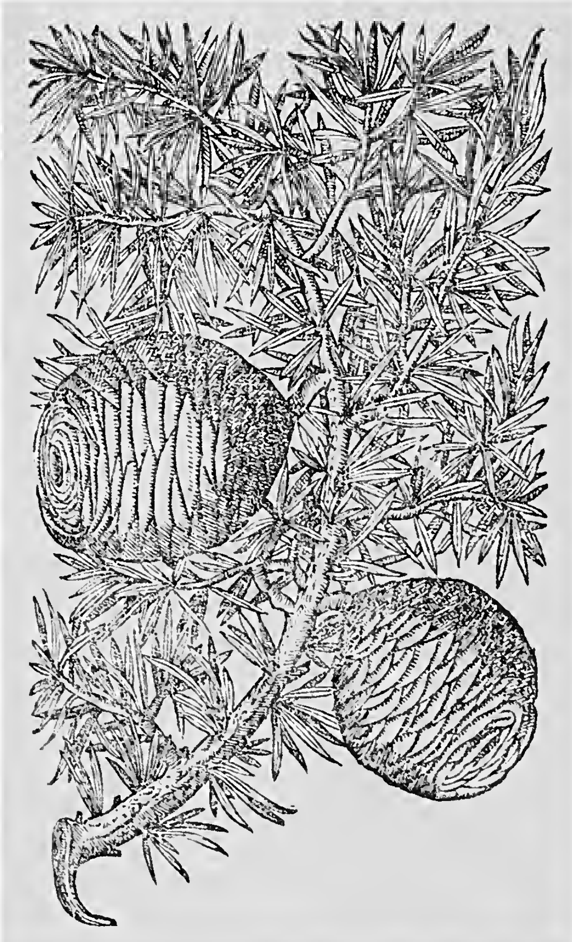
# The Quest for the Hardy Cedar-of-Lebanon

*Anthony S. Aiello and Michael S. Dosmann*

Genetic variation within plant species has not only been richly documented in science but also widely exploited for horticultural use. Individual plants have often been selected from wild populations for their deviations in growth habit, flower size, and leaf color, but another primary driver of plant exploration has been the promise of winter hardiness due to provenance. In many cases, this, too, is under the auspices of science, for it allows botanical gardens and arboreta to cultivate species that may normally be out of reach due to lack of hardiness. We present here a prime example of such work: the quest by the Arnold Arboretum to introduce into cultivation hardy stock of the cedar-of-Lebanon, *Cedrus libani.*

The genus *Cedrus* has a natural range that extends from North Africa around the Mediterranean Sea into Lebanon, Syria, Cyprus, and Turkey and west to the Himalayas (Farjon 1990). Depending on the treatment, there are a variable number of species of true cedar, and Farjon (2001) recognizes four. The beautiful long-needled deodar cedar *(Cedrus deodora)* occurs in a wide range of habitats in the Himalayas of Afghanistan, Pakistan, Kashmir, and Nepal. The atlas cedar *(Cedrus atlantica)* grows in the Atlas Mountains of Algeria and Morocco while the short-needled Cyprus cedar *(Cedrus brevifolia)* is restricted to that island; both of these taxa have by some botanists been considered separate subspecies of *Cedrus libani,* the cedar-of-Lebanon, which occurs naturally in Lebanon, Syria, and the Cilician Taurus mountains of southern Anatolia, or modern-day Turkey. It is this group of cedars from Turkey that most interests us and that is the focus of this article.

Authors have variously recognized the Turkish provenance of cedar with subspecific status (Farjon 1990). *Cedrus libani* subspecies *stenocoma* was first described by Schwarz (1944) and then Davis (1949), who both recognized that it





Cedrus libani *as illustrated in John Gerard's 1597* Herball.

was intermediate between the typical cedar-of-Lebanon and the atlas cedar. Volume One of *The Flora of Turkey* (Davis 1965) did not recognize subspecies *stenocoma,* although it is recognized as a variety in the eleventh volume of the same work (Guner 2000). More recently, the Turkish provenance was classified as *Cedrus libani* ssp. *stenocoma* (Farjon 2001) and these trees usually are called the hardy cedar-of-Lebanon. The Turkish trees are generally considered to be more upright and conical

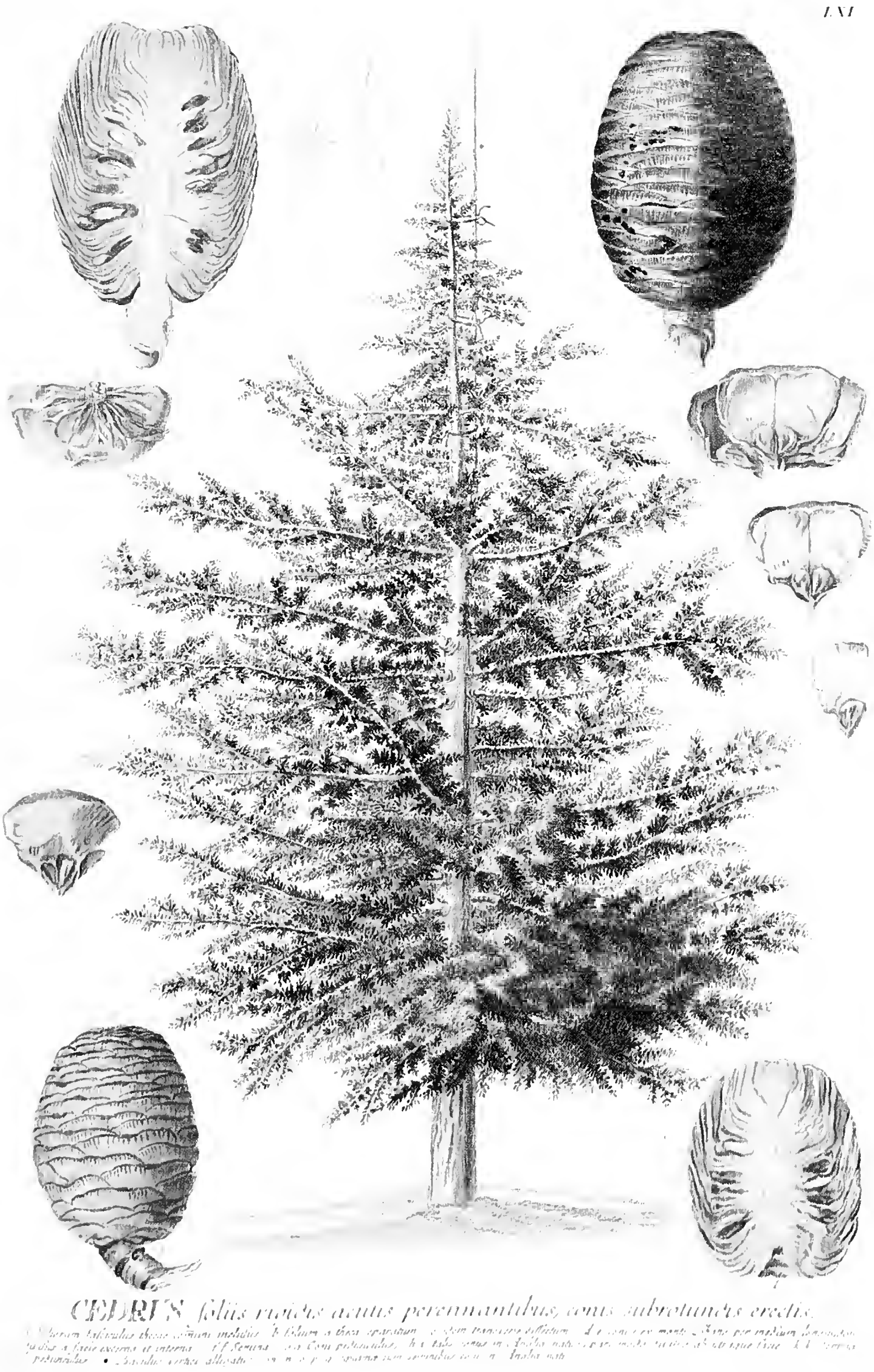



*Image of* Cedrus libani *from Trew's* Plantae Selectae, *1750–1773.*

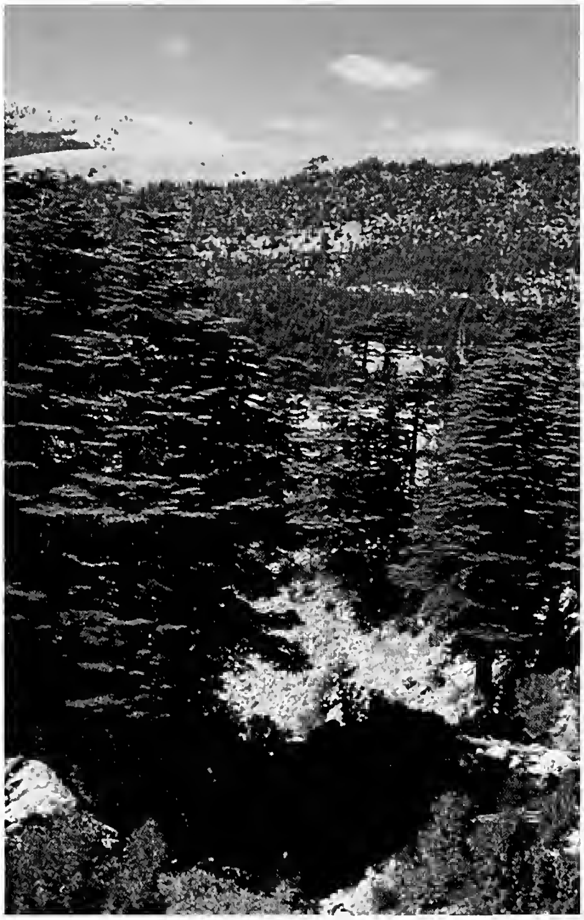
(not forming the flat "umbrella" top of other cedars) and to have shorter needles than those from Lebanon (Farjon 1990), although there is variability particularly in the former trait and is likely more a function of environment than pure genotype. The epithet *stenocoma* literally means "narrow hair," referring to pubescent twigs of the Turkish plants.

### *Cedrus libani* in Asia Minor

During the 1800s *Cedrus libani* was grown throughout Philadelphia and New York but was not hardy in Boston and New England (Wilson 1926). Josiah Hoopes, a nurseryman from West Chester, in southeastern Pennsylvania, wrote that "the cedar-of-Lebanon is found to be pretty hardy . . . [and] with us it has succeeded to our entire satisfaction, and we can therefor recommend it without reserve, if proper cultivation and a moderate amount of care be given to it." In his 1868 book, Hoopes also mentions Pierre Belon, a French botanist and physician who traveled throughout the Levant in the 1540s. In 1553 Belon published *De arboribus coniferis,* probably the first text devoted entirely to conifers, and in it he included the first description of cedar-of-Lebanon growing in the Amanus (Nur) and Taurus Mountains of southern Anatolia. In 1597, John Gerard cited Belon in his *Herbal,* saying:

> The cedar trees grow upon the snowie mountaines, as in Syria on mount Libanus, on which there remaine some euen to this day, saith *Bellonius* planted as it is thought by *Salomon* himselfe: they are likewise found on the mountains *Taurus,* and *Amanus,* in colde and stonie places.

MARK FLANAGAN



Cedrus libani *ssp.* stenocoma *growing in the eastern Taurus Mountains of Turkey, near the Syrian border.*

Gerard's statement reveals that as early as the sixteenth century authors took notice of these unique trees from Anatolia and recognized that this more northern provenance possessed greater potential for cold hardiness.

Nineteenth-century botanical and horticultural literature was replete with references to the northern populations of cedar-of-Lebanon. Several European botanists were exploring and describing the flora of Asia Minor and their works describe a growing understanding of the natural range of cedar in this region. *Asie Mineure* by P. A. Chikhachev is an extremely thorough account of the physical geography, climate, fauna, and flora of Asia Minor, based on his travels throughout the region. Among his extensive botanical listings is *Cedrus libani,* which he described as growing in numerous locations. Chikhachev describes their locations using the ancient names for the regions of Anatolia, moving from west to east: in Pisidia between Lakes Beysehir and Egridir; in Isauria at Mount Topyedik growing around 2,000 meters; in Cilicia growing on the northeast and southeast exposures of all the mountainous regions of the Bulgar Daglari (Bolkar Daglari mountains of the Taurus range), where it descends to 4,600 feet (1,400 m); growing in groves in the Antitaurus Mountains between the villages Sarkanty-oglu and Tchedeme [sic] at 5,600 feet (1,700 m) (Chikhachev 1860).

ARCHIVES OF THE ARNOLD ARBORETUM

Cedrus libani *ssp.* stenocoma *growing in the Taurus Mountains of Turkey, photographed by Walter Siehe, likely in 1900 or 1901.*


*Plantation of* Cedrus libani *ssp.* stenocoma *growing on Bussey Hill in the Arnold Arboretum, photographed by G. R. King, summer 1915.*

Just two years later, Joseph Hooker gave detailed location information on *Cedrus libani* in Asia Minor, clearly building on contemporary botanical work:

> The nearest point to the Lebanon [Mountains] at which Cedars have been found, is the Bulgar-dagh chain of the Taurus in Asia Minor, and from that point forests extend eastward to Pisidia, in long. E. 32°, westward to long. E. 36°, and northward to the Anti-Taurus, in lat. 40° N.; growing at elevations of 4000 to 6400 feet above the sea. The Lebanon may be regarded as a branch of the Taurus, and is 250 miles distant from the Cedar forests upon that chain . . . Northern Syria and Asia Minor form one botanical province; so that the Lebanon grove, though so widely disconnected from the Taurus forests, can be regarded in no other light than as an outlying member of the latter.

Ravenscroft gave a colossal summary of all known accounts of cedar-of-Lebanon, with beautiful color plates, in his 1884 *Pinetum Britannicum*. He describes the species in amazing detail, including comparisons made to other *Cedrus* and descriptions of the Syrian and Lebanese trees. Particularly interesting is a table that accounts for all visits made by individuals from 1487 to 1864 to the sacred grove that lies on Mt. Lebanon. He also writes of the Anatolian population, providing a description practically identical to that of Hooker.

Yet another thorough description of the locations of the Anatolian cedars is given in Boissier's 1884 *Flora Orientalis,* where he reported cedar-of-Lebanon growing in the mountainous and subalpine regions of southern Anatolia, in the mountains of the Lycian, Cilician and Anti-Taurus mountains. He wrote that the species grew extensively throughout forests with *Abies cilicica* and *Juniperus foetidissima* at 4,000 to 6,500 feet (1,200 to 2,000 m). Stapf noted in 1885 that in the southwestern corner of Turkey (Lycia) dense woods of cedar were observed in the Baba Dagh and between Zumuru and the Bulanik Dagh [sic].

**How the Hardy Cedar-of-Lebanon Found Its Way to North America**

A contemporary of the botanists writing and exploring Asia Minor in the late 1800s was Walter Siehe, an interesting and somewhat mysterious character who played an integral role in introducing the hardy cedar-of-Lebanon into the United States. Siehe was a German botanical explorer living in Smyrna (Izmar), Turkey. In his *Die Nadelholzer des cilicischen Taurus (Conifers of the Cilician Taurus),* he described the natural habitat of conifers growing in the mountains of southern Anatolia and the conifers themselves, including *Abies cilicica, Taxus baccata,* several species of *Juniperus, Cupressus sempervirens,* and of course *Cedrus libani.* Of the cedar he wrote, "the proud tree is a child of the high altitude," growing in a severe climate where the snows lie a few meters deep for five months of the year (Siehe 1897b). In these mountains where the cedars grow on the steep walls and high saddles between peaks, Siehe romantically describes the roaring wild rivers, the whiteness of the snow, and the long silences broken only by the screech of birds or tumbling stones kicked loose by an escaping mountain goat. He notes that despite the usefulness of cedar's wood, the large populations of cedar persisted because of the inaccessibility of the mountains. He describes trees up to 130 feet (40 m) tall and describes their column-like trunks supporting branches as regular as floors of a building (Siehe 1897a). It is clear from his travel accounts that Siehe knew the mountains of southern Turkey very well and was the right person, in the right place, and at the right time to send seed to North America.

It is in the context of nineteenth-century botanical exploration and description throughout Asia Minor that one understands Charles S. Sargent's interest in the more northern population of cedar. Cedar-of-Lebanon—with its handsome and stately form, its association with grand estates throughout Europe and the mid-Atlantic United States, and its historic associations—is a highly desirable landscape tree. With this in mind, it's easy to understand how Sargent, director of the Arnold Arboretum from 1873 until 1927, would have surely longed to grow cedars in New England. However, hardiness in New England was indeed an issue. He certainly would have read with great interest the accounts of the cedars and understood that trees from the Taurus mountains held the key to increased hardiness.

With this in mind, Sargent hired Walter Siehe to collect seed from trees in the Taurus Mountains and have these sent to the Arnold Arboretum. In a letter from Siehe to Sargent, dated 18 November 1900, from Mersina, Turkey, Siehe wrote:

> Dr. Bolle . . . has repeatedly informed me of your desire [to acquire] cedar cones from cold resistant trees of high altitude (1900 m [6,250 feet]). Only a few days ago did I manage to obtain, after several futile attempts, 50 kilos [110 pounds] of cones with good seeds. Since it was necessary to make a special trip, use many pack animals, and spend eight days of time for this, I am certain that you will not find the fee of 60 Mark German currency too high.

Apparently Sargent did not find the fee too high because the Arboretum's plant records show that they received cones with ripe seeds from Siehe on February 4, 1902. The Arnold Arboretum was not the only recipient of Siehe's seed: in 1908 H. J. Elwes and Augustine Henry wrote another excellent description of the cedars from the Taurus mountains and noted, "Siehe has sent seed from the Cilician Taurus to various places, and I have two vigorous young trees raised from them."

Early reports from the Arnold Arboretum noted great success with this seedlot. The seeds had a high rate of germination and by 1915, Sargent

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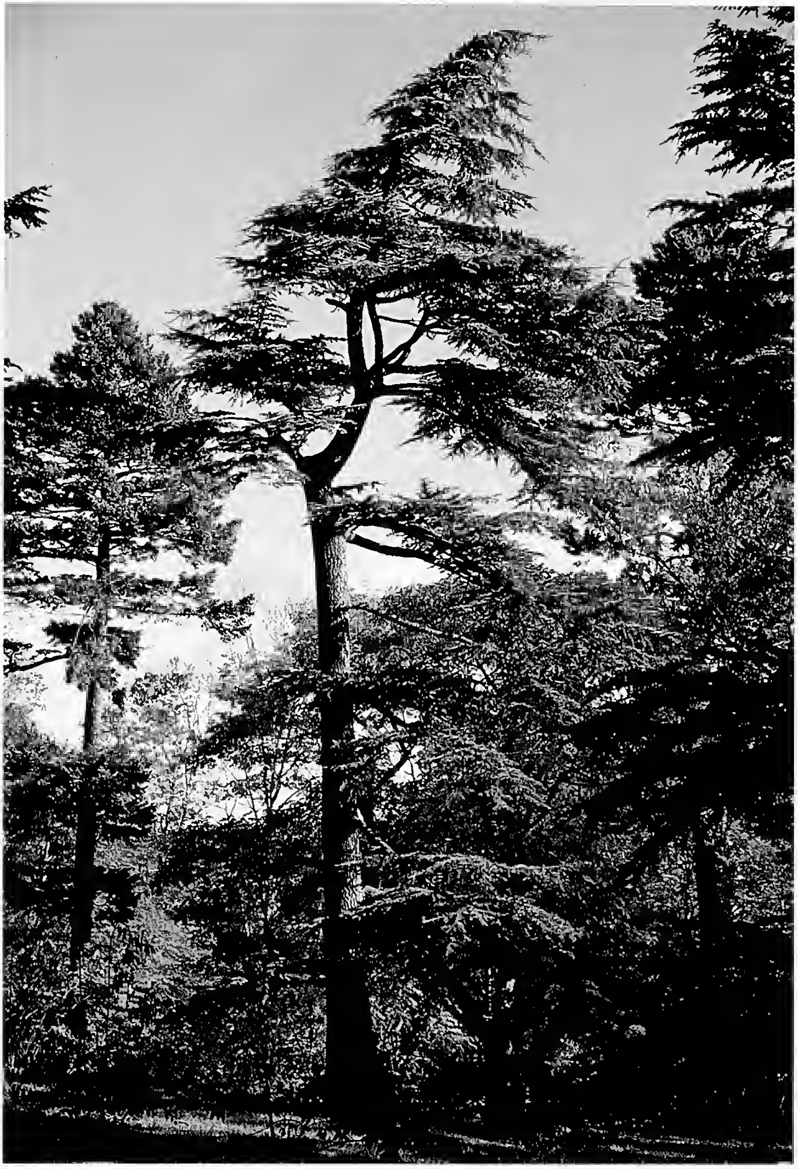

Cedrus libani *ssp.* stenocoma *(AA #4697*G). Despite the loss of its central leader, this original seedling, part of the 1902 Arnold Arboretum introduction, stands tall on Bussey Hill.*

reported in the Arboretum's *Bulletin of Popular of Information* that the cedars-of-Lebanon had "all proved perfectly hardy, not one having suffered from drought or cold." A plantation of trees was established on Bussey Hill, and other individual specimens were planted throughout the collection. The average height of these trees was about 13 feet (4 m), with the tallest having reached 21 feet (6.5 m), prompting Sargent to reflect, "It is doubtful if any other conifer can be grown in New England from seed to the height of twenty-one feet in thirteen years." Wilson also seemed pleased with the rapid growth and hardiness of these trees, writing in 1919 that although the dreadful winter of 1917–1918 scorched the needles of the cedars, they recovered fully and "had grown more rapidly in the Arnold Arboretum than any other conifer has ever done." And just five years later, the *Bulletin* reported that the trees had already reached 30 feet (9 m) in height. In 1926, twenty individuals of this accession (AA 4697*A-T) appear in the plant records, although over time there has been some attrition and currently only eight trees from Siehe's original 1902 collection remain extant in the Arnold's collection (AA #4697*A,C,G,I,K,M,O,P). Cold winters were not the cause for their decline, however; Donald Wyman wrote in 1946 that the cedars were thriving, growing for over forty years and withstanding temperatures of minus-20 degrees F. Strong winds were responsible for the loss of at least eight of the twelve trees, including five from the infamous 1938 hurricane alone.

**The Current State of Trees in the Wild**

In Lebanon and Syria, the species is rare due to millennia of human impact (logging, burning, grazing). However, in Turkey, where the topography has prevented easy access, there remain extensive forests of *Cedrus libani* ssp. *stenocoma*. During a collecting expedition to the Taurus Mountains in 1990, Mark Flanagan (Keeper of the Royal Gardens, Windsor Great Park) encountered the hardy cedar-of-Lebanon running for nearly 620 miles (1,000 km) along the 5,900-foot (1800-m) contour line. Due to the high, open canopies in the overstory, the ground layer of these forests is very rich, including a diversity of taxa such as *Acer hyrcanum, Sorbus umbellata,* and *Kitaibelia balansae.* At present there are over

ANTHONY AIELLO

Cedrus libani *ssp.* stenocoma *at the Morris Arboretum (MOAR #32-0398*A). This tree, planted in the early 1900s, is likely one of seedlings from the 1902 Arnold Arboretum introduction. It has a diameter at breast height of 44 inches (1.1 m), is 68 feet (20 m) tall, and has a 40-foot (12 m) spread.*

250,000 acres (100,000 ha) of cedar forest in Turkey, but this area is but a sixth of what used to occur in the Taurus Mountains (Boydak). With luck, though, these amazing stands will be appreciated for many more centuries due to recently established conservation efforts.

### Other Notably Hardy Specimens

Among the Morris Arboretum's extensive conifer collection are five mature specimens of hardy cedar-of-Lebanon. They are growing throughout the Arboretum, some tucked away, others in full view, and all of them handsome. The oldest tree was planted before the Arboretum's founding in 1932 when the property was known as Compton, John and Lydia Morris's estate. A cedar appears in this location in the 1909 Atlas of Compton—a survey of the Morris' gardens and plants—and according to notes written by John Tonkin, the Morris' gardener and Morris Arboretum's superintendent from 1913 to 1961, this cedar came from the Arnold Arboretum. It is likely that this tree is a seedling from the original 1902 collection of Turkish seed, sent to the Morris's from the Arnold Arboretum. Over the years, staff at the Morris Arboretum have marveled at the hardiness of this tree, recording that it showed no visible injuries during the devastatingly cold winters in the early 1930s (Lambert 1936). Although it has suffered storm damage during the past 25 years, today it shows a remarkable amount of young, vigorous re-growth for a tree of its age and size.

As students of Harrison Flint at Purdue University we often admired the selection 'Purdue Hardy' (*Cedrus libani* ssp. *stenocoma* 'Purdue Hardy'), which grows in West Lafayette, Indiana, in a hardiness zone that routinely reaches minus-20 degrees F (USDA zone 5a). This 40-year-old specimen is remarkable for its graceful form and nearly pendant branches; like many others of the subspecies, it has not become flat-topped. It has certainly lived up to its name, withstanding winter temperatures of minus-25 degrees F with only minimal browning of needles (Flint 1997).

The selection's provenance is uncertain. It was one of several seedlings germinated from seed collected by the late Purdue professor Ted Shaw in the 1950s. Shaw had been in Lebanon working on reforestation projects supported by the United States when he obtained it. Oral history at Purdue has it that Shaw found the seeds "up in the Hills," which could mean Lebanon or it could have been Turkey, where he vacationed. Since no Lebanese cedar has been successfully grown out-of-doors north of zone 6, it is far more likely to have originated in the mountains of Turkey.

Another noteworthy specimen, a mammoth cedar-of-Lebanon that is a Pennsylvania state champion, is at the Tyler Arboretum, in Media, Pennsylvania. Jacob and Minshall Painter, horticulturists and owners of the property that became the Tyler Arboretum, recorded purchases of cedars of Lebanon from the Philadelphia nurseries of John Evans, Josiah Hoopes, and Morris in the 1850s (Appleby 1992). It is one of the most remarkable conifers in the Delaware Valley: it stands 87 feet high (26.5 m) with a spread of 93 feet (28.4 m) and a diameter at breast height of 69 inches (175 cm).

The story of the majestic hardy cedar-of-Lebanon mixes history, geography, plant ecology, horticulture, and a love of conifers. When you next visit the Arnold, Morris, or Tyler Arboreta, take time to enjoy their magnificence and muse on their long journey from the mountains of Turkey to the eastern United States.

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# *Arnoldia* Online

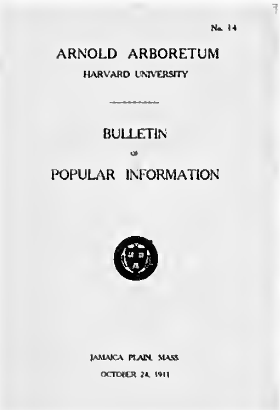
Ninety-five years and 13,000 pages of *Arnoldia* (1940–present) and its predecessor, *The Bulletin of Popular Information* (1911–1939), are now available on the Arboretum's website at www.arnoldia.arboretum.harvard.edu.

This trove of rich and varied content invites browsing by date, author, and title or by using the yearly indexes (1915–2006) and the two cumulative indexes (1941–1969, 1970–2000). Plants, places, and people are the chief but not the only constituents of the indexes, and they can be searched online in the same way as in printed versions. As you'd expect, either Latin binomials or common names will take you to plants, although the Latin binomial is likely to yield more comprehensive results. In cases of frustration, look for the "Help" button provided by webmaster Sheryl Barnes, who orchestrated the two-year project.

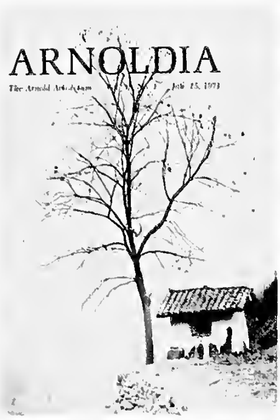
A bit of history: *The Bulletin of Popular Information* was launched by Charles Sprague Sargent, founding director, in response to complaints from visitors who had missed the peak bloom of certain plants. To the expected dates of bloom he added the phylogeny, history, and culture of many Arboretum plants, particularly those introduced from East Asia by staff members and other agents. Sargent's *Bulletin* was a four-page affair issued weekly during the growing season until his death in 1927. E. H. Wilson took up where Sargent left off, adding more illustrations but otherwise without change.

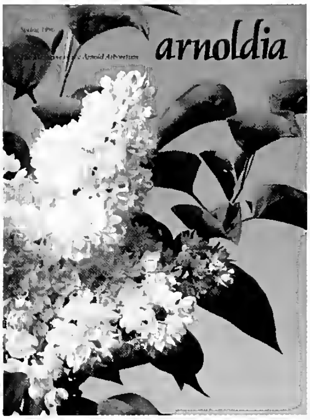
It was after Wilson died, in 1930, that the publication began to expand its length and scope. The next editor, Edgar Anderson, wrote *The Bulletin's* first article on botanical nomenclature, aptly titled "Jabbywocky." Other staff members also contributed longer articles: *e.g.*, Ernest J. Palmer's "Trees Used by the Pioneers" and Hugh Raup's "Injurious Effects of Winds in the Arnold Arboretum" and "Notes on the Early Uses of Land Now in the Arnold Arboretum."

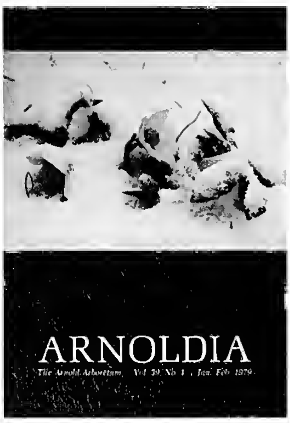
Donald Wyman assumed the editorship of *The Bulletin* when he arrived in 1936. In 1940 director Elmer Drew Merrill shortened the title to *Arnoldia*, following his penchant for one-word titles and honoring benefactor James Arnold. For over thirty years Wyman wrote nearly all of the articles in *Arnoldia*, an accomplishment not likely to be soon matched. Subsequent editors (listed in the 1970–2000 cumulative index) expanded the range of content, updated the design, and added color and variety while emphasizing scholarship and style. Please visit the site at www.arnoldia.arboretum.harvard.edu.

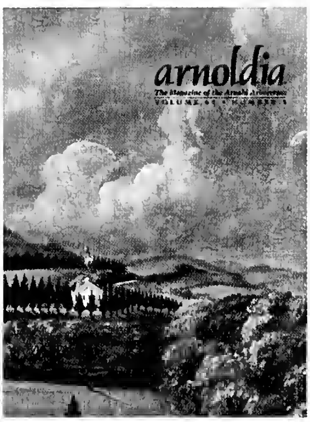






Yellow-throated Vireo, or Greenlet.

Male.

Swamp Snowball. Hydrangea quercifolia.

Drawn from Nature by J. J. Audubon F.R.S. F.L.S. Lith.d Printed & Col.d by J. T. Bowen Philad.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*Front cover:* The paperbark maple *(Acer griseum)*, AA # 12488-A, growing near the Bradley Garden of Rosaceous Plants, photographed by Peter Del Tredici.

*Inside front cover:* Nothing says summer at the Arnold Arboretum like a flowering golden-rain tree *(Koelreuteria paniculata)*, photographed by Peter Del Tredici.

*Inside back cover:* The paperbark maple *(Acer griseum)*, AA # 12488-B, growing along Chinese Path below the summit of Bussey Hill, photographed by Peter Del Tredici.

*Back cover:* Visitors enjoying the cherry trees growing at Mt. Takao, Japan, photographed by Mayumi Shigeta, of The University of Tokyo.

# 'Vardar Valley' Boxwood and Its Balkan Brothers

*Peter Del Tredici*

**In 1934, I visited Rumania, Bulgaria, and Yugoslavia under the joint auspices of Harvard University and the United States Department of Agriculture, choosing by preference the sun-baked areas of the northwestern Balkans, which have cold, dry winters like ours [St. Louis]. I attempted to collect seeds and cuttings of four interesting evergreens, holly, ivy, yew, and box, on the theory that, even though they looked more or less identical with these same species in northern Europe, they must be different on the inside.**

**—Edgar Anderson, 1945**

With these words, the former director of the Missouri Botanical Garden and one-time Arnold Arboretum staff member, Edgar Anderson described his memorable trip across eastern Europe in search of reliably hardy, broadleaved evergreens. At the time, it may have appeared as just another Arboretum collecting expedition to a distant corner of the globe. But looking back on it—seventy-three years later—we know it was a special trip that resulted in the introduction of a horticulturally important strain of the common or English boxwood, *Buxus sempervirens,* collected from wild plants growing along the Treska River just outside the city of Skopje, the capitol of Macedonia.

In 1957—some twenty-three years after the fact—the first of Anderson's boxwood selections was named 'Vardar Valley' because of its outstanding winter hardiness and mounded growth form. As this cultivar spread slowly through the nursery trade during the 1970s and 80s, it became apparent that 'Vardar Valley' was resistant to virtually all pests and disease—including the dreaded boxwood decline—that were damaging or killing common boxwood across eastern North America. The recognition of this resistance, together with its hardiness and compact habit, caused an explosive increase in the landscape use of 'Vardar Valley', beginning in the 1990s and continuing through today.

**Edgar Anderson, the Man**

Before proceeding further with the story of *Buxus* 'Vardar Valley', it would be appropriate to take a look at the man who discovered this important cultivar. Edgar Anderson was born in Forestville, New York in 1897, and moved to East Lansing, Michigan as a child. He attended Michigan Agricultural College (now Michigan State University), where his father was a professor of dairy husbandry, and graduated in 1918. Anderson received his doctorate from the Bussey Institution of Harvard University in 1922, where he studied the tobacco genus, *Nicotiana,* under the direction of Dr. Edward M. East. The Bussey was located adjacent to the Arnold Arboretum and provided Anderson with an opportunity to familiarize himself with the collections and get to know various staff members. While at the Bussey, Edgar met Dorothy Moore, a laboratory assistant working for East while finishing up her master's degree in botany from Wellesley College. The two were married in 1923.

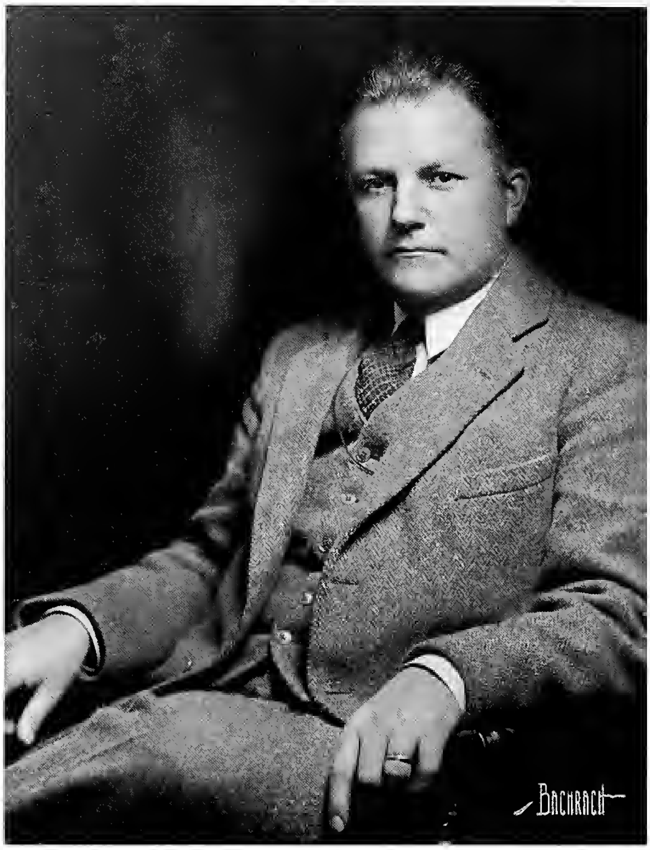
Following his graduation from Harvard in 1922, Anderson went to work for the Missouri Botanical Garden, and in 1929 was awarded a National Research Fellowship for study in England with a focus on genetics under the guidance of J. B. S. Haldane. He also studied cytology with C. D. Darlington at the John Innes Horticultural Institute, and statistics with


*The original plant of* Buxus sempervirens *'Vardar Valley,' AA 352-35-E, was 23.3 feet wide by 8.3 feet tall (7 m x 2.5 m) in December, 2006.*

R. A. Fisher at the Rothampstead Field Station. Anderson returned to the Missouri Botanical Garden in 1930 and, a year later, accepted an appointment as arborist at the Arnold Arboretum where he worked until the fall of 1935. The primary responsibilities of Anderson's position were care of the living collections and furthering the Arboretum's relations with the public. In his biographical sketch of Anderson, John Finan notes that the four years he spent at the Arnold Arboretum were frustrating because of "the large number of speaking and other public service obligations at the Arboretum did not allow him to pursue his research interests. Indeed, the press of duties became so great that, as Dorothy Anderson's diary records describe, he suffered severe exhaustion in the spring of 1934. He went with his family to England in July, 1934 and he spent August and September on a collecting trip to the Balkans." Anderson resigned his position in the summer of 1935 and returned to the Missouri Botanical Garden, where he spent the remainder of his botanical career.

Today, Anderson is remembered primarily for his groundbreaking work on the role that hybridization plays in the evolution of plants, summarized in his book *Introgressive Hybridization*, published in 1949. He was also interested in the history of domesticated plants

ARCHIVES OF THE ARNOLD ARBORETUM




*Edgar Anderson, "Arnold Arboretum Arborist 1931."*

and in 1952 published a popular book on the subject, *Plants, Man and Life,* which is still in print. Anderson was appointed director of the Missouri Botanical Garden in 1954, but resigned in 1957 to go back to the teaching and research that he so dearly loved. During his lifetime Anderson was awarded many honors, including membership in the American Academy of Arts and Sciences and the National Academy of Sciences, and the Darwin-Wallace Medal of the Linnaean Society. He died in St. Louis in 1969 at the age of seventy-two. Writing in 1972, his good friend, G. Ledyard Stebbins of the University of California, Davis, described Anderson's well-known humanitarian side with the following words:

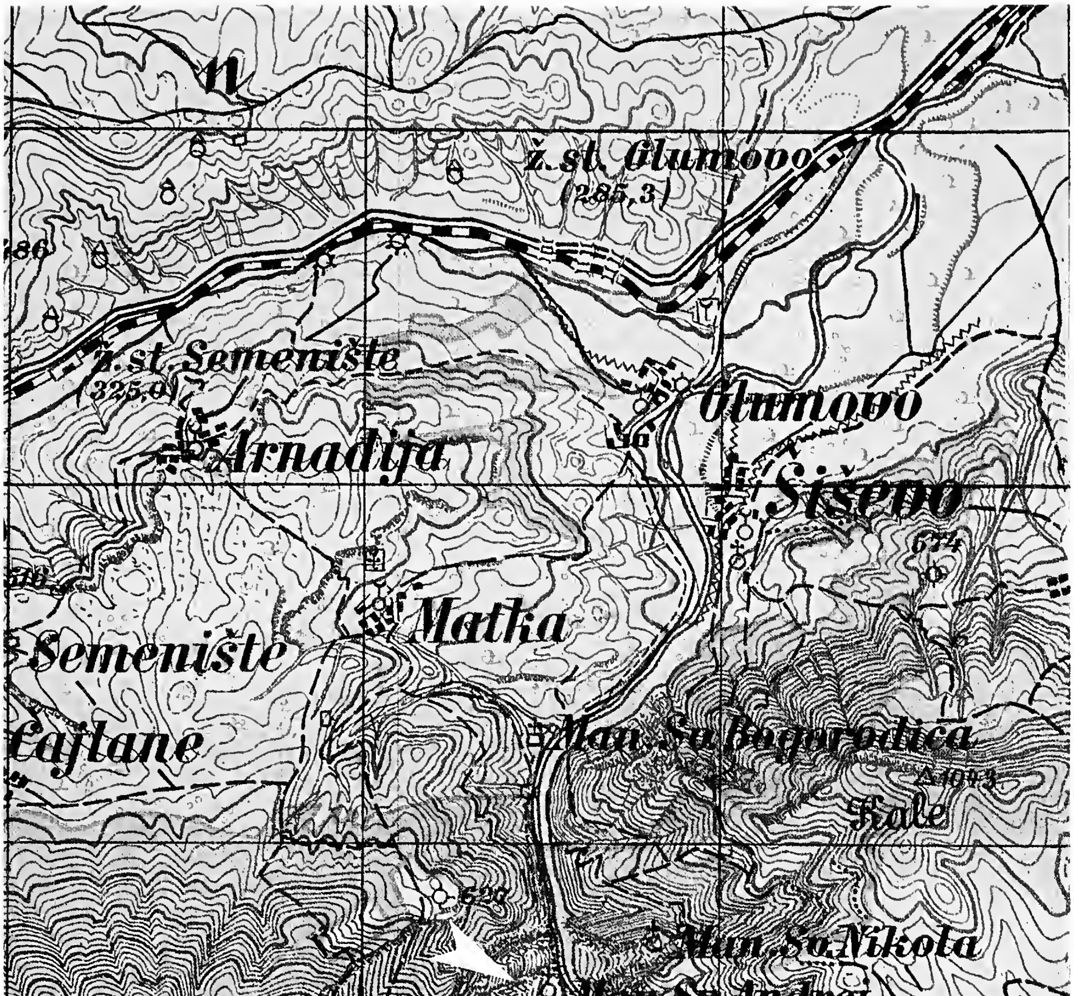
> I cannot conclude without referring to Edgar Anderson's great faith in mankind, which let him to adopt and follow zealously the Quaker religion and way of life. He accepted family tragedies calmly and resolutely. His inner conflict with himself was never wholly resolved, but he never wavered in his belief that he could make life better for others by his kindness toward them, and his ability to share with them his extraordinary perception of the wonders of plant life, and what plants could mean to people.

### The Balkan Expedition

Anderson's trip to the Balkans during the summer of 1934 is not usually mentioned in his list of scientific accomplishments, but it was Anderson's most important foray into the field of ornamental horticulture, and 'Vardar Valley' its most significant result. Indeed, the only other ornamentals—besides *Buxus*—that Anderson collected on the trip, which are still commercially grown, are two cultivars of Baltic Ivy (*Hedera helix* var. *baltica*) 'MBG Rumania' and 'MBG Bulgaria.' Anderson was not successful in his attempt to introduce a winter-hardy butcher's broom (*Ruscus* spp.), cherry laurel (*Prunus laurocerasus* var. *shipkaiensis*), or English holly *(Ilex aquifolium).* Several specimens collected from the trip, however, are still growing on the grounds of the Arnold Arboretum: including three accessions of European yew (*Taxus baccata,* AA #935-34, 370-35 and 371-35), one wild lilac (*Syringa vulgaris,* AA #949-34), and one wild pear (*Pyrus elaeagrifolia,* AA #948-34).

The story of how Anderson came to collect Balkan boxwood is best told in his own words, from an article he wrote for *The Boxwood Bulletin* in 1963:

> Boxwoods are not evenly distributed all over Europe; there is a northern area where they are found and then another separate area at the south. At the Royal Botanic Garden at Kew and at the Botanical Gardens in Belgrade by consultation and study in the herbarium I found that the northernmost extension of this southern strain was just outside of Skopelie [Skopje] in the valley of the Vardar River, in the Macedonian edge of Yugoslavia. The government gave me a courier to travel with me and help in buying tickets, reporting to the police, carrying luggage and generally serving as a companion. He was a White Russian and spoke almost no English but he spoke fluent German and we communicated in that language.
>
> Our directions had been to go to a monastery in the outskirts of Skopelie and that there we would find boxwood in quantity. My memory




HARVARD MAP ARCHIVES

*A German Army map from 1937 showing the Treska Gorge and the Treska River. The white arrow indicates the location of the Monastery of St. Andreja near where Anderson collected 'Vardar Valley.' The region has changed considerable since Anderson's time, due to the construction of a masonry dam near the Monastery. The coordinates for the Treska Gorge are 41° 58′ N and 21° 18′ E.*

is that we took some sort of conveyance out to the bridge over either the Vardar or one of its tributaries and then proceeded afoot along the pathway which led to the unpretentious little whitewashed monastery. [*Author's note: This is most likely the Monastary of Sveti Andreja on the banks of the Treska River, which flows into the Vardar River southwest of Skopje.*] The river bed, broad and gravelly, was at one side and the mountains from which the stream rose loomed ahead, dry and rocky with some shrubs on the lower slopes and here and there an occasional battered tree. The records of the monastery showed that up to a few hundred years ago the mountain was largely covered with a beechwood forest, from which the monastery had drawn a substantial part of its revenue. Over-cutting and over-grazing had destroyed the forest. Heavy erosion had done the rest and much of the mountain was down to the bare rock. Goats, which were still everywhere, were the worst offenders and when we came to the acres and acres of boxwood they too were nibbled, sometimes almost down to the ground; seldom or never were they over shoulder high. While the boxwoods grew in great abundance there were other characteristic evergreen shrubs in with them; big bushy thyme and rosemarys I remember in particular.

At the time of our visit the seeds were already ripe and had been scattered by the browsing

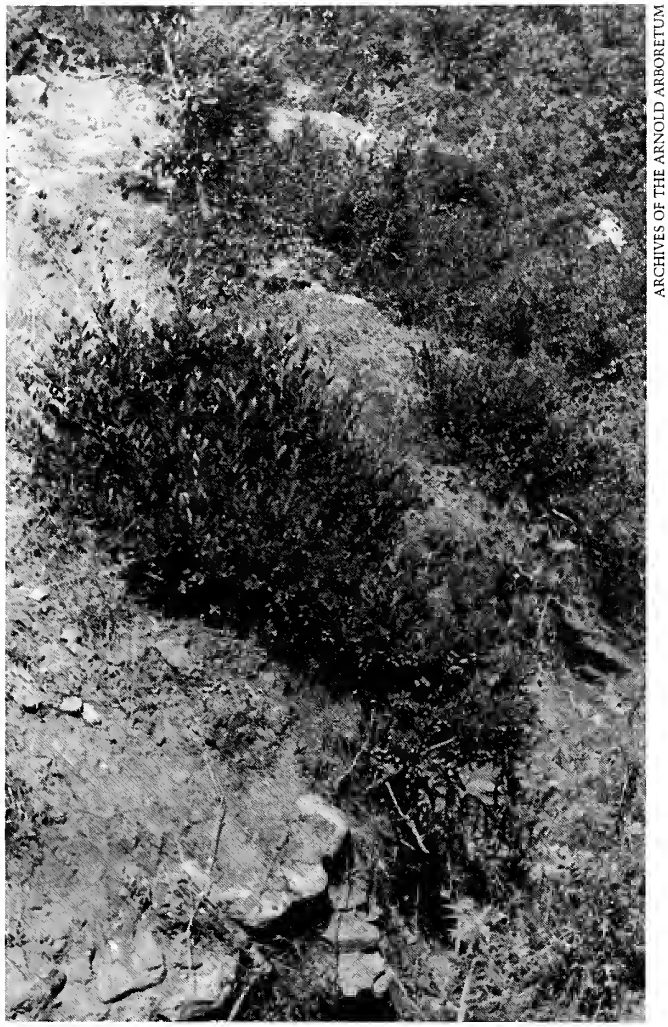


*Anderson photos #17415 with the following caption: "Yugoslavia, Skoplje [sic], Treska Gorge.* Buxus sempervirens *habitat. Photos. by Edgar Anderson, Sept. 19, 1934. Locality where herbarium specimen #133 was collected." In the picture on the left, note the boxwood growing along the edge of the road and up the steep slope of the gorge. In the picture on the right, note the Treska River flowing at the base of the Treska Gorge and the boxwood dominating the slopes.*

goats. We got down on our hands and knees and picked up the shiny black sees (a little smaller than apple seeds) from underneath the bushes. It was slow work but we eventually got a hundred or so. We also took cuttings to send back airmail to my collaborators in England and made herbarium specimens of the boxwoods and other shrubs. The bushes had been so heavily grazed it was difficult to tell anything about their growth habit but from the stubs that were left it was easy to see that there was much more variation from bush to bush than in the boxwoods which grew wild (or apparently so) at Box Hill in the south of England. They varied conspicuously in leaf size and in leaf shape and in the amount of bluish bloom on the leaves.

In the Arnold Arboretum Archives I unearthed several of the photographs Anderson took while on his Balkan trip, including several taken on September 19 of location #133 in the Treska Gorge area, and of boxwoods that were growing there. These photos are particularly noteworthy because this is where Anderson collected the plant that would eventually become the cultivar 'Vardar Valley' (AA #352-35).

I was elated at the thought that I might have discovered a photograph of the original 'Vardar Valley' growing in the wilds of Macedonia. But the joy was quashed after I located an undated, typewritten manuscript that Anderson wrote, probably in mid to late 1935, "Report on Balkan Expedition to the Arnold Arboretum." It lists all of his collections, including *Buxus sempervirens* #133, which he describes as consisting of seeds from two plants (given AA numbers 789-34 and 818-34), and cuttings from two plants, (given AA numbers 352-35 and 353-35). The report clearly indicates that Anderson used #133 to designate a collection location rather than in reference to a specific, individual plant. The truth of this supposition was confirmed when I obtained a high resolution scan of Anderson's original *Buxus sempervirens* herbarium specimen #133 from the Harvard University Herbaria, which showed a plant with long, narrow leaves as opposed to the distinctly rounded leaves that are typical of 'Vardar Valley'. Lynn Batdorf, boxwood curator at the U. S. National Arboretum and registrar for the genus *Buxus,* examined the scan and reported that "the leaves of herbarium specimen #133 are elliptic to oblong with an obtuse apex, while the leaves of 'Vardar Valley' are larger, far more ovate shaped with an acute apex."




*Anderson photos #17416 with the following caption: "Yugoslavia, Skoplje, Treska Gorge.* Buxus sempervirens. *Photos. by Edgar Anderson, 1934. Herbarium specimen #133."*

### The Publication of 'Vardar Valley'

Anderson collected cuttings from four different boxwood plants during the course of his Balkans expedition: two from cultivated plants in Bucharest, Romania and two from wild plants at location #133 outside Skopje. Anderson sent the plants and cuttings directly to the John Innes Horticultural Institute in London rather than to

## *Buxus sempervires* accessions received by the Arnold Arboretum from Anderson's 1934 Balkans Expedition:

350-35 = "Buxus sempervirens #1 Bucharest E. Anderson. (from the John Innes Hort Inst., Mostyn Rd., London SW. 19) April 1, 1935. 20 cutts April 2, 1935. 18 boxed Dec. 3, 1935." [According to Anderson's undated report, these cuttings were collected from a cultivated plant. One specimen was planted on the AA grounds in 1950; it was removed in July, 1982.]

351-35 = "Buxus sempervirens #2 E. Anderson. Bucharest, Rumania April 1, 1935. 66 cutts April 2, 1935. 58 boxed Dec. 3, 1935." [According to Anderson's undated report to the Arnold Arboretum, these cuttings were collected from a cultivated plant. Two specimens of #351-35 were planted on the AA grounds in 1950; plant A was removed in April 1981; the name of plant B was changed to *Buxus sempervirens suffruticosa* by Donald Wyman on Oct. 25, 1956, and on Sept. 24, 1960 it was "stolen by vandals". In 1984, this clone was assigned the cultivar name 'Edgar Anderson' by Mary Gamble in *The Boxwood Bulletin* 24: 41–53.]

352-35 = "Buxus sempervirens. Treska Gorge, Skoplje #133. E. Anderson, April 1, 1935. 44 cutts April 2, 1935. (42). 40 boxed Dec. 3, 1935." [This accession was named 'Vardar Valley' by Donald Wyman.]

353-35 = "Buxus sempervirens, E. Anderson no label, April 1, 1935; 58 cutts April 2, 1935. (52) 50 boxed Dec. 3, 1935." [According to Anderson's undated report to the Arnold Arboretum, these cuttings were part of collection #133 at Treska Gorge. An unsigned note at the bottom of the accession card reads: "Do not name this clone. It is not as good as 'Inglis', and has a few browned leaves 4/27/66. On this date it is 6' tall, 7' across. Foliage lighter green than the much lower 'Varder Valley.'" According to Arboretum records, one specimen was planted on the grounds in 1950, and was removed in November, 1982. A cutting of this plant at the National Arboretum was given the cultivar name 'Scupi' in 1998 and registered in 2000.]

789-34: "Buxus sempervirens. seed #133 E. Anderson. Treska Gorge, Skoplje, Yugo-Slavia. Oct 5, 1934. germ Dec. 27, 1934. 25 boxed Dec. 27, 1934." [According to Arboretum records, one specimen was planted on the grounds in 1950, and was reported missing in 1986. One plant from this seed lot at the National Arboretum was given the cultivar name 'Treska Gorge' in 1998 and registered in 2000.]

818-34: "Buxus sempervirens. seed #133 E. Anderson. Treska Gorge, Skoplje. Oct 30, 1934. germ June 20, 1935. 7 potted July 16, 1936." [According to Arboretum records, none of these seedlings were planted on the grounds or distributed.]

the Arnold Arboretum for two reasons: first, the stopover would cut down on the length of time the fragile material would spend in transit; and second, Anderson knew people at the John Innes Institute from the time he spent there in 1929. In one of the letters he wrote from Yugoslavia to Oakes Ames,[1] the supervisor of the Arnold Arboretum, Anderson listed the material he sent to the Innes Institute for propagation: "Cutting and plants of the following sent to London: *Hedera helix*—5 localities; *Taxus baccata*—1 locality; *Prunus lauro-cerasus shipkaiensis*—2 localities; *Buxus*—1 locality; *Ruscus*—2 localities."

The staff of the John Innes Horticultural Institute successfully rooted all four of Anderson's *Buxus* selections, and sent them on to the Arnold Arboretum, where they arrived on April 1, 1935, and were accessioned under numbers 350-35 through 353-35 [see box this page]. The Arboretum's propagator took a second generation of cuttings from the Innes Institute plants on April 2, most of which rooted and were potted up on December 3, 1935. At some point during the early 1940s, a number of these rooted cuttings were planted out on the Arboretum grounds amidst its other boxwood accessions.

Around this same time, in November, 1942, one plant each of the four cutting-grown selections and one seedling from accession number AA 789-34 were distributed to the geneticist Orland E. White,[2] Director of the Blandy Research Farm of the University of Virginia in Boyce, Virginia and to Henry Hohman, owner of Kingsville Nursery in Kingsville, Maryland. While other individuals and institutions undoubtedly received rooted cuttings of Anderson's boxwoods at a later date, it is likely that White and Hohman were the first to receive them because they were friends of Anderson's and both had special interests in boxwood.

In 1957, Donald Wyman, who had been appointed Arnold Arboretum horticulturist in late 1935 to replace Anderson,


*A high resolution scan of Anderson's original herbarium specimen for* Buxus sempervirens *#133 housed at the Harvard University Herbaria in Cambridge and incorrectly annotated as the cultivar 'Vardar Valley'.*

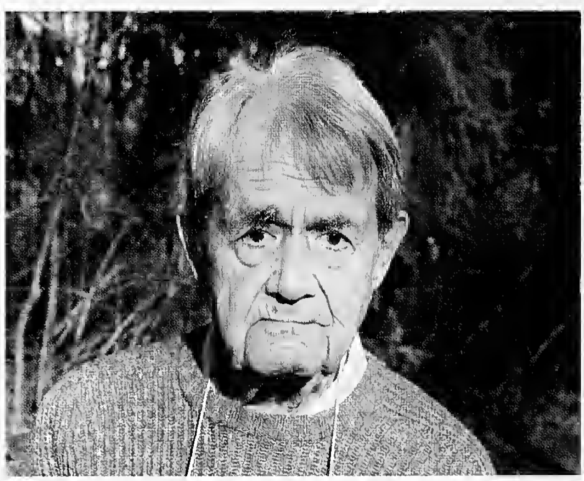
formally named one of his predecessor's boxwoods 'Vardar Valley.' In an article in *Arnoldia*, Wyman explained why the plant he selected was special:

> Eight plants were grown to size over a period of many years. Several of these were sent outside the Arboretum for trial elsewhere. Cuttings were sent to at least one commercial nursery which, in turn, rooted them and propagated more, selling the resulting plants [this was probably Henry Hohman]. Enthusiastic responses have come from several of these sources so that now it is thought wise to name this plant *Buxus sempervirens* 'Vardar Valley' and to start propagating it for a wide distribution. . . . Cuttings, rooted in 1935, have grown into plants that are now four feet across, with a fairly uniform flat top, but only two feet high. This habit is of outstanding importance, for it is low enough to be covered or partially covered by snow in winter, or else it is an easy matter to protect the plant in other ways when necessary. It is unlike other varieties of *Buxus sempervirens* in having this low, flat-topped shape. Apparently, it is as hardy as any clone we have yet tried. In January of 1957, the temperature dropped to -23° F at Weston, and although there was some snow on the ground, the top of the plant was not covered nor was it injured. A large plant in the Arboretum has not shown any marked winter injury. Reports from others in Cleveland show that it has withstood temperatures of -20° F there, and we know that it had withstood similar temperatures in Boston. The foliage is a glossy, dark green, similar to that of the species, while new young foliage is first bluish green.

### An Interesting Postscript

The story of 'Vardar Valley' is a worthy subject in its own right, but what really peaked my interest was a letter that Anderson wrote from the Balkans to Professor Oakes Ames, then supervisor of the Arboretum. I was reading through the archival material at the behest of my friend from Longwood Gardens, Dr. Tomasz Anisko, who was planning a trip to Skopje in the summer of 2007, and had asked me to help locate any of Anderson's original collecting books in the Arboretum Archives. The books weren't there, but the letters were. One letter in particular caught my attention; it was written on September 3, 1934, while Anderson was at the mouth of the Danube River in Salina-Tuscea, Romania, describing his earlier travels: "At Cluj my companion, Erhart Muller started back for the Harvard Medical School. He has been very helpful in many ways, gathering seeds, labeling packages, building up my German, and has greatly reduced traveling expenses since he always paid his half of cab and boat fare. I celebrated his departure by going to bed with an acute attack of diarrhea."

What stunned me about this passage was that I actually know Erhart Muller and that he is well and living in the town of Harvard, Massachusetts, about thirty miles west of Boston. I first met him in 1972, when I was living in Harvard and working at the Harvard Forest in Petersham, Massachusetts. I knew that Erhart had traveled with Anderson on his Balkan trip, but somehow failed to appreciate the full significance of this fact when he told me about it thirty years ago. It wasn't until his name popped out at me from a letter written in 1934 that the proverbial light bulb went on. Maybe Erhart had been with Anderson when he collected 'Vardar Valley' was my first thought. But the date of the letter in which he is mentioned, September 3, clearly indicates that he went home before Anderson collected the 'Vardar Valley' cuttings on September 19. So, in much the same way that I was foiled in my attempt to turn up either a photograph or herbarium specimen of 'Vardar Valley', I was thwarted in my attempt to locate a living witness to its collection.



AUTHOR PHOTOGRAPH

*A portrait of Erhart Muller, December, 2006.*

Nevertheless, I decided to pay Erhart a visit to see what he might remember about Anderson and their trip together. The answer is, as it turns out, not very much. Erhart was born in 1909—his father had immigrated to the United States from Barmen, Germany and his mother was a New Yorker of German descent. He grew up in the New York City area, spent a year at boarding school in Germany after World War I, and attended Harvard College where he studied anthropology. One highlight of his college days made newspaper headlines in April, 1929, when a small biplane he was traveling in was forced to make an emergency landing on Memorial Drive, a major roadway along the Charles River in Cambridge. Later, after graduation from Harvard in 1932, Erhart spent the summer in Montenegro with one of his professors, documenting the physiognomy of people living in the highlands.

Erhart first met Anderson—or Andy as he called him—in 1933, at the Keewaydin boy's camp on Lake Temagami in Ontario, Canada, famous then, as now, for its wilderness canoe trips. Erhard had been a camper there during a previous year and had returned for another summer to help out in the "running of the thing." Anderson was there to lead groups of campers on canoe trips. The two became friends and remained in contact after they both returned to the Boston area. Erhart remembers visiting Anderson at the Arboretum, not so much to

PHOTOGRAPHS AND LETTERS FROM THE ARCHIVES OF THE ARNOLD ARBORETUM

*Anderson's photo #17432 taken on September 2, 1934 at the Letea Forest Reserve in Valcov, Romania, at the delta of the Danube River. In a letter to Oakes Ames on September 3, 1934, Anderson described the scene: "The last two days have been spent on the ultimate delta of the Danube, hot in summer, cold in winter; a vast swampy region with a very low rainfall. One does not know whether to refer to it as a dusty swamp or a swampy desert. Among the ancient sand ridges there are long strips of a most peculiar forest. The topography reminds one strongly of the Lake Michigan sand dunes. Like them it has been made a natural reservation and is in charge of the department of forestry. . . . The great plant of the delta is Phragmites. It builds the land and like the palms of the tropics is used for everything. The young growth is forage, the dried canes are fuel, housing, roofing, fences, sticks, rafts!"*

## Balkan Boxwood, the "K-series"


AUTHOR PHOTOGRAPH

Buxus sempervirens *# 131-64 (K-24) at the Arnold.*

Anderson left the Arnold Arboretum at the end of the summer in 1935 and returned to the Missouri Botanical Garden, taking his interest in Balkan boxwood with him. Writing in *The Boxwood Bulletin* in 1963, he describes how he, "... got in touch by mail with the acquaintances I had made in the Yugoslav forest service[3] and imported a pound or so of boxwood seed which was raised at the Gray Summit Arboretum of the Missouri Botanical Garden."

Horticultural selections from Anderson's second importation of Balkan boxwood have come to be know as the "K-series" boxwood, as a means of distinguishing them from the earlier selections distributed by the Arnold Arboretum. The history of the K-series boxwood has been painstakingly pieced together by Mary Gamble in her articles in *The Boxwood Bulletin* published in 1975 and 1984. As she recounts the story, Paul A. Kohl, floriculturist at the Missouri Botanical Garden for forty years, told her that a boxwood seed arrived in September, 1936 from Anderson's contact in the Yugoslavian Forest Service. The seed, which had most likely been collected earlier that summer, was propagated in two locations, at the main garden in St. Louis by Kohl, and at Gray Summit Arboretum (now the Shaw Nature Reserve), about 35 miles from St. Louis, by Martin Bagby. Eventually, seedlings from both locations were brought together in a special boxwood nursery at Gray Summit.

In June, 1954 Anderson distributed cuttings from a number of these Balkan plants to the National Arboretum with cultivar names reflecting their Yugoslavian origin: 'Agram,' 'Nish,' 'Petch,' and 'Ipek,' all being ancient names for famous cities in the region. In 1955, following this initial cultivar selection and distribution, Mr. Clarence Barbré, a retired chemist and avid horticulturist from Webster Groves, Missouri, selected 155 of the Balkan seedlings at Gray Summit for further horticultural trial. These selections were assigned numbers preceded by the letter "K", which designated the Kingsville Nursery run by Henry Hohman, to whom the unrooted cuttings were sent for propagation and distribution.

Hohman rooted the cuttings and in 1957 and 1958 sent sets of plants under their original K-numbers to the University of Washington Arboretum in Seattle, the United States National Arboretum in Washington, DC, the Blandy Experimental Farm in Boyce, Virginia, and Longwood Gardens in Kennett Square, Pennsylvania. According to the latest research (2004) by Lynn Batdorf, the National Arboretum has fifty of the original plants; the Blandy Farm has twenty-nine; the Washington Park Arboretum has six; Longwood Gardens has twenty; and the Missouri Botanical Garden, including the Shaw Nature Reserve, has thirty-five.

The Arnold Arboretum received unrooted cuttings of 64 of the K-series boxwoods from the National Arboretum on January 29, 1964 (AA # 83-64 through 146-64), and still has three living plants from this distribution: #131-64 (= K-24), a conical plant, currently 11.7 feet wide by 13.3 feet tall; #113-64 (= K-33), a tall plant, 13.3 feet wide by 21.7 feet tall; and #116-64 (= K-75), a low-growing plant resembling 'Vardar Valley', 16.7 feet wide by 7.3 feet tall.

talk about plants, but to get some guidance from him about what he should do with his life. Probably because of Erhart's past experience in Montenegro and his ability to speak German, Anderson invited him to go on the Arboretum's expedition to the Balkans, planned for the summer of 1934. Erhart's memories of that trip are vague, but he remembered well one of the botanists they met, a Professor Stoyanoff from the University of Sofia in Bulgaria:

> He was probably the chief botanist there because he was the one who went botanizing with the king, Boris. And I was very much impressed with him. He seemed more aristocratic in demeanor. We went down by bus. The thing that impressed me tremendously was what a gentleman he was. A woman getting on the bus with quite a bit of luggage and so forth, he didn't try to press in ahead of her or anything. He treated her as though she has as much right to be there as he did—that sort of thing. I remember particularly later when we got to the monastery of Rila, and one of the monks there was really quite spruced up, I don't know what to say, but, he had long curly hair and that sort of thing. And I made the comment that it looks as though he had curled the hair, and this botanist, I think his name was Stoyanoff, said in response to my comment, "It is not impossible."

Indeed, Professor Stoyanoff's response could well be used to describe the serendipitous circumstances surrounding the discovery and propagation of *Buxus* 'Vardar Valley'.

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**Endnotes**

1 Ames had been one of Anderson's botany professors at the Bussey Institution and was appointed Supervisor of the Arboretum in 1927 following the death of its founding director, C. S. Sargent. I suspect that it was Ames who persuaded Anderson to work at the Arnold Arboretum in 1930 and that Ames's retirement in 1935 may have been a factor in his decision to leave. Anderson's 1952 book, "Plants, Man and Life" is dedicated to Oakes Ames, Orland White, and Carl Sauer.

2 Like Anderson, Orland White was one of Dr. East's graduate students, who earned his D.Sc. degree from the Bussey Institution in 1913.

3 For clues as to who this person might be, I turned to Anderson's undated "Report on Balkan Expedition to The Arnold Arboretum." In this document he mentions only one person who worked for the Yugoslavian Forest Service: "Herr Ing. Ohm, Forest Service, Skoplje [sic]. This forester, stationed at present in Skoplje is the best botanist actually located in the neighborhood, though he is liable to transfer at any time. He has an herbarium of his own and has a very real interest in botanical problems. Most of the foresters whom I met are more interested in hunting wild boars than in botanical problems allied to their work."

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Peter Del Tredici is Senior Research Scientist at the Arnold Arboretum and a Lecturer in the Department of Landscape Architecture at the Harvard Graduate School of Design. Edgar Anderson is one of his botanical heroes.

# Climate Change and Cherry Tree Blossom Festivals in Japan

*Richard Primack and Hiroyoshi Higuchi*

Climate change is already having an influence on plants throughout the world, with warming trends creating conditions that cause many plant species to extend to cooler zones on mountain slopes or farther north of their original ranges. Plants are leafing out earlier in the spring and holding leaves longer in the autumn, creating an extended growing season. Of all of the characteristics of plants that relate to global warming, the timing of flowering is the one for which there are the greatest number of observations. These data demonstrate that plants are now flowering earlier than they did a few decades ago, and that changes are mainly a product of temperature increase, rather than a result of other aspects of the weather. Although observations of flowering time tell a convincing story of the impacts

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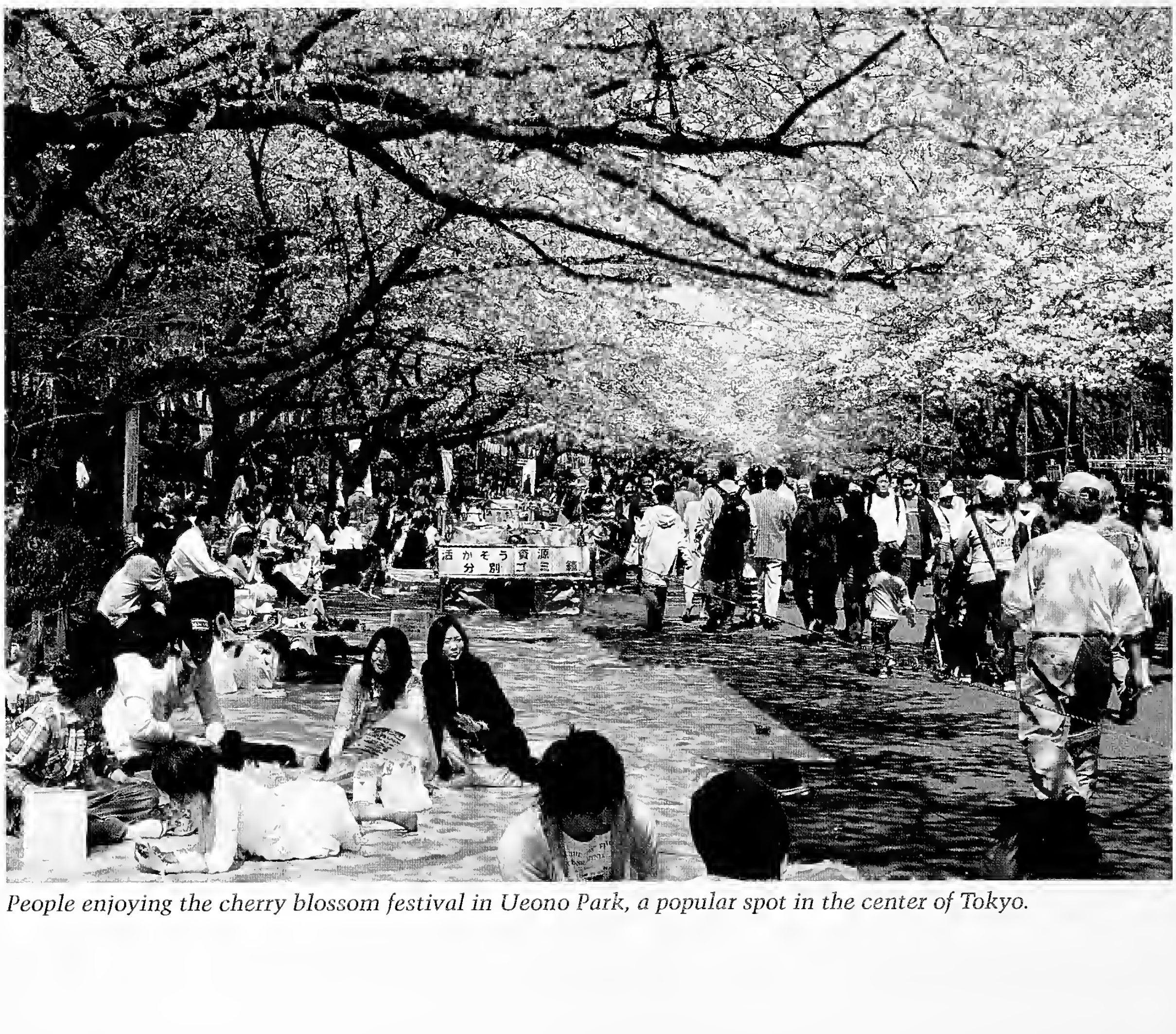


*People enjoying the cherry blossom festival in Ueono Park, a popular spot in the center of Tokyo.*

PHOTO COURTESY OF HIROYOSHI HIGUCHI

*A well-organized cherry blossom party being celebrated by a group of business people at Yasukuni, a park in the center of Tokyo.*

of global warming, the record extends back a mere 150 years, at most. The studies are predominantly from Europe, with a scattering of more recent studies from the United States, and many of these studies of climate change are from cities where additional warming is associated with urbanization. Scientists working on long-term climate change need additional studies from elsewhere in the world and conducted over a longer period of time. Such studies could provide evidence that the earlier flowering time—observed in Europe and the United States—is caused by a warming trend, a truly global phenomenon extending beyond the historical weather record of the 19th and 20th centuries.

### Kyoto Cherries as Indicators of Climate Change

A unique data set that can potentially supply these insights is the record of annual cherry blossom festivals in Japan. Cherry blossom festivals, or *Hanami*, are a special feature of Japanese life that really has no equivalent in other countries. During modern festivals, all ages spend time outdoors, enjoying the beauty of the cherry blossoms by day and by night, with their family, friends, and workmates. Festival activities include eating seasonal foods, such as bamboo shoots, rice cakes with red beans, and wild vegetables, playing games, listening to musical instruments, and singing. More enthusiastic pursuits include dancing and drinking sake—Japan's special rice wine—and beer. The festivals have been the subject of numerous poems and songs and have been depicted in paintings, pottery, and textiles for hundreds of years. Because of their great popularity and cultural significance, local governments, meteorologists, botanists, and newspapers have recorded the flowering times of cherry blossom times for an extraordinarily long time. In Kyoto, a beautiful ancient city on the main island of Honshu, the cherry blossom

PHOTO COURTESY OF HIROYOSHI HIGUCHI

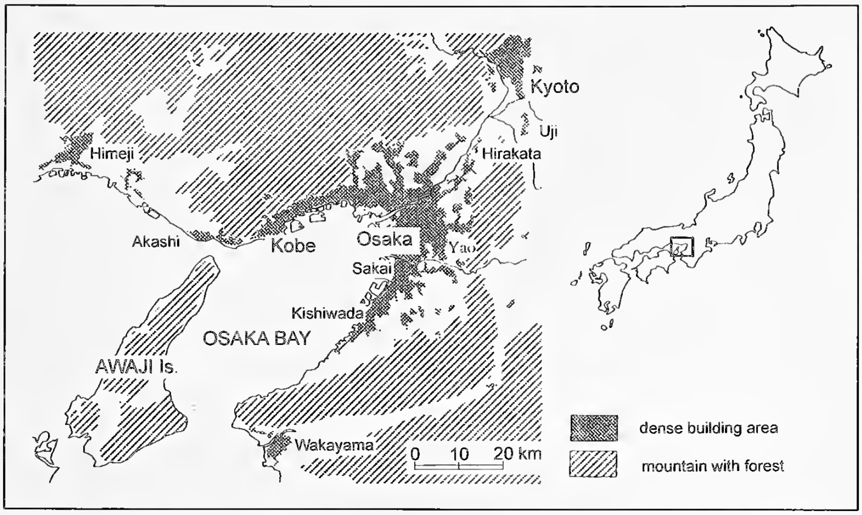
*People boating in the moat surrounding the Imperial Palace in Tokyo, when the cherry trees are in full flower.*

festivals have been part of court life for over one thousand years. The diaries of court officers often include mention of the festival dates, a peculiarity of the region's history that allows modern scientists to track the influence of a changing climate on flowering times.

Kyoto became the capital city of Japan in 784 A.D., and was the focus of a rich court life for several hundred years, a time known as the Heian Period. Cherry trees were prominently planted in the gardens of aristocratic residences, and cherries were an important imperial symbol. During the flowering period, people made special trips to visit particular sites around Kyoto to view cherry trees planted in attractive settings, such as temple gardens, and imperial parties went on excursions of up to several days into the surrounding Arashiyama hills to enjoy the cherry blossoms at their peak.

While double-flowered cherries and unusual cultivars were sought for the gardens of the nobility, ancient cherry blossom festivals focused on the blossoming of wild cherry trees, known in English as the Japanese mountain cherry and in Japanese as the *yama-zakura.* Scientifically this species is known as *Prunus serrulata* var. *spontanea,* or less commonly as *Prunus jamasakura.* It is typically found in the foothills of central Japan, often in secondary forests. In contrast with many other species of cherries, the mountain cherry is long-lived and easily raised from seed. Its white five-petaled flowers, about 1 to 1½ inches (5 to 8 cm) across, help with identification, and the species is more readily recognized because the young leaves are brownish-red to red in color, presenting a striking contrast with the green leaves of most other cherries.

The mountain cherry trees are still found in abundance around Kyoto and have been planted extensively in gardens. The hills of Arashiyama are especially noted for them. Paintings from






*The location of Kyoto and Osaka in Japan. The urban area of Kyoto is densely shaded.*

Kyoto depict boatmen paddling small boats in the nearby Oigama River, with their passengers observing the flowering trees on the riverbanks nearby and the hills above. And the Arashiyama Hills have featured prominently in Japanese literature, most notably as the occasional 17th century residence of the great Haiku poet Matsuo Basho.

For over eighty years, Japanese scientists have been examining court records and diaries from Kyoto to extract information on when the cherry blossom festivals have been celebrated in Kyoto. The date of the celebrations are determined several days before peak flowering by observations of the flower buds, and may be adjusted some days earlier if the weather is unusually warm or later if the weather is unusually cold. The past dates of the festival thus indicate when the Japanese mountain cherries were in full flower and provide an estimate of the temperature in that year. The earliest of these studies, published in 1939 and 1969, were carried out by meteorologists primarily interested in using this data to reconstruct past climate and to predict the timing of the modern cherry blossom festivals based on climate variables. The researchers were able to find fairly abundant records for the 15th and 16th centuries, with less complete records extending back to the 11th century, and forward to the present.

### Studies by Aono and Omoto

In the 1990s, the agricultural meteorologist Dr. Yasuyuki Aono of the Osaka Prefecture University, along with his colleague Yukio Omoto, began to search all available court records and diaries, with the goal of having a complete set of cherry blossom festival dates for Kyoto. These documents were stored in libraries, archives, and museums, primarily in Kyoto, Nara, and other historical centers of Japan. The documents were hand written in ancient Japanese script on paper and parchment. Over many years, Dr. Aono taught himself to read these documents, and he gradually converted them to modern Japanese characters. In addition, the dates on the documents corresponded to the Japanese calendar and had to be converted to the Western calendar. His lifetime goal of analyzing ancient and modern climate data has filled his modest office with boxes of photocopies of court records, old books, and computers.

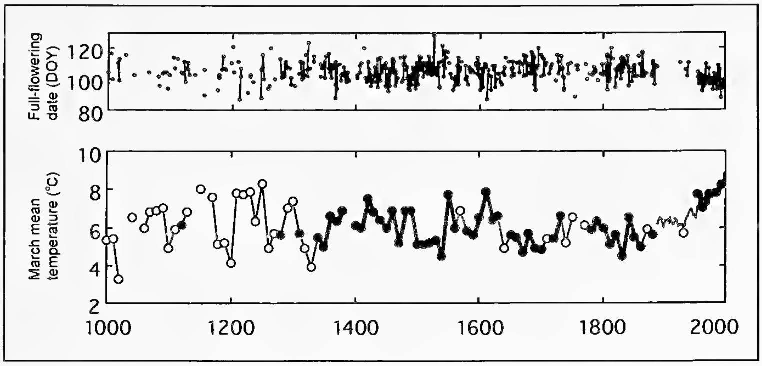
During fifteen years of dedicated searching, Dr. Aono was able to greatly increase the number of years for which there were dates of the Kyoto cherry blossom festivals, with many additional dates going back to the 11th century. From 1401 to the present time, a 605 year time span, there are now records of the festivals for most years. For the period 1476 to 1553, there is a record for every single year.

The cumulative flowering record shows a six week range in flowering dates from as early as late March to as late as early May. The extreme flowering dates are scattered throughout this time period. There are, however, periods of decades with earlier than average flowering and decades with later than average flowering. Many of the flowering records from the 12th and 13th centuries are noticeably earlier than average, along with the decades before and after 1600. In contrast, the period from the mid-1600s to the early 1800s is characterized by later than average flowering. After approximately 1830, the flowering times become progressively earlier. By the 1980s and early 1990s, average flowering times had become earlier than at any time previously during the entire flowering record of over one thousand years.

Using these old records and more modern temperature data, Dr. Aono's goal was to develop a model that could predict the modern flowering time of cherry trees from temperature data, then use this model to predict past spring temperatures from past flowering dates. The modern values used for calibrating the model come from the Arashiyama Hills, the same site where ancient court officials went for their parties. He and Omoto published the results of their work in the *Journal of Agricultural Meteorology* in 1994, a journal appropriate to his background in agricultural meteorology, and his appointment in a College of Agriculture within his university. Using a complicated equation, he was able to show that estimates of flowering time of the Japanese mountain cherry could be made using just the temperature in the months before the cherry trees flowered. These estimates using temperatures corresponded closely with the actual flowering times of


*Old court diaries and records let us know the past dates of the cherry blossom festivals in Kyoto. This diary of Tokistune Hiramatsu, a well-known court figure of the Edo era, provides the following entry on April 14, 1644: "In Seiryoden Palace, Kyoto, we enjoyed watching cherry blossoms and took sake provided by the emperor." The translation of the highlighted sentence is shown in red. The black entry is the date, according to the Japanese calendar.*

ARRANGED BY DR. YASUYUKI AONO, WITH PERMISSION FROM THE KYOTO UNIVERSITY LIBRARY




COURTESY OF DR. YASUYUKI AONO AND YUKIO OMOTO, 1994

*Upper figure. Known dates of the cherry blossom festival (full flowering of* P. jamasakura*) in Kyoto from the 11th century to the present time. April 1 is the 91st day of the year (in years without a Leap Year); May 1 is the 122nd day of the year. In recent decades, flowering times have become earlier than in the past.*

*Lower figure. Estimated March mean temperature in each decade, as calculated from flowering dates. Means calculated from 5 or more years are shown as solid dots. Decades with less than 5 years of data are shown as open circles. While temperatures have varied over this period, recent decades have been warmer on average than any time during the past 1000 years.*

cherry trees in Kyoto during the last few decades.

With this equation and past dates of cherry blossom festivals, Dr. Aono was then able to estimate March temperatures in Kyoto going back to the 11th century. Obviously the accuracy of the estimates depends on the number of years for which data exist, with the greatest certainty available for the middle and later periods of this one thousand year span. The calculations show that during the 11th through the 13th centuries, average temperatures were at their warmest averages, often as high as 8° C , as indicated by early dates of the cherry blossom festival. There were occasionally very cold years, as indicated by late flowering years, but on the whole this was the warmest average period. From 1400 to the mid 1500s, temperatures were variable, but they appear to have declined slightly on average. Certain decades, both before and after 1600, were noticeably warmer. In the following centuries, temperatures generally declined to 6° C, with particularly low temperatures in the periods from 1690 to the 1710s, and from 1810 to the 1830s.

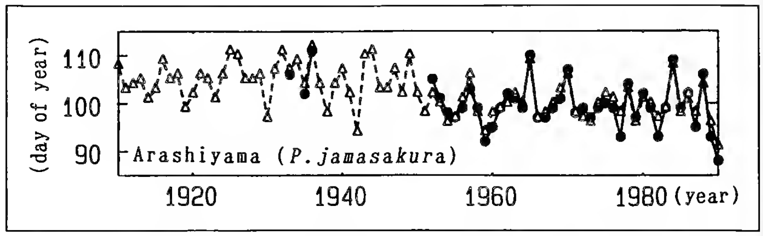
And by using estimates made from the cherry blossom records, over the past 170 years, Dr. Aono saw a general rise in temperature in the Kyoto area of 3.4° C. The estimated temperature increase during this period corresponds well to the increase in temperature recorded from regular meteorological records, and is attributed, primarily to the warming associated with the urbanization of the Kyoto area, and secondarily with the general global climate warming of Japan. If we assume that Kyoto has experienced the average global increase of 0.6° C , then the remaining 2.8° C is due to urbanization.

Dr. Aono has been active in tracking down ever more obscure historical records to fill in the remaining gaps in the records of Kyoto's cherry blossom festival times. He has located records going back even further in time, back to the early 9th century, and many scientists around the world are awaiting the published results of his new work.

**Cherry Tree Flowering Affected by Urbanization**

As mentioned above, cherry tree flowering times have been strongly influenced by the urban heat island effect, the warming that comes from the added heating caused by removing trees and replacing them with roads, parking lots, buildings and other aspects of a human-dominated landscape. In studies of the impact of global warming, it is important to separate the effects of localized warming caused by urbanization from the more general aspects of warming caused by global climate change. Cherry trees can be used to separate these effects because they are planted at many locations—in cities, suburban areas, and more remote rural locations. It is again Drs. Aono and Omoto who lead the way in this research.

The most widely planted cherry species since the late 19th century, and therefore the most useful for climate change research covering the past one hundred years, is Somei-yoshino (*Prunus* x *yedoensis*), also known in the nursery trade as the Yoshino cherry. This cherry is




*The flowering dates of mountain cherry trees* (P. jamasakura) *on the Arashiyama Hills outside of Kyoto have been getting earlier over the past 90 years; the different symbols represent different types of observations of flowering dates. Courtesy of Dr. Yasuyuki Aono and Yukio Omoto, 1994.*

almost certainly a hybrid between the Edo-higan cherry (*P. pendula* f. *ascendens*) and the Oshima cherry (*P. serrulata* var. *speciosa*). The somei-yoshino is the most striking of the cultivated cherries with a profusion of white to pink, five-petaled flowers that appear on the branches before the leaves are produced. The 1½ inch (4 cm) wide flowers are produced in umbels of three to four flowers. This hybrid began to be widely planted in the late 19th century, and is now commonly cultivated in Japan. In the view of many Japanese, the Somei-yoshino is the most beautiful cherry tree, and it has replaced the yama-zakura as the focus of the cherry blossom festival. This is the same cherry tree that is planted in Washington, DC, and enjoyed by Americans during the flowering season. Its flowering behavior is similar to the Japanese mountain cherry, so the results from the two species are comparable.

Due to the abundant records of cherry blossom festival records at numerous locations in Japan, it is possible to use the flowering dates

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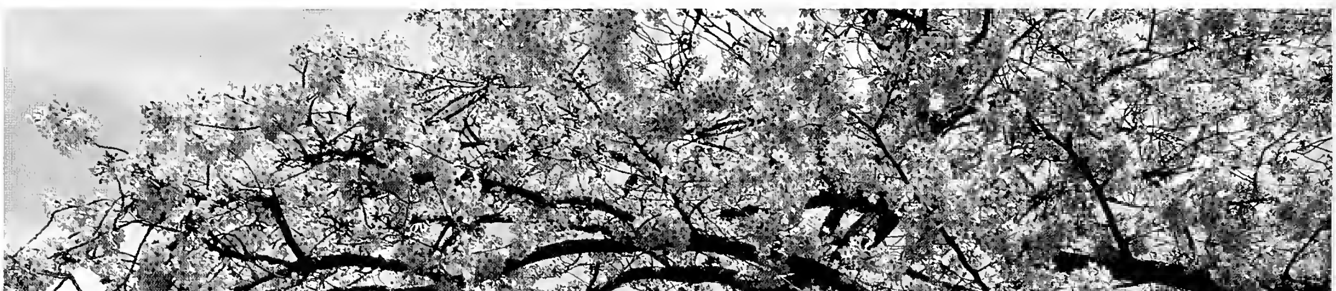
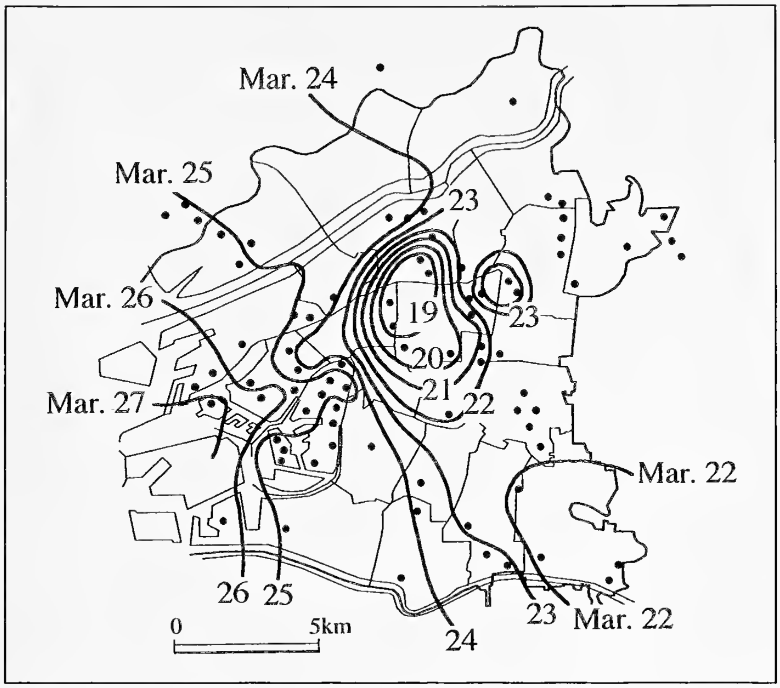


*A cherry tree in flower in the built-up center of Osaka, the second largest city in Japan.*

of the Somei-yoshino to measure how many days earlier plants flower as a result of the urban heat island effect. At locations near Kyoto, Osaka and Tokyo, urban, suburban, and rural locations had similar times of cherry blossom festivals in the 1950s. This indicates that urban, suburban, and rural areas still had essentially the same temperatures in the spring. Over the next 50 years, however, urban, suburban, and rural sites at each of these cities gradually began to diverge in flowering times, with urban areas flowering earlier than nearby rural and suburban areas. By the 1980s, the warmer temperatures in the city had shifted the flowering of cherry trees by eight days earlier in central Tokyo in comparison with nearby rural areas, and four to five days earlier in central Kyoto and Osaka than in their nearby rural areas.

The temperature effects of urbanization on flowering times for Osaka City have been mapped in detail. In 1989, the first flowering times of somei-yoshino cherries were recorded at around eighty locations in Osaka City. First flowering was recorded starting on March 19 at locations in the city center. Flowering was recorded at successively later dates at distances farther from the city center. At around seven kilometers from the city center, plants were starting to flower as late as March 22 to March 27, as much as eight days later than in the city center. The latest dates were found along the bay to the west where the cooling influences of the water may have caused a further reduction in temperature, slowing flowering. Cherry trees in a city park just northeast of the city center also have a delayed flowering, indicating a local cooling effect. Based on models that relate temperature to flowering times, Drs. Aono and Omoto were able to show that these earlier flowering times in the center of Osaka City correspond to a temperature increase of 1 to 1.5° C.




*Cherry trees were monitored for their flowering times in 1989 at numerous locations in Osaka, shown as black dots in this map. Isoclines are produced by a computer program to show the geographic pattern of flowering. Trees flower earliest on March 19 in the center of the city and progressively later at greater distances from the center. The latest flowering is along the coast to the west of the city, due to the moderating influence of the sea. A city park to the northeast of the city center also creates a small area of later flowering.*



**Conclusion**

The dates of cherry tree festivals in Japan have emerged as one of the most important sources of information on the impacts of climate change on plants. The data set is exceptionally detailed, and extends back in time more than any other known data set on plant flowering times. Because cherry trees have such great cultural importance in Japan, the results of this climate ehange research have been widely appreciated and publicized, both in Japan and among the international scientific community. Even the cherry trees in Washington, DC, donated by the Japanese government, are responding to higher urban temperatures by flowering one week earlier than in the past, providing an example of the biological impacts of climate change right on the doorstep of the American government.

## People and Cherries in Japan: The Shinagawa Family

The Japanese people often mark events in their lives by corresponding events in the natural world, and one of the most significant events on the Japanese calendar is the time of the cherry blossom festival. Mr. Fujiro Shinagawa, a well known psychologist and author of books on raising healthy children, often associates himself with the cherry blossom festival. He was born in Okayama Prefecture in western Honshu on April 15, 1916, a day on which the cherry blossom festival was being celebrated. As a child, the trees were always in flower on his birthday, and he considered himself a child of the cherry blossom. Living in Tokyo as an adult, however, the cherry blossom festival gradually moved forward in time and was celebrated before his birthday; in some years, the cherry trees had finished flowering by his birthday.

His twin daughters, Hiromi and Yoshimi, growing up in Tokyo from 1955 to 1965, associated cherry blossom festivals with their school opening ceremony—always held on April 8, an exciting day, when students, parents and teachers joined at the school for special activities. On that day, the cherry trees in the schoolyard were always covered in blossoms, creating a joyous start to the school year, and in some years, April 8 was even the day of the cherry blossom festival, creating a double holiday. But in the 1990s, when Hiromi sent her own son to school in Tokyo, the cherry blossom festivals were often held before April 8, and in some years the trees no longer had any flowers by that date. Hiromi felt that something joyous and beautiful was missing from her son's school ceremony without the profusion of cherry blossoms. But for her son, the earlier flowering time of cherry trees seemed normal.

At the retirement community in the western suburbs of Tokyo, where Mr. and Mrs. Shinagawa now live, the annual cherry blossom festival remains an important event. On this day, the staff put chairs and tables in the parking lot of their building, and serve a special meal under the gorgeous flowers of the cherry trees. Now, however, the date is typically at the end of March, two to three weeks earlier than in 1916, when Mr. Shinagawa, the cherry blossom child, was born.

PHOTO COURTESY OF HIROMI KOBORI

*Mr. and Mrs. Shinagawa and their grandson enjoying a cherry blossom festival on April 5, 1992.*

**Further Reading**

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Richard Primack is a professor at Boston University and a current Putnam Fellow. During the fall of 2006, he was in Japan working on the impacts of climate change with Professor Hiroyoshi Higuchi of the University of Tokyo. Prof. Higuchi is an ornithologist specializing in bird migration and conservation.

# The Future of Research at the Arnold Arboretum

*Robert E. Cook*

**In this article, the director of the Arboretum examines the role of research in botanical gardens, and the singular circumstances that position the Arboretum to become a center for the scientific study of plants. In this context, he discusses plans for a future research program on the biodiversity, genomics and developmental biology of plants.**

I recently came across the title of an opinion piece that I thought I should read. "What genes make a tree a tree?" was published in the May, 2005 issue of *Trends in Plant Science* by Andrew T. Groover. A decade ago I would have passed over this title without notice. But the Arnold Arboretum has recently put forward a plan to make a major investment in molecular and genomic approaches to research on the biology of woody plants and this research will call upon the resources of our living, herbarium and library collections. It will also cost a lot of money. Because the Arnold Arboretum receives no funds from the University (we are financially self-sufficient, depending almost entirely on past and present philanthropy), a large invest-

PETER DEL TREDICI

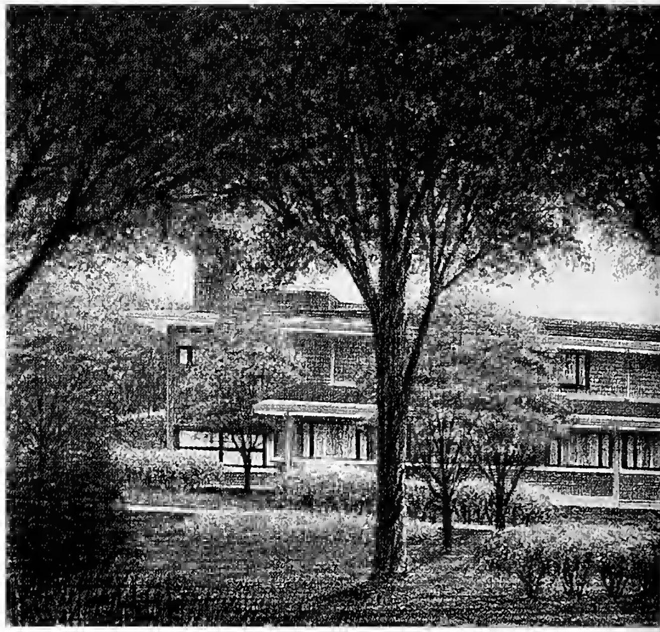
*The oak collection at the Arnold Arboretum in late spring.*

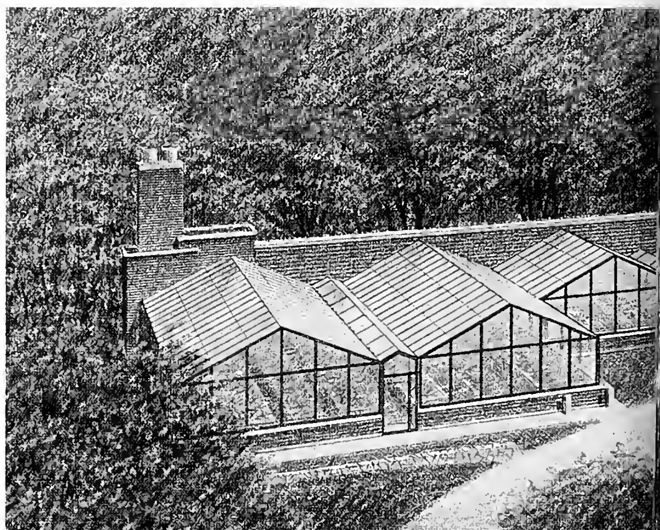
ment in research presents a major financial challenge to the institution. Let me discuss collections-related research in more general terms first, and then return to those genes that make a tree a tree.

Over the past couple of decades, directors of many botanic gardens and arboreta, especially those associated with colleges and universities, have wrestled with the question of the role that research should play in their institution's mission. In part this reflects the historical roots of botanical collections gathered and curated as a basis for advancing knowledge of the botanical world and as an important foundation for economic advancement and commerce through the development of new plants. At modern research universities, the substantial budget allocations once enjoyed by botanical collections have increasingly come under scrutiny by the administration as the research use of those collections, particularly living collections, has shrunk in importance. Likewise, the availability of external research funds from federal agencies to support the use of living collections (to say nothing of their upkeep) is non-existent. In many public gardens and arboreta, the purposes of the living collections have expanded to include educational and horticultural display values which have surpassed any research use the collections may have once served. This leaves the fiscally conscientious director to ask: how important a role should research play in the mission of the organization?

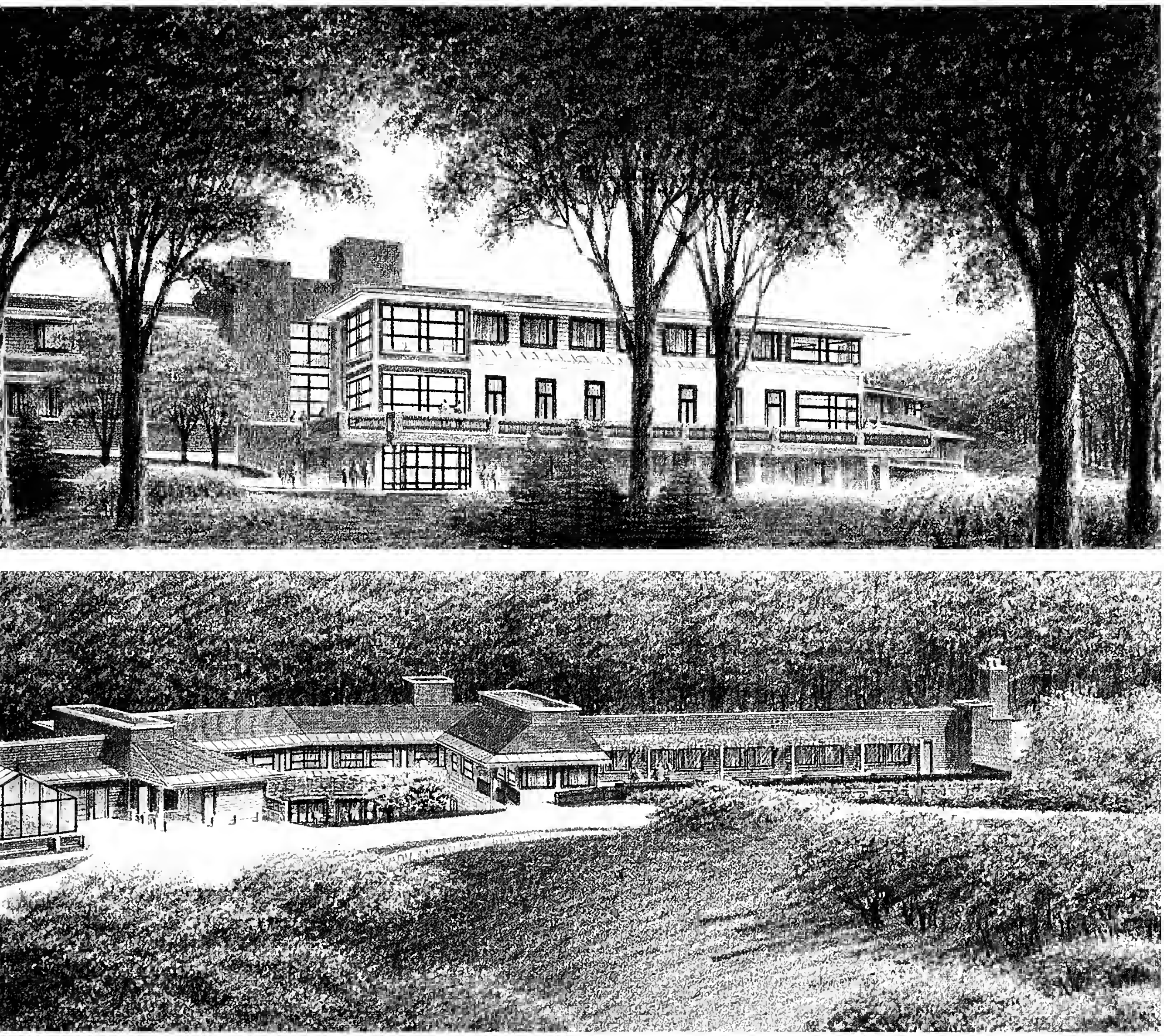
**Supporting a Research Function**

For many institutions whose mission is fundamentally educational, supporting a research dimension confers great interest and legitimacy in the eyes of the institution's supporters. The investment required may be modest and the rigor of the research can be high if pursued systematically. The research can bolster the primary mission to educate and increase scientific literacy. But major research investments require a realistic assessment of what will be the cost of achieving long-term, high quality results as judged by publication in peer-reviewed journals. Most institutions are not well positioned to make such open-ended investments.





Since research comes in many flavors, very different financial implications accompany the initiation of a research program. In the simplest case, an institution may create a formal monitoring protocol designed to provide environmental and horticultural data with which to improve the care of collections whose primary functions are aesthetic and educational. Gathered systematically over longer periods of time, such data may also yield valuable insights into local trends related to larger environmen-



*The proposed research facility on Weld Hill as designed by KlingStubbins Architects.*

tal variables such as climate and soil chemistry. Depending upon the scope of the measured variables, and the quality and duration of the monitoring records, this can yield publishable information that constitutes valuable research. The creation of such formal programs can, but need not, require expensive equipment; rather, it requires a long-term commitment to the management and evaluation of data, and its subsequent publication. These days the web can be an excellent medium for providing inexpensive access to this information.

Beyond the gathering of data for the purposes of collections management, research investments are often motivated by the desire to discover unknown aspects of the natural world, by the application of existing knowledge to the development of improved horticultural plants

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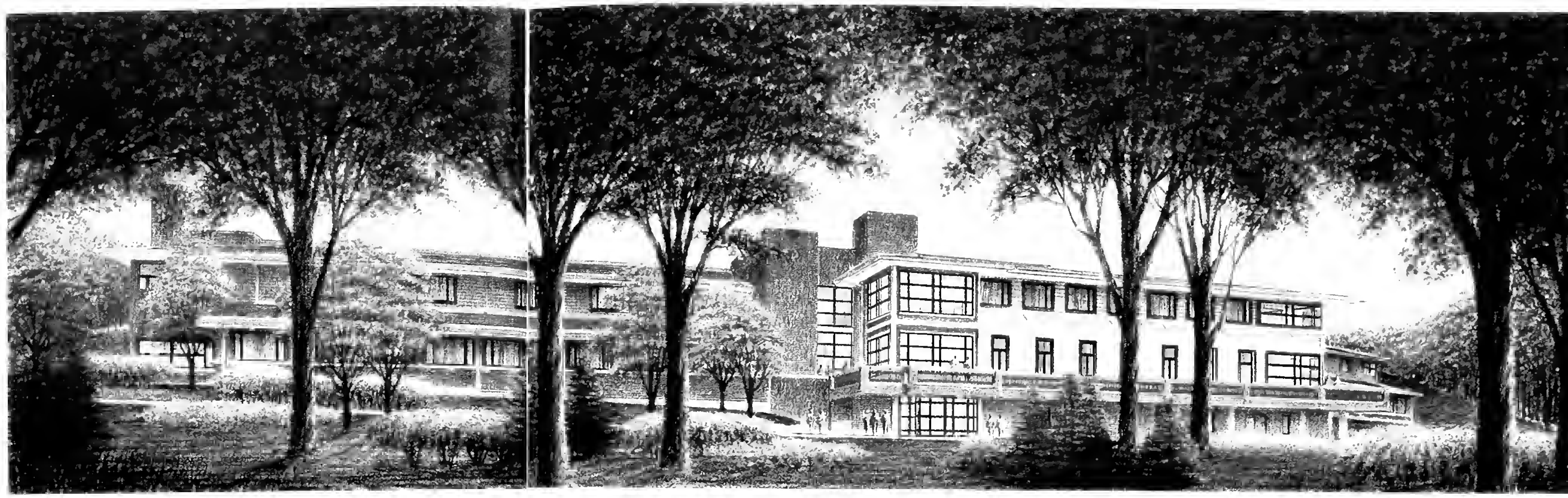

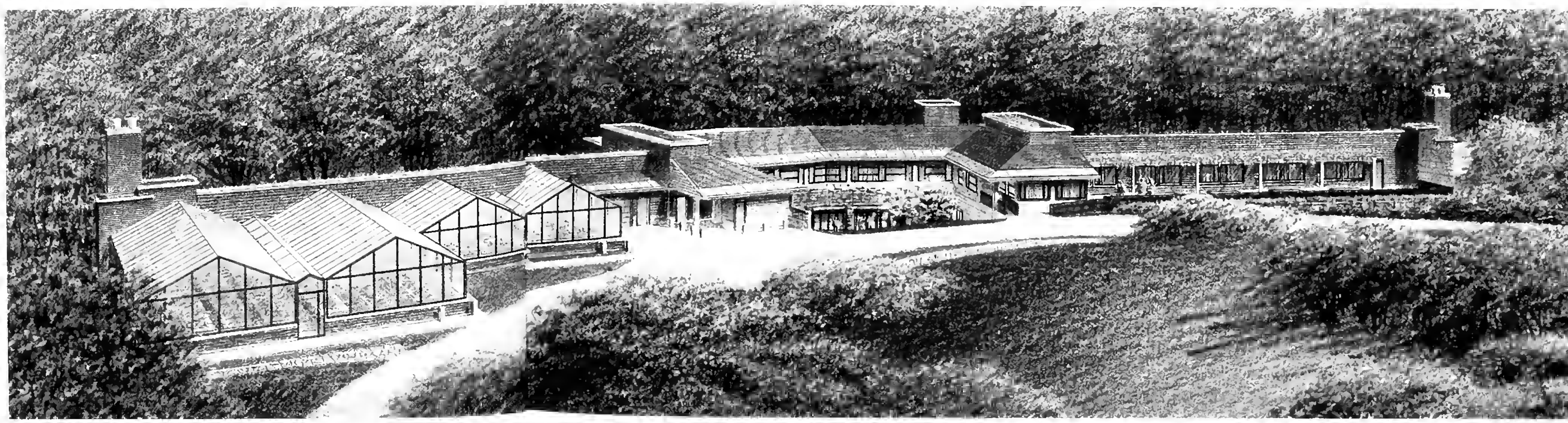

*The proposed research facility on Weld Hill as designed by KlingStubbins Architects.*

Beyond the gathering of data for the purposes of collections management, research investments are often motivated by the desire to discover unknown aspects of the natural world, by the application of existing knowledge to the development of improved horticultural plants

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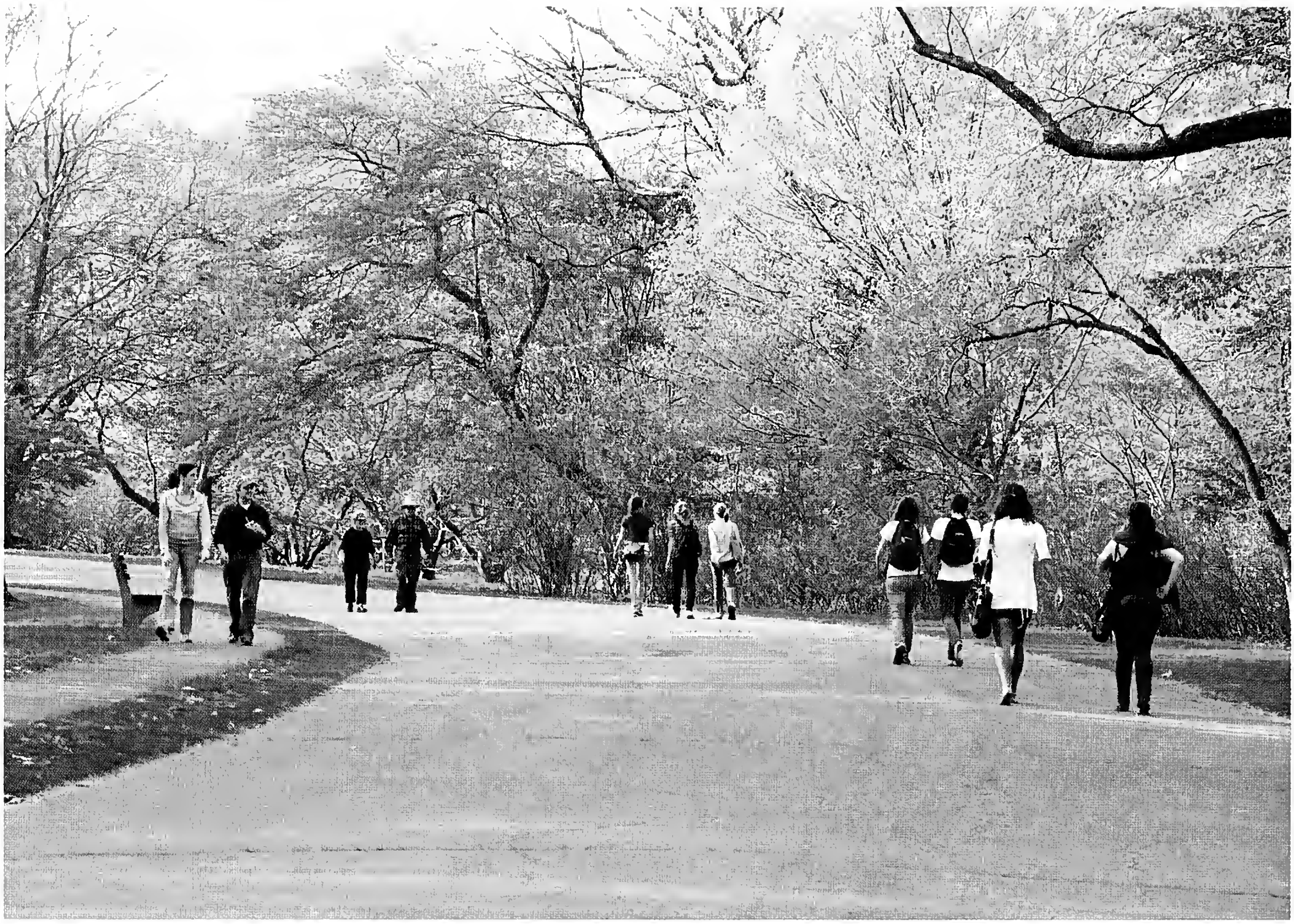

*A well-laid out research collection can be enjoyed by people with little or no interest in science.*

(stress tolerance, pest resistance, morphological variety, urban horticulture), or to the testing of specific hypotheses about the evolutionary history and functional biology of plant diversity. Whether an institution should invest in any or all of these types of research, and how much investment is appropriate, depend very much on the specific circumstances of that institution.

**Discovery Research**

Among large botanic gardens in this country that are involved in discovery research, the Missouri Botanic Garden and the New York Botanic Garden clearly stand out as leaders. Both institutions continue to mount major efforts in botanical exploration at multiple locations around the world, and this work is accompanied by significant publications in plant floristic and monographic research. The Arnold Arboretum, by virtue of its age and history, and in collaboration with other botanical institutions at Harvard University (the Gray Herbarium, the Botanical Museum, the Farlow Herbarium, the Oakes Ames Orchid Collection) maintains a modest effort in this type of research, and it will continue to do so in the future, with particular emphasis on the floras of Asia. Absolutely essential to this kind of work is the collection and maintenance of a large herbarium (over 5 million specimens at Harvard) and the related library collections (280,000 volumes, 900 current journals) without which such research would be impossible. In recent years, this type of research has been complimented at the Arboretum with molecular systematic studies utilizing its well documented living collections. Of particular interest are phylogenies that relate to our understanding of the biogeography and evolutionary history of the disjunct floras of eastern Asia and eastern North America.

**Improved Horticultural Plants**

The use of the living collections of a botanic garden or arboretum for the development of better plants for agricultural production, for landscape use in suburban and urban settings, and for improving basic mechanisms of stress tolerance and pest resistance has been closely tied to the land grant university system with its long history of support from the Department of Agriculture and related commercial sources. The research mission of botanical gardens within such a setting will always depend upon its relationships with various research departments (horticulture, crop physiology, plant breeding) and the idiosyncratic needs of faculty members and senior research scientists for the resources of the gardens. Directors of these gardens may feel captive to these academic sources of power and funding, and independent investment in research not defined by faculty needs and external funding sources can be politically risky. Of course, independent institutions outside the academic system of universities have much greater leeway to pursue problems of applied research of their own choosing.

**Evolutionary Relationships and Functional Biology**

Basic research into the evolutionary history and functional biology of plants has generally been less closely allied with botanical gardens than with academic departments of botany, biological sciences or ecology and evolution. On the face of it, the great diversity of the living collections of botanic gardens and arboreta would seem a particularly valuable resource for such research, especially for comparative experimental approaches to addressing functional and evolutionary questions about plants. Twenty-five years ago, my predecessor as director, Professor Peter Ashton, put forth a vision for the use of the living collections of the Arnold Arboretum to investigate basic questions of plant functional biology in an evolutionary context. At that time, however, Peter's vision did not find fertile soil among his faculty colleagues and he was unable to implement it.

There are a number of challenges facing a director inclined to invest in such research. Generally large questions of this nature require the development of specific hypotheses about mechanisms and controls that can only be addressed through experimental designs using molecular, genetic, and biochemical approaches. This kind of research can only be done in a highly sophisticated laboratory setting with expensive equipment and protocols. Technical support is essential and, therefore, expensive. Senior research scientists usually establish large labs consisting of multiple technicians, post-doctoral researchers, undergraduate assistants, and several graduate students working on elements of the problem at hand. The research is highly collaborative, both within the laboratory setting and among different labs located at other institutions. Funding the research requires a continual flow of money, most often provided by the federal government through grants from organizations like the National Science Foundation. This system of funding is closely tied to the peer review system that dominates both the publication of results from such research and the advancement of faculty members through traditional ladder positions within university departments.

As this implies, the director of an independent botanical garden needs to think twice before embarking upon such research investments without having in place close working relations with an academic institution that can provide access to students and faculty resources. The investment in modern research laboratory and growing facilities must be of a large scale to attract the quality of researchers able to support their research through successful, peer-reviewed grant applications. Finally, an institution will want a critical mass of such researchers, at least five or six senior scientists, each capable of supporting a laboratory staffed with up to half a dozen technicians and students. The hiring of each is usually accompanied by significant start-up requirements (laboratory equipment, laboratory assistance until the first grants are received). It is all a very expensive affair and it can't be done in incremental steps.

**Investing in Research**

At the Arnold Arboretum, we are prepared to make such an investment. Ironically it will be very much based on the vision of research with the living collections articulated by Professor Ashton twenty-five years ago. How can such a vision succeed today if it was not able to do so two decades ago?

Two major advances in the biological sciences have fundamentally altered the context surrounding such a vision. First, the proliferation of molecular approaches to investigating the evolutionary history of organisms has dramatically altered our understanding of the phylogenetic relations among species. This new understanding provides a solid evolutionary foundation for the comparative study of the functional and developmental biology of closely and distantly related species. Second, with the sequencing of the human genome in the past decade, biological science has made tremendous advances in creating genetic and molecular tools for investigating basic questions about the functional and developmental biology of organisms. These tools have led to the subsequent sequencing of the genomes of the tiny herbaceous plant *Arabidopsis thaliana,* in the mustard family, and the first woody plant in the genus *Populus* as model species for the understanding of plant biology at the genetic and molecular level. Over the coming decade, the genomes of a number of other species will also be partially or fully sequenced, creating an immense opportunity for comparative studies of plant diversity.

To provide just an illustration of this, let me briefly return to the publication, "What genes make a tree a tree?" Woody stems, of course, develop from growth in the vascular cambium that is generated by meristematic stem cells whose daughters differentiate into the carbohydrate-conducting phloem and water-conducting xylem (wood). As Andrew Groover, the author of this article, points out, "trees" may be categorized at the local nursery as a group based on the presence of a woody trunk; but it is a completely artificial classification. Nearly all orders of higher plants in the Angiosperms contain tree-like species and many families have both herbaceous and woody species. Because woody growth is evolutionarily ancient and probably predates the divergence of Angiosperms and Gymnosperms, the appearance of woody taxa may be a matter of degree rather than a trait that has arisen uniquely within a single lineage. Even within a species, the expression of woody growth can depend upon environmental conditions. Not surprisingly, then, we find that woody species on remote islands have evolved rapidly from closely related, herbaceous ancestors on the mainland. Groover concludes that the genes regulating woody growth ought to be evolutionarily ancient and common to all taxa, ought to be present in a broad range of taxa including herbaceous species, and ought to be readily modifiable to express or suppress woody growth in the process of speciation or in response to changes in the environment.

With the sequencing of the genomes of the herbaceous species *Arabidopsis* and the woody species *Populus,* scientists can now determine whether woodiness in the latter species depends on genes not found in the former species. In fact, the same genes that regulate primary growth in the shoot apical meristem in *Arabidopsis* are also involved in the regulation of secondary growth in *Populus.* Thus these genes are probably present, but suppressed, in many herbaceous species. Tree forms therefore reflect differences in the expression of a similar set of genes that are present in a vast number of taxa. Woodiness—the genes that make a tree a tree—could be studied and artificially manipulated in almost any species. Groover argues that this fundamental understanding, and the genetic tools that have led to it, will usher in a revolution in approaches to increasing our knowledge of woody plants.

**The Arnold's New Research Initiative**

I believe that these new approaches to addressing basic research questions about the evolutionary diversification of plants through a deeper comparative understanding of their functional biology should be at the heart of the Arnold Arboretum's research mission. At the same time, I do not believe that this should necessarily serve as a model for other botanical gardens and arboreta. The Arnold is in a relatively unique position because of several important factors. First, we have an exceptionally well-documented collection of woody taxa, many of known wild origin. Second, we are part of a university able to provide a constant stream of students (if not money) and a brand identity that can be immensely helpful in recruiting the finest scientists. Finally, a long history of philanthropy has created a substantial endowment able to provide a dependable financial foundation upon which to build new programs.


*Sarah Matthews collecting leaf tissue from* Cedrus deodara *growing at the Arboretum.*

To staff this large investment in research, the Arboretum has created a new type of research position which we have named Sargent Fellows. We intend to recruit individuals of the highest quality as judged by their colleagues and permanent appointment will require rigorous peer review. Two Sargent Fellows are currently appointed. Sarah Matthews is an expert on the molecular biology and evolutionary history of the light sensing pigment phytochrome in plants, and Maciej Zwieniecki studies plant hydraulics, the microfluidic systems that control the long-distance movement of water, solutes and energy from roots to leaves.

In 2007, we will break ground for the construction of a $38,000,000 laboratory and greenhouse facility able to support up to eight senior researchers and their associates. This state-of-the-art facility will also serve to integrate the research efforts of our Sargent Fellows with those of faculty and students in Cambridge through common use of greenhouses, growth chambers and experimental gardens. This substantial investment will return the Arboretum to the forefront of basic research on the biology of trees. As Peter Ashton stated shortly after arriving as director in 1979, "Only if it maintains its preeminence in research and education can the Arnold Arboretum continue to develop its complementary function as a unique public amenity and an authoritative source of information on the culture of woody plants."

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Robert E. Cook has been director of the Arnold Arboretum since 1989. An earlier version of this article appeared last year in *Public Garden*, vol. 21, no. 1.

# The Arnold Arboretum's Living Collections: A Repository for Research

*Michael S. Dosmann*

As Bob Cook has expressed in the article preceding this one, the Arnold Arboretum is embarking on a dramatic programmatic expansion into research. This includes housing an expanded research staff in a modern facility sited on Weld Hill, adjacent to the Peters Hill section of the Arboretum. As the newly appointed Curator of Living Collections charged with overseeing the development and enhancement of this most precious of Arboretum assets, this new initiative has served to focus much of my energy on the dynamic interplay between living collections and scientific research. As a result, in the coming months, the Arboretum will be unveiling a new collections policy that will reaffirm its commitment to research.

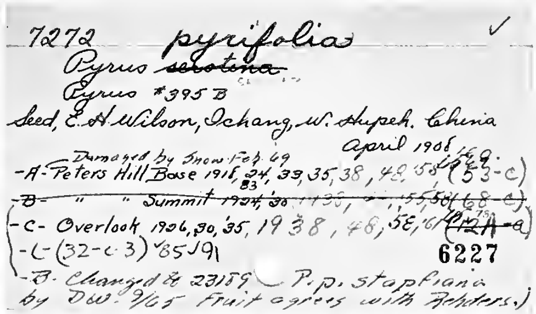
While the resurgence of a strong research agenda is heartening for the Arboretum, it does not seem to be a trend being followed by similar institutions. Over the past decade, many members of the natural history collection community, which includes a full spectrum of museums, herbaria, zoos and aquaria, have been concerned about their future. Despite their intrinsic value, some of these collections, particularly those affiliated with universities, have become fiscally endangered and are at risk of abandonment by their parent institutions. At the very core of the issue is a decline in collections-based research. Dubbed a "crisis" by those in the field, this state of affairs has prompted an array of discussions and calls-to-arms demonstrating the vital importance collections have to science and to society (Krishtalka and Humphrey, 2000; Dalton, 2003; Pekarik, 2003; Miller et al., 2004; Suarez and Tsutsui, 2004).

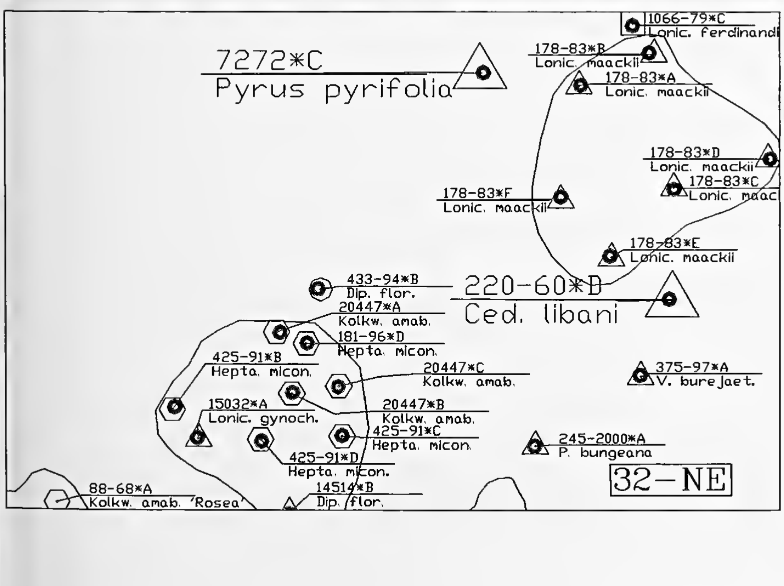
While following these dialogues, I was puzzled by the absence of botanic gardens and arboreta—long-standing members of the collection's community—from the debate. Even more surprising was the discovery that there was very little discussion within the botanic garden literature about the collections crises and its implications for research. I began to ponder a broad question: What does the future hold for collections-based research in our gardens and arboreta? What eventually came to fruition was a review, published last year in *The Botanical Review* (Dosmann, 2006), of the historical and contemporary literature related to living plant collections, the research derived from them, and strategies and tactics that gardens and arboreta can take to avert their own crisis. This article summarizes some of that work, describes the central role the living collections can play in supporting research, imparts some rationales and approaches for fostering collections-based work in the future, and frames several take-home-messages in light of the Arnold Arboretum's mission and history.

### Research in the Collection: Why is it Important?

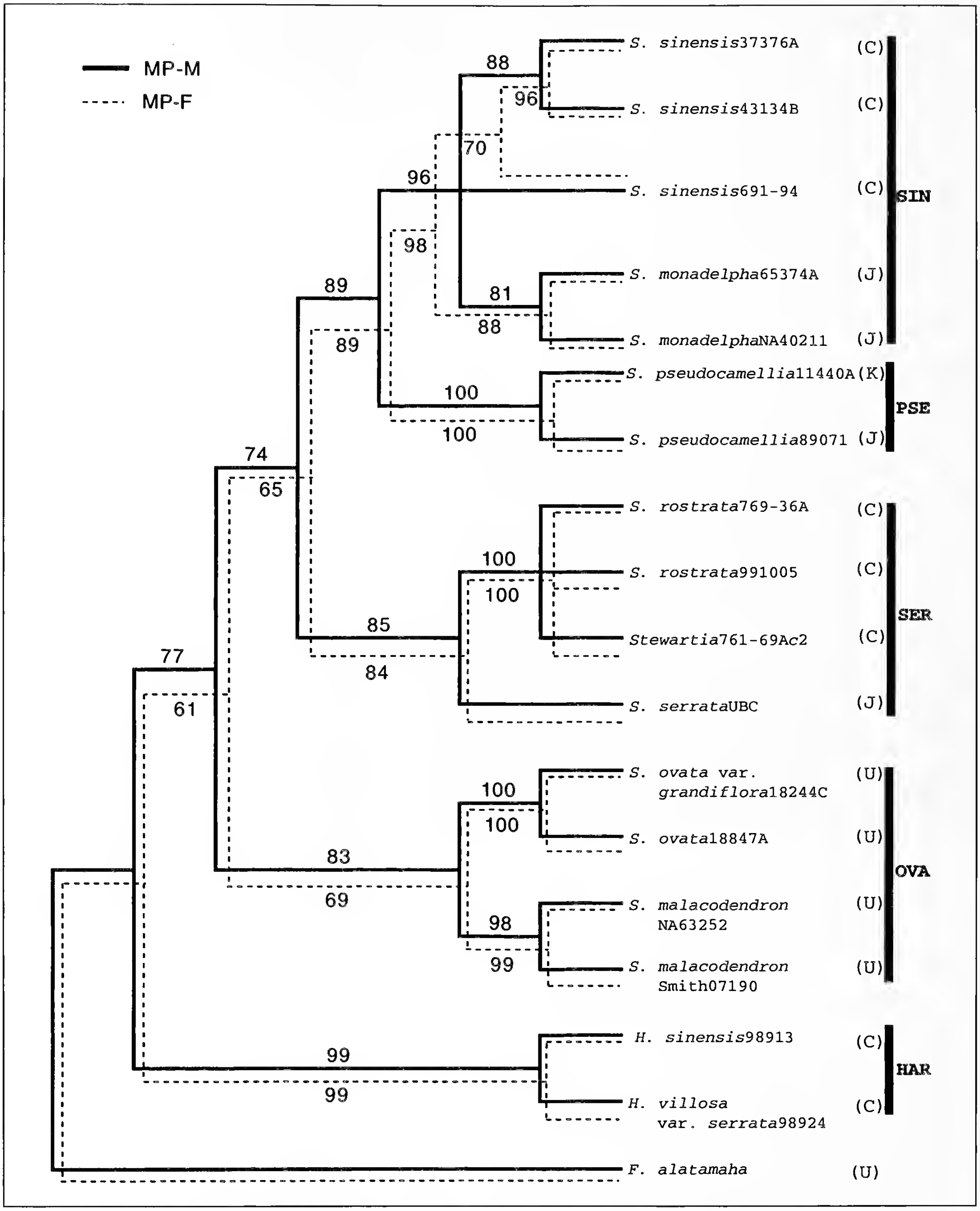
There are many reasons why research is important to botanical gardens, and I would like to highlight but a few. Because of their original missions and mandates, many instititutions are obligated to engage in research activities, even if it is only to accommodate requests for material by off-site researchers. At one time it was argued that "no institution is privileged to call itself a botanical garden unless it is doing research of some kind and to some degree" (Steere, 1969). Estimates of the number of gardens and arboreta whose collections are used in research vary considerably, from 10% (Raven, 1981) to nearly 50% (Sacchi, 1991; Watson et al., 1993), depending upon the type and nature of the institution. Regardless of the percentage, a common perception among curators is that their collections are underutilized for research (Rae, 1995). It should be noted that while research may play a central role in numerous gardens and arboreta, oftentimes that which is lauded is field-based floristics and genomics rather than collections-based and could occur in the absence of curated living collections (see Marris, 2006; Nature, 2006).

Due to trends within academia, gardens and arboreta are some of the last bastions where collections-based research can occur because of the combined presence of documented accessions and trained staff. Here at the Arboretum, with the planned construction of the new research facility and the expansion of its staff, the research potential of the collections ought to increase dramatically. Not only will the scientists have full access to the plants, but as they observe them on a daily basis, hypotheses will flow freely and experimental results will become easier to interpret. It is also important not to underestimate the off-site pool of researchers who must rely upon gardens and arboreta as a source of material. All too often, the cost


7272 pyrifolia ✓
Pyrus ~~serotina~~
Pyrus #395 B
Seed, E. H. Wilson, Ichang, W. Hupeh. China
April 1908
Damaged by Snow Feb. 69
-A- Peters Hill Base 1918, 24, 33, 35, 38, 48, 58 (53-C)
~~-B- " " Summit 1924, 30~~
-C- Overlook 1926, 30, 35, 1938, 48, 58
-C-(32-C-3) 85 91
6227
-B- Changed to 23159 P. p. stapfiana
by DW. 9/65 Fruit agrees with Rehders.)


*Collection documentation increases its value. This sand pear* (Pyrus pyrifolia), *AA 7272-C, growing on Bussey Hill was collected by E. H. Wilson near Ichang, Western Hubei Province in 1907 and accessioned in April of 1908. Original accession cards were used to record information until the late 1980s, when the data were transferred to a computerized database. Computer-generated maps make it easy to locate plants in the field, and accession tags that hang from the plant contain essential information. Photos by M. Dosmann.*




*As illustrated in this phylogenetic tree of* Stewartia *(From Li et al., 2002), living collections are frequently used by researchers studying biogeography. In this analysis, molecular data derived from documented Arboretum accessions were used to delimit relationships between Old World and New World* Stewartia *taxa.*

(both in time and dollars) of assembling collections at their own institutions is prohibitive, making places like the Arboretum a vital resource, especially for individuals working with limited budgets.

In a very practical way, research can pay a dividend for gardens and arboreta because it actually improves the management and care of their collections. Every time an accession is targeted for study, it is accessed and evaluated by a member of the curatorial staff. This increase in field-check frequency allows for timely evaluations of the plant's condition and when necessary (e.g., poor health), appropriate maintenance or vegetative repropagation can occur. At the same time, the accession records are reviewed, previous information is checked for accuracy and new information is added. This includes a notation that the accession was used in a research project, and oftentimes notes or observations the researcher may have made. These periods also provide opportunities for additional voucher herbarium specimens to be collected, if necessary. Also, one of the best ways to ensure verification is to encourage its use as a reference collection for taxonomic studies. The various additions to the records increase the collections' value and also catalyze future discovery, for those collections with a history of characterization serve as benchmarks against which future results can be compared. This has been demonstrated in other germplasm repositories where researchers prefer to characterize accessions that had been previously studied. To put it another way, a collection's value is directly linked to its "past, present, and future uses" (Widrlechner and Burke, 2003).

**Research in the Collection: Making it Happen**

Maximizing the potential for collections-based research requires several things, the most important of which is strong advocacy. In 1984, Judy Zuk posed an important question to the curators of botanic gardens and arboreta: "Are our collections underutilized because we have not been successful advocates, or because we are advocating a resource for which there is no widespread demand?" In light of the current collection crisis, her question is still timely. My answer to both parts of the question is a qualified yes: we must be better collection advocates, and we must work to increase their demand among a range of users.

Here at the Arnold Arboretum, collection advocacy is well-established and the historic link to scientific endeavors is strong. In fact, Ida Hay's 1995 history of the Arboretum, *Science in the Pleasure Ground,* epitomizes this connection. By declaration of the indenture signed by the trustee's of the will of Mr. James Arnold and the President and Fellows of Harvard College, the arboretum was established on the 29th of March, 1872 with a clear collections-based mandate: ". . . [to] contain, as far as is practicable, all the trees, shrubs, and herbaceous plants, either indigenous or exotic, which can be raised in the open air at the said West Roxbury." The appointment in November of the following year of Charles S. Sargent to the position of Director of the Arboretum and Arnold Professor set into motion the realization of this mission. In one of his earliest reports, Sargent (1877–78) described his research vision for the Arboretum: "In such a museum, every thing should be subservient to the collections, and the ease with which these can be reached and studied; and none of those considerations of mere landscape effect, which properly govern the laying out of ordinary public parks, should be allowed to interfere with these essential requirements of a scientific garden, however desirable such effects undoubtedly are." From day one, it was clear to Sargent what the priorities of the Arnold Arboretum should be.

As a word, *research* was not part of the printed lexicon in the early days of the Arboretum; however, as a process of *science,* it most certainly was a priority. In his many written statements, Sargent often placed research activity under the scope of *education* and the Arboretum's general goal to "increase the knowledge of trees." In his fifty year review of the Arboretum's accomplishments, written in 1922, he outlined the key components to its dramatic success: "a collection of living plants arranged for convenient examination and study . . . the distribution of surplus material obtained in the Arboretum explorations, and . . . the publication of the results of the dendrological investigations carried on in its laboratories."

As an example of planning, Sargent and Frederick Law Olmsted arranged the collection according to Bentham and Hooker's natural classification sequence outlined in *Genera Plantarum.* This not only increased its educational value but facilitated comparative studies among related plant groups (Spongberg, 1989). Less well known is the fact that the original plan also took in to account comparisons beyond the taxonomic. For many North American species, Sargent (1922) intentionally sited individual specimens in the open as well as in groves, so "that they may show their habit under different conditions." While the term did not exist at the time, this demonstration of phenotypic plasticity (the capacity of a species to adjust its morphology or physiology in response to distinct environmental conditions) was part of a larger plan for studying the interaction between plants and their environment.

The development of the living collection under scientific auspices was clearly part of the culture and its importance extolled by others in addition to Sargent. In describing the Arboretum to the broader museum community, Ernest H. Wilson wrote in 1924 that it was different from many other public arboreta, because while "[i]n many countries individuals have planted collections of trees . . . such collections lack scientific control and permanency, and sooner or later they disappear without having made any great addition to knowledge. It has been left to Harvard to establish the first garden which is exclusively a *tree museum* and which has the size and the promise of permanency necessary for success in its field."

More recently, Arboretum leadership has lauded the use of living collections in meeting research needs and goals. In his maiden report as new director, Peter Ashton wrote in 1979: "We have, perhaps, thought of the herbarium as our principal center of research, but we must not underrate the research potential offered by the living collections. . . . Opportunities exist here for basic research to bridge the traditional divisions between biology, horticulture and forestry." This mantra launched a vigorous restoration of the Arboretum's living collection, as well as a modernization of its curatorial practices (Ashton, 1989). And now, this well-documented collection of woody plants is first among several anchors as the Arboretum positions itself to achieve preeminence in studying the evolutionary history and functional biology of trees.

Beyond advocacy, gardens and arboreta must continually evaluate their collections, enhance their value, and develop them through steady acquisition—a static collection is the antithesis of a working collection. This includes shifting perspectives of what may constitute a research collection. They may be long-term and obligatory collections, like the six genera the Arboretum grows as part of the North American Plant Collections Consortium *(Acer, Carya, Fagus, Stewartia, Syringa,* and *Tsuga);* they may be short-term and discretionary collections, such as the *Crataegus* assembled for study by Sargent on Peter's Hill or plants grown for a specific experiment; or some place in between. Regardless of their position on this sliding scale, it is important to document intended use(s), priority, and commitment.

It also behooves us to broaden how we intellectually categorize our collections. Traditional types of classification (e.g., taxonomic, phytogeographic, habitat, use) have served gardens well and will continue to do so, yet other designations (e.g., conservation status, expedition, collector, cultural significance, research project, location in the garden) can also be used to maximize both their interpretive and research potential. In this regard, it is important to recognize that a single accession can fall under multiple collection categories. For example, a lone katsura tree, *Cercidiphyllum japonicum,* may occupy a place in an institution's taxonomic (Cercidiphyllaceae), geographic (Eastern Asia), conservation (threatened), ecological (disturbance-induced stem sprouting), collector (E. H. Wilson), horticultural (trees with outstanding autumn color), educational (specimens included centenary tree tour) and research (dimorphic leaf project) collections. Also, the collection may contain unaccessioned plants found in natural areas of the grounds, or may extend outside the institution's boundaries (see Box on page 35 describing the 1980 SABE collection). With

## Case Study: Tracking the Fate of the 1980 SABE Living Collections

In 1980, the Arboretum participated in the Sino-American Botanical Expedition to the Shennongjia Forest District, Hubei Province, a monumental trip that not only improved scientific ties with China, but yielded a considerable amount of valuable herbarium and germplasm material (Bartholomew et al., 1983). New and notable introductions to cultivation included *Magnolia zenii, Heptacodium miconioides, Sorbus yuana,* and *Rubus lasiostylus* var. *hubeiensis.* All told, 621 germplasm collections were brought back to the United States and divided into equal shares among the four participating institutions (The Arnold Arboretum, The US National Arboretum, the University of California Botanical Garden at Berkeley, and the Cary Arboretum, which at the time was affiliated with the New York Botanical Garden). There was some sharing of excess germplasm by the individual institutions, including a distribution of nearly the entire Cary Arboretum's lot during the 1983 American Association of Botanical Gardens and Arboreta meeting, however no system had been in place to document what material was distributed and to whom it was distributed.

In 2000, Peter Del Tredici and I began to sleuth the fate of those plants collected on the trip. We pooled the Arboretum's extant holdings of SABE plants with those of the other participants and nearly 30 other institutions we suspected had SABE material, to create a master database. Upon analyzing these and other archival data, we drew some conclusions that were informative on many levels (Dosmann and Del Tredici, 2003; Dosmann and Del Tredici, 2005). At the core, we found 258 (42%) of the original collections to be alive, however what was startling was that 115 (45%) of these existed as a single accession growing in a lone garden, arboretum, or USDA research facility. The fact that nearly half of the plants in cultivation were at extreme risk of loss clearly demonstrates that the process of plant introduction is much more tenuous than generally assumed. Perhaps most importantly, we recognized that without sharing of collection information, institutions have no way of determining the uniqueness of their own collections. After putting our database on-line, we shared it with Quarryhill Botanic Garden which combined it with its own botanical inventory to create a Database of Asian Plants in Cultivation (DAPC): http://www.quarryhillbg.org/DAPC/DAPC.htm. Continuing to grow, the DAPC provides collection information on documented Asian germplasm and serves not only as a valuable resource for collection managers and curators, but provides a catalogue for researchers as they seek germplasm for study.

the aid of databases and other information systems, it is now much easier to see collections in the multiple dimensions within which they exist and appreciate their unlimited research potential.

In addition to advocating and redefining their collections, gardens must concomitantly advocate and redefine perceptions of collections-based research. As I consider the Arboretum's living collections, I see research potential across a wide swath of disciplines—far too many to list here. For certain, taxonomic and horticultural research will continue to be important areas of study, as will work in plant conservation and natural products. I also foresee the collections becoming more valuable in areas not traditionally studied using living plant collections, such as ecology and developmental biology. For these and other fields, our concept of collections-based research must be broad, spanning a scale that includes the multiple genomes residing within a given accession, genotypic responses to the abiotic environment, and interactions between plants and other organisms.

While Peter Ashton lauded the work on model systems because of their use in experi-

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*The 1980 Sino-American Botanical Expedition yielded over 600 collections of seeds, cuttings and plants. SABE 1084 was a collection of but 16 seeds of* Staphylea holocarpa, *and four of each were sent to the four participating institutions. However, only one seed germinated and that was one at the Arnold Arboretum: AA 59-81A. When this tree flowered, it was found to be of the pink-flowered type, and its name was changed in 1991 to* Staphylea holocarpa *var.* rosea. *Because of its rarity, the Arboretum has been attempting to vegetatively propagate this accession.*

mentation, he (1981) went on to state "There is no doubt that future research must be directed increasingly at developing the technology required to expand this dangerously slender base, and competently curated collections, particularly of living plants, will prove invaluable." As we seek to apply the lessons gleaned from *Arabidopsis thaliana* and other models to the diversity within the plant kingdom, the Arboretum's collection is well positioned because of the genetic diversity it comprises. Our accessions of documented wild origin will continue to be important in illuminating mysteries related to genetic variation, adaptation, and biogeography. We should not discount the research potential of cultivated taxa—particularly those cultivars that are aberrant forms of the botanical species—as they may find new footing in the research of the future. Just imagine the typical ornamental border: a colorful circus of cuticular waxes, pigment combinations, bizarre leaf and floral morphologies, contorted habits, atypical growth rates, and unusual tolerances to environmental stresses. These ornamental mutants, in many ways similar to those found in the contrived collections of *Arabidopsis*, could well become important research collections of tomorrow.

Ever the seer, Ashton also recognized that a living collection's research potential could never be exhausted, that there would be a constant need for its use, growth and development.

It does not require clairvoyance to realize the basic premise that new technologies and new research interests always have a way of shedding light on old, "anachronistic" collections. Many museums have found this to be true, impacting collections of mummies (Irving and Ambers, 2002), preserved pigs (Larson et al., 2005), and dried plants (Stern and Eriksson, 1996). When a new perspective is brought to a collection, discovery follows. Take for instance the paintings of Caravaggio, which have been extensively studied by artists and historians. When scrutinized by a horticulturist, these works, in unanticipated fashion, revealed a unique glimpse of the crop diversity, pests and diseases present in the late 16th and early 17th centuries of the Old World (Janick, 2004).

Living plant collections are no different, and those amassed for one reason frequently become useful for others. Countless synoptic collections assembled for taxonomic comparison have been extremely practical in the screening of natural products for medicinal use, an area of research that will become more important as natural populations of plants become threatened in the wild. Harrison Flint (1974) recommended plant collections would be ideally used to study phenology, and recently they have been—not to examine genecology as he suggested but to study climate change (Primack et al., 2004; Wolfe et al., 2005). Sometimes the unanticipated use is the result of unfortunate events, leading to the application of the adage "When life gives you lemons, make lemonade." Ongoing research at the Arboretum on the hemlock wooly adelgid includes studies on forest floor regeneration, biogeochemistry, and the identification of replacement hemlock species. When it comes to the last, it is doubtful that when E. H. Wilson collected a single plant of Chinese hemlock, *Tsuga chinensis,* in 1911, he had in mind that this accession would play a key role in understanding the behavior of the insect (Del Tredici and Kitajima, 2004).

Because one cannot predict the future, a challenge presents itself: How to prepare the Arboretum's collections for these unanticipated research needs? There are two areas where the institution can plan accordingly. The first deals with the nature of the collections and what makes them valuable. As future development of the collection ensues, it is important to target taxa (genera, species, populations, clones) that are not only unique to the Arboretum's holdings, but also have a greater than normal reseach potential. For example, future acquisitions to the six genera grown as part of the North American Plant Collections Consortium will be to specifically bolster their status as world-renown reference collections. Clearly, an accession's value is directly proportional to the information attached to it, and that which may lie in waiting. Thus, it is crucial that new additions have as much of the desired passport information related to their source as possible, and for accessions already in the collection, we

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*Studying gas exchange in the field on the golden-rain tree,* Koelreuteria paniculata.

must attempt to repatriate any collection information that may have been lost over the years. It is also important that collaborating researchers have ready access to all types of collections data in order to be able to select the plants best suited to their projects. Luckily, the Arboretum continues to obtain material whose origin is well documented, and as we improve our ability to track and document research usage, the accessions become more robust benchmarks for future assessment.

The second area of preparation is associated with the researchers themselves. One dilemma that living collections often face is the inability of researchers to know what gardens have to offer; conversely, gardens often do not know what researchers need (Rae, 1995). Such problems are particularly acute when researchers are located off-site, but they can also occur between and among staff members employed by the garden. As researcher pools expand into nontraditional disciplines, it is ever more important for gardens to engage these audiences directly and build the necessary relationships. The late Arboretum director, Richard Howard (1970) was an early proponent of a system where researchers outside of the garden and arboretum world could seek out and obtain research material in cultivation. Now, with the advent of the internet, access of collections to potential researchers is vastly improved, in part answering Howard's call. The Arboretum's website allows researchers to search for accessions in the living collections inventory, as well as vouchers held in the cultivated herbarium.

Beyond access to the living collections themselves, the Arboretum can provide scientists with a wealth of other things, including affiliated collections (records, archives, images, herbarium specimens), expertise, greenhouse and lab space, and even financial assistance in the form of grants and fellowships. Although the institution may be the primary provider in this relationship, there are also things that researchers can do in return for collection access. One of the most basic is following-up when the project is completed, which includes sending updates and/or reprints of any published work. I have found that while nearly all gardens and arboreta request this, it unfortunately occurs less than a third of the time. It is also important that results that did not make it into publication because of their anomalous or questionable nature be reported, particularly when the study is taxonomic in nature, as they may indicate that the name on the label is not correct. Researchers are also able to assist with the development of the living collection by donating well-documented plant material. By understanding and valuing the mutually beneficial relationship between the Arboretum and researchers, we can more ably respond to, and meet, the future needs of science.

When it comes to the collections crisis afflicting other museums, gardens and arboreta are not immune. However, with strong collection advocacy and commitments to the collections use in research, I believe the future to be bright. In fact the relevancy of gardens and arboreta will only continue to increase as they become dynamic citadels comprising living plant collections and specialized botanical expertise. As for the Arboretum specifically, it is well poised for this future because of its historic and contemporary commitments to collections and research. With the physical manifestation of a research center on site, our living collections will become more bountiful and valuable.

**Acknowledgements**

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# The Paperbark Maple—One Hundred Years Later

*Peter Del Tredici*

The living collections of the Arnold Arboretum hold many important trees, but few are as significant as two of its paperbark maples *(Acer griseum)* which are celebrating their hundredth anniversary this year. Not only are these trees exquisitely beautiful, but they are also the oldest specimens of this rare Chinese species growing in North America. One of them is the well-known, low-branched individual growing on Bussey Hill along Chinese Path (see inside back cover), while the other is much taller and grows at the edge of the maple collection near the Bradley Garden of Rosaceous Plants (see front cover). Given their status as the original introduction of this highly ornamental species into North America, it is worth telling the story of how these two landmark trees came to be growing at the Arboretum.

In the fall of 1907, Ernest Henry Wilson collected at least two seedlings of paperbark maple in Hubei Province, China. In his field notebook for this trip, under the number 719, Wilson entered the following notation: "Acer griseum. tree 25–50 ft. margin of woods 4500–6000 ft. North Plants." Ten years later, in 1917, Wilson rewrote this cryptic entry in Volume III of *Plantae Wilsonianae,* edited by C. S. Sargent. The following entry appears on page 427: "Acer griseum: Western Hupeh: north of Ichang, margin of woods, alt. 1500–2000 m., 1907 (No. 719; trees 8–16 m. tall; plants only)." According to our card files, two of the *Acer griseum* seedlings that Wilson collected under number 719 in Fang Xian, in Hubei Province, were accessioned in December 1907. They were originally assigned accession number 5813-2, which was later changed to 12488, the number under which both trees are still listed today.

Among botanists, the maple family is notorious for having complex flowers, and *Acer griseum* is no exception. Technically the species is considered to be "androdioecious," which means that some individuals produce only staminate (male) flowers while others produce perfect flowers with both male and female parts. Individual "A", near the Bradley Garden, is a male specimen that produces no seed and stands some 64 feet tall (19.5 meters), with a spread of 44 feet (13.5 meters), and a diameter at breast height of 28 inches (70 centimeters) at the age of 100. Individual "B" has a more unusual form, having lost its leader some time ago. It stands only about 30 feet tall (9 meters), with a spread of 38 feet (11.5 meters), and a diameter of 37.5 inches (95 centimeters) at two feet off the ground. It produces perfect flowers and regularly produces viable seed which germinate spontaneously under the tree. This specimen was undoubtedly the source of the first generation of paperbark maples planted in North America. Indeed, the Arboretum's distribution records indicate that seedlings of *Acer griseum* were first distributed in 1927, some twenty years after its introduction from China. All together some 79 seedlings, 4 seed lots, 3 packets of scions, and 1 packet of softwood cuttings of *Acer griseum* were distributed to various plant collectors and nurserymen between 1927 and 1945, firmly establishing the species in North American gardens.

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# arnoldia

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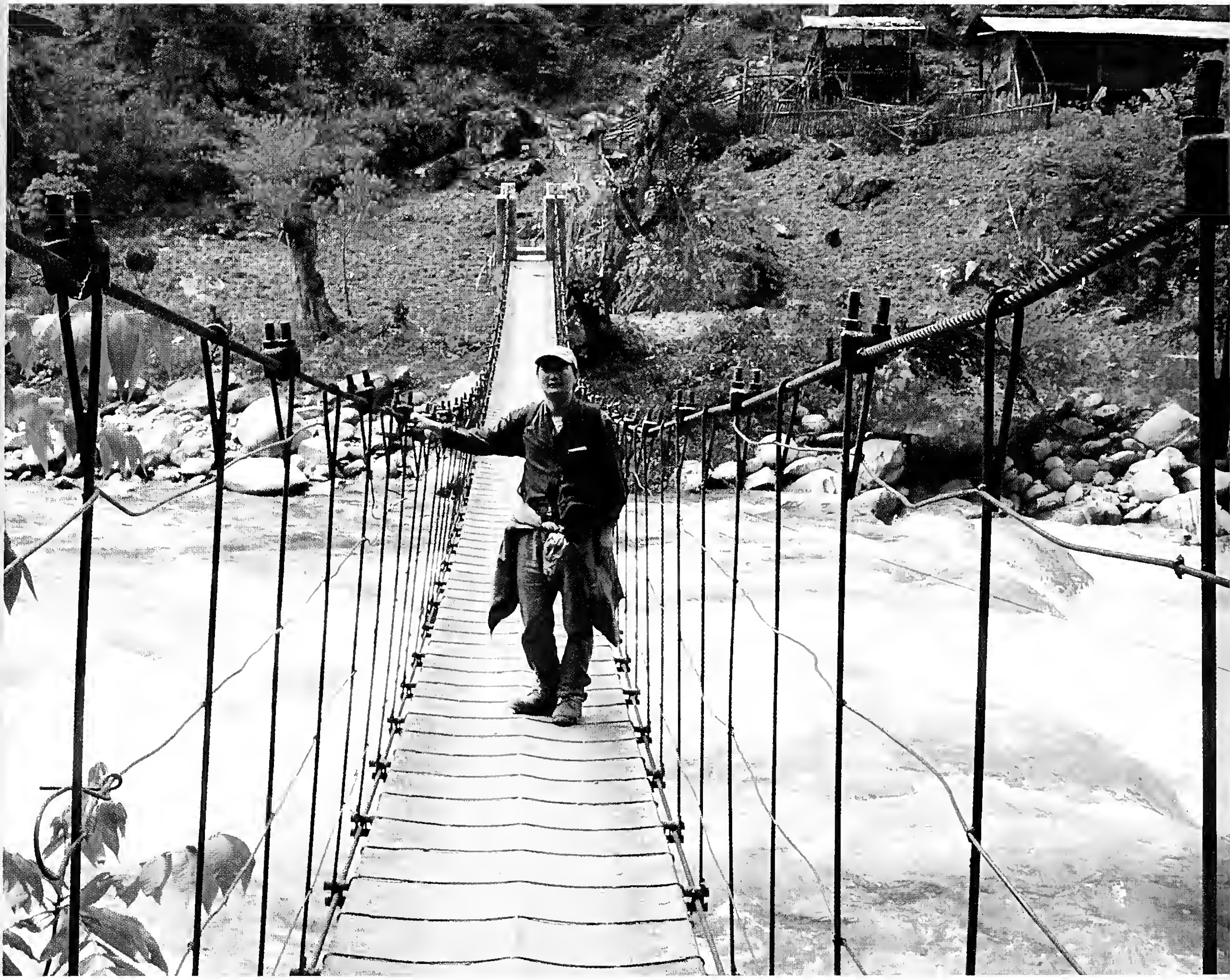

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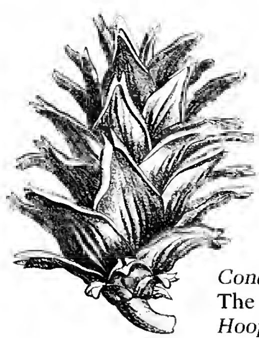
*Front and back covers:* A stand of *Tsuga dumosa* growing on Luoji Shan, Sichuan Province, China, photographed in August 2005 by Peter Del Tredici.

*Inside front cover:* Dr. Jianhua Li crossing over a river near Gongxhan Xian, Yunnan Province, China, photographed by Jin Xiaohua.

*Inside back cover:* The Golden Larch *(Pseudolarix amabilis),* AA #16779-A, in full fall color near Bussey Brook at the Arnold Arboretum, photographed by Michael Dosmann.



*Cone of* Pseudolarix amabilis *from* The Book of Evergreens *by Josiah Hoopes, published in 1868.*

# The Role of Arboreta in Studying the Evolution of Host Resistance to the Hemlock Woolly Adelgid

*Nathan P. Havill and Michael E. Montgomery*

The hemlock woolly adelgid, *Adelges tsugae,* is an introduced pest of hemlock which is, unfortunately, all too familiar to many readers of *Arnoldia.* Adelgids are a small family of sucking insects, related to aphids, which feed only on conifers[1]. Because they are so small and typically not very common, most adelgids usually go completely unnoticed by all but a handful of entomologists that specialize on them. This can change dramatically when an adelgid species is transported outside of its native range into an ecosystem that is not adapted to keeping it in check. In the United States and Canada, this was first experienced with the balsam woolly adelgid, which killed millions of fir trees (genus *Abies*) in first half of the 20th century and continues to severely threaten these ecosystems. We are now seeing similarly devastating effects by the hemlock woolly adelgid (HWA) on eastern hemlock, *Tsuga canadensis,* and Carolina hemlock, *T. caroliniana*[2].

In this article, we will take a worldwide look at the relationship between the adelgid and its various hemlock hosts. While most of our research was done with plants growing in their native habitats, we also made extensive use of cultivated hemlocks growing in various botanical gardens around the world, including the Arnold Arboretum. The living collections and herbaria at these institutions have proved to be an invaluable resource for us in developing an evolutionary context for understanding hemlock resistance to HWA. In addition, the records and herbarium specimens from expeditions sponsored by the Arnold Arboretum—from the time of E. H. Wilson and Joseph Rock through the Sino-American Botanical Expedition of 1980—were invaluable in helping us to pinpoint where to look for hemlock specimens in southwestern China.

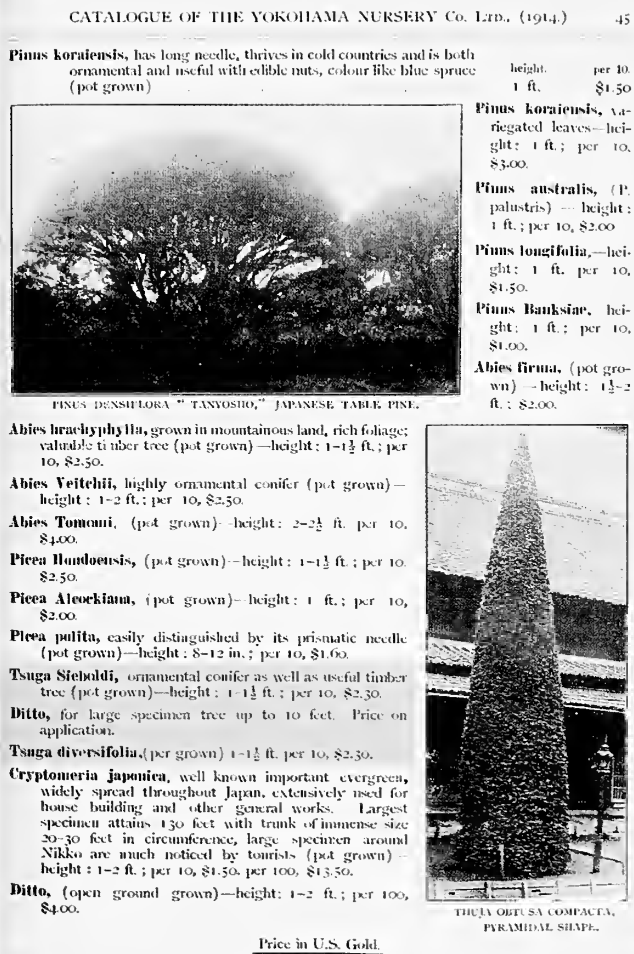
Our collaborative research on HWA began in 1999. Nathan had just received his master's degree in entomology from the University of Wisconsin and Mike needed someone to do a field evaluation of a tiny lady beetle *(Scymnus sinuanodulus)* that had been collected three years earlier in China, and had just been released from quarantine for biological control of the adelgid. Going to China to look for biological controls for HWA had been something of a gamble. The adelgid had never been collected from mainland Asia, only from Japan and Taiwan. But the fact that China was home to three of the nine species of *Tsuga* as well as several

ALL PHOTOGRAPHS BY THE AUTHORS

*Overwintering hemlock woolly adelgid nymphs settled on eastern hemlock,* Tsuga canadensis.

closely related genera (*Nothotsuga, Keteleeria,* and *Pseudolarix*) suggested that hemlock had a long evolutionary history in the region. Such a time span would have provided ample opportunity for stable tri-trophic relationships to have evolved between the host *(Tsuga),* its herbivores (HWA), and the predators of the herbivores. This hunch has proved correct, as more than sixty species of lady beetles have been collected from the hemlocks in China since the early 1990s, with twenty-five of them being new to science[3].

In 2001, Mike artificially infested every hemlock species at Arnold Arboretum and at the Morris Arboretum in Philadelphia with HWA. These tests confirmed Dr. Peter Del Tredici's observation that Chinese hemlock *(T. chinensis)* growing in the Arboretum were immune to HWA[4]. This seemed odd, because in China we found this hemlock species to be infested by HWA, sometimes with very dense populations. We wondered if there were genetic and behavioral differences among the world's geographic populations of HWA and where the HWA introduced to the eastern U.S. originated. In the fall of that year, Nathan began to address these questions as part of his Ph.D. thesis for the Department of Ecology and Evolutionary Biology at Yale University.



CATALOGUE OF THE YOKOHAMA NURSERY Co. LTD., (1914.) 45

**Pinus koraiensis,** has long needle, thrives in cold countries and is both ornamental and useful with edible nuts, colour like blue spruce (pot grown) — height. 1 ft. per 10. $1.50

PINUS DENSIFLORA "TANYOSHO," JAPANESE TABLE PINE.

**Pinus koraiensis,** variegated leaves—height: 1 ft.; per 10, $3.00.

**Pinus australis,** (P. palustris) — height: 1 ft.; per 10, $2.00

**Pinus longifolia,**—height: 1 ft. per 10, $1.50.

**Pinus Banksiae,** height: 1 ft.; per 10, $1.00.

**Abies firma,** (pot grown) —height: 1½–2 ft.; $2.00.

**Abies brachyphylla,** grown in mountainous land, rich foliage; valuable timber tree (pot grown) —height: 1–1½ ft.; per 10, $2.50.

**Abies Veitchii,** highly ornamental conifer (pot grown)—height: 1–2 ft.; per 10, $2.50.

**Abies Tomomi,** (pot grown)—height: 2–2½ ft. per 10, $4.00.

**Picea Hondoensis,** (pot grown)—height: 1–1½ ft.; per 10. $2.50.

**Picea Alcockiana,** (pot grown)—height: 1 ft.; per 10, $2.00.

**Picea polita,** easily distinguished by its prismatic needle (pot grown)—height: 8–12 in.; per 10, $1.60.

**Tsuga Sieboldi,** ornamental conifer as well as useful timber tree (pot grown)—height: 1–1½ ft.; per 10, $2.30.

**Ditto,** for large specimen tree up to 10 feet. Price on application.

**Tsuga diversifolia,**(per grown) 1–1½ ft. per 10, $2.30.

**Cryptomeria japonica,** well known important evergreen, widely spread throughout Japan, extensively used for house building and other general works. Largest specimen attains 130 feet with trunk of immense size 20–30 feet in circumference, large specimen around Nikko are much noticed by tourists (pot grown)—height: 1–2 ft.; per 10, $1.50. per 100, $13.50.

**Ditto,** (open ground grown)—height: 1–2 ft.; per 100, $4.00.

THUJA OBTUSA COMPACTA, PYRAMIDAL SHAPE.

Price in U.S. Gold.

*A page from the 1914 Yokohama Nursery catalog showing the availability of live plants of* Tsuga sieboldii *and* T. diversifolia *for import to the United States from Japan (from the Archives of the Arnold Arboretum).*

**How Did HWA Get Here?**

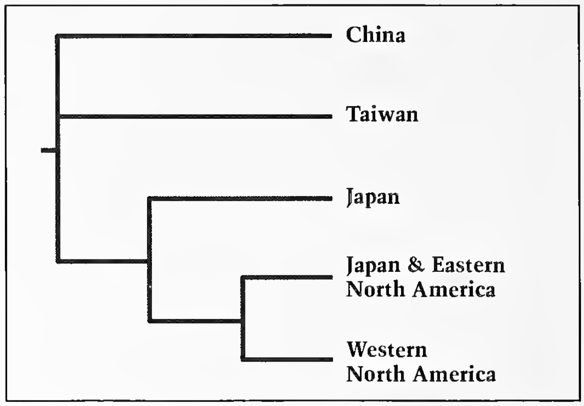
The origin of HWA in North America has been the subject of considerable speculation. Most people have assumed that it arrived from Asia early in the 20th century, first on the west coast and then migrated to the east coast. By doing some detective work with museum specimens and modern molecular technology, we were able to separate fact from fiction. During the 19th and early 20th centuries, exotic hemlock nursery stock and bonsai purchased from Japanese nurseries usually arrived in the United States through ports on the West Coast. Around this same time, China was opening up as a new frontier for plant exploration, and live plants collected by the Arnold Arboretum as well as the United States Department of Agriculture were typically sent to San Francisco and then shipped east by rail. A particularly noteworthy example of this is a seedling of Chinese hemlock collected by E. H. Wilson in Hubei Province in 1910 that is still alive and well at the Arboretum. That imports like these had the potential to bring HWA with them to the U. S. was reinforced during a recent visit to the U. S. National Arboretum where we noticed that an herbarium specimen of *T. dumosa* collected in 1932 by Joseph F. Rock in southwestern China had the distinctive remains of HWA still attached to it.

At the U. S. National Collection of Insects in Beltsville, Maryland, we found a specimen collected in 1907 in South Bend, Washington that was not identified as HWA until 60 years later.

The first published account of an adelgid causing damage to North American hemlocks is from 1916 in Vancouver, British Columbia[5] and the formal description of HWA as a new species was based on insects collected in 1922 from Oregon and California[6]. In contrast, the first report of HWA in the eastern United States was not until 1951, from eastern hemlocks growing in Maymont Park in Richmond, Virginia. This 100-acre municipal park had formerly been part of the estate of Major James and Sallie Dooley (see http://www.maymont.org). Mrs. Dooley was an avid horticulturalist who collected plants from around the world. In 1911, with the help of the master Japanese gardener known simply as Muto, she created a traditional Japanese-style garden that was in vogue at the time. While we cannot be certain that HWA arrived on the east coast on nursery stock ordered by the Dooleys from Japan, its slow spread from a small area to several states is typical of introductions of non-native species.

Based on all of the circumstantial evidence, it seemed reasonable to assume that HWA had arrived on the west coast from Asia early in the 20th century. But we were not satisfied with this speculation and decided to look into the matter more deeply. Between 2002 and 2004, we collected samples from the mountains of Yunnan, Sichuan, Shaanxi, and Hubei provinces in China and throughout Honshu Island in Japan. Several collaborators sent us additional samples from eastern and western North America to include in our study.

When we compared DNA sequences from HWA collected in the different locations we found an exact match between HWA in eastern North America and HWA in southern Japan[7,8]. On the east coast, there was only a fraction of the natural variation found in Japan, which is characteristic of a recently introduced species. We also found that DNA sequences from HWA on the west coast do not match HWA from either the east coast or Asia, and that there was much more genetic variation in HWA on the west coast than on the east coast. These results suggest that HWA from western North America is a separate endemic lineage that has been diversifying there for thousands, or even millions of years. And finally, we were able to show that HWA in China is genetically divergent from HWA in Japan and North America and should probably be considered an entirely separate species.

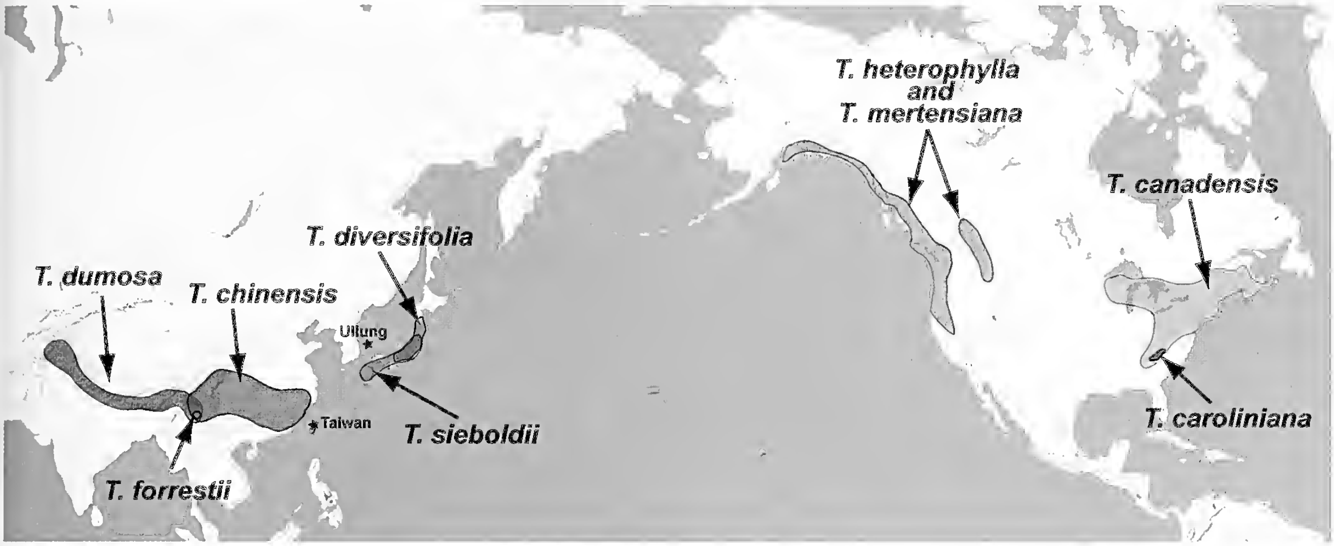



*Phylogenetic relationships among geographic lineages of the hemlock woolly adelgid inferred using mitochondrial and nuclear DNA sequence data. Adelgids from China and Taiwan are different enough that they may be different species from the one that was introduced to eastern North America from Japan. There is a second lineage in Japan that is not the source of the introduction, and hemlock woolly adelgids in western North America are a separate lineage that appears to be native, not introduced as some have assumed (Figure based on the results of Havill et al. 2006, and Havill et al. 2007).*

## Hemlock Biogeography

In conjunction with this research on HWA genetics, we have also been exploring the evolutionary relationships among hemlock species around the world. Both of these studies were supported by grants from the USDA Forest Service, the Yale Institute for Biospheric Studies, and the Arnold Arboretum's Deland Endowment. We have also enjoyed the invaluable collaboration of colleagues in China and Japan, including Guoyue Yu, Li Li, Jianhua Zhou, and Shigehiko Shiyake.

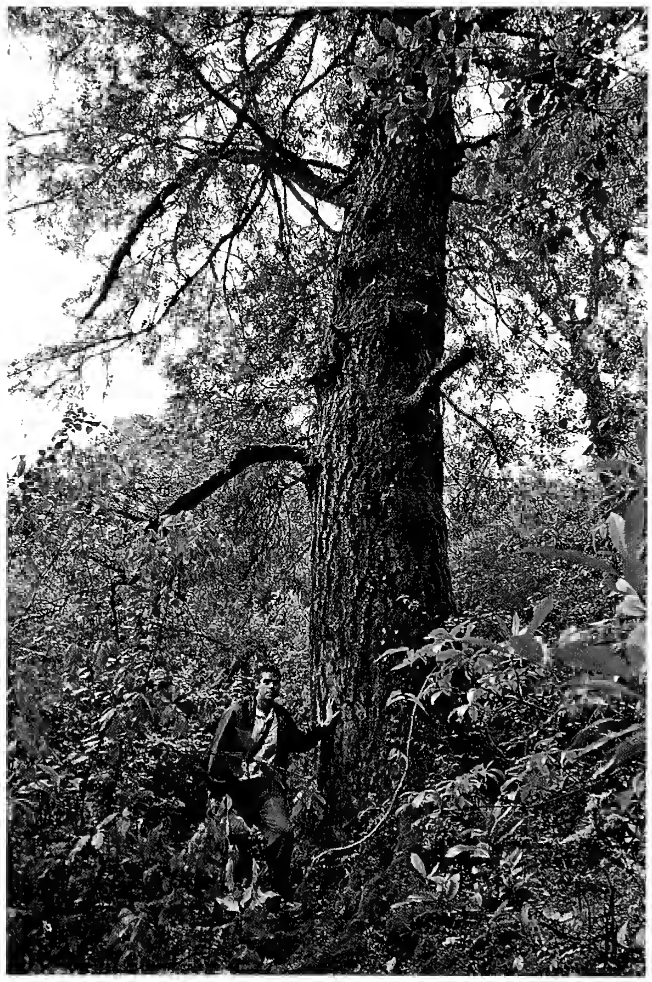
Most plant taxonomists recognize nine species of hemlock worldwide[9]. There are four species in North America and five in Asia. There are no hemlocks native to Europe but the fossil record tells us that hemlock was once widespread on that continent but went extinct somewhere around one million years ago because of climate change and repeated glaciations[10]. There are two species of hemlock in eastern North America. The eastern hemlock, *T. canadensis*, is widely distributed from southern Canada to the Great



*Map showing the worldwide distribution of the genus* Tsuga *(Reprinted from Havill et al., in press).*

Lakes and New England down through the Appalachians into Georgia. The other species in the east is the Carolina Hemlock, *T. caroliniana,* which is native to the Blue Ridge Mountains from Virginia to Georgia. In western North America, there are also two species—western hemlock, *T. heterophylla,* usually found at low elevations, and the mountain hemlock, *T. mertensiana,* which grows at high elevations. There is a similar pattern in Japan, with *T. sieboldii* occurring mostly in the south and at low elevations, and *T. diversifolia* mostly in the north and at high elevations. There are three other hemlock species in Asia—*T. chinensis* has several described varieties and is widely distributed in China; *T. dumosa,* occurs in a narrow band from southwestern China along the Himalayas to Nepal; and *T. forrestii,* overlaps with the two other species in Yunnan and Sichuan provinces in southwestern China.

Our research has given us the pleasure of observing hemlocks growing in a variety of natural habitats in China and Japan. In both countries, hemlock occurs where it is cool and wet in the summer, such as the fog belt of high mountains. They are in the transition zone between deciduous hardwoods and boreal conifers and are often a climax species in diverse forests. The hemlocks may rise above the canopy, often with broad, domed, or flat crowns which is very different from the conical or pyramidal crowns of the North American species. The understory of a Chinese hemlock forest not


*Dr. Nathan Havill standing next to a large* T. forrestii *in Lijiang, Yunnan Province, China.*

Tsuga chinensis *var.* tchekiangensis *growing on Mount Maoer in Guangxi, China.*

Tsuga sieboldii *in the background with fir in the foreground growing on Mount Tsurugi, Shikouku, Japan.*

only contains *Rhododendrons* and other genera of plants commonly found in the forests where eastern hemlocks grow, but also has species of camellia, bamboo, peony, primrose, and other Asian plants which we only find here in cultivated landscapes.

In southwestern China, the range of hemlock and the panda overlap, and ancient hollow conifers are used as maternity dens by the panda. *Tsuga* is a Japanese word meaning "mother tree" and is the highlight of several national parks in Japan. Standing in a hemlock stand in east Asia, the opening lines of the poem *Evangeline* by Henry Wadsworth Longfellow comes to mind:

> *This is the forest primeval. The murmuring pines and the hemlocks,*
> *Bearded with moss, and in garments green, indistinct in the twilight,*

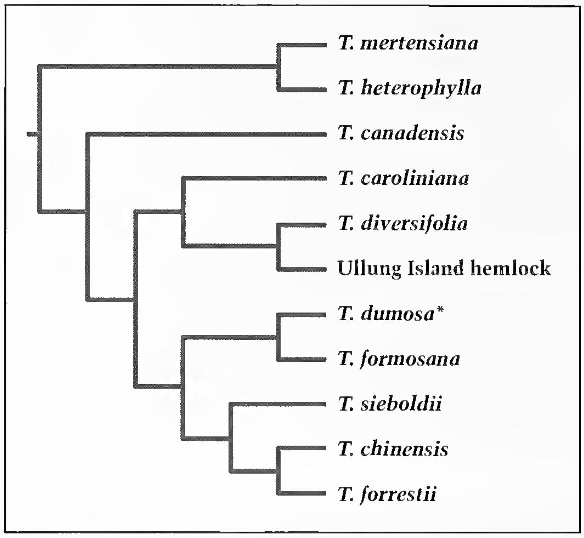
**Modern Taxonomy Reveals Ancient Relationships**

With the help of colleagues at Yale University, the University of Maine, the Academy of Natural Sciences in Philadelphia, and the University of Memphis, we used DNA sequences to reconstruct the evolutionary relationships and biogeographic history of hemlock, in part to see what this could tell us about how to manage HWA. We assembled multiple samples of each hemlock species, either collected by us in the field or from the living collections at Arnold Arboretum, the U.S. National Arboretum, Hangzhou Botanical Garden in China, and the Royal Botanic Garden in Edinburgh.

As with the HWA, some of the relationships among the hemlocks were a surprise to us[11]. One interesting result of this study was that the two hemlock species in eastern North America are not closely related to each other. *Tsuga caroliniana* is more closely related to the Japanese species *T. diversifolia* than to *T. canadensis*. Despite this close affinity, *T. caroliniana* is susceptible to HWA damage, while *T. diversifolia* is resistant.

*Moss covered* T. dumosa *trunk in Laojun Shan in Yunnan, China.*

Tsuga chinensis *with hanging lichens growing near Danba in Sichuan, China.*




*Phylogenetic relationships among* Tsuga *species inferred using chloroplast DNA sequence data. Analysis using the nuclear ITS region agreed with this except that* T. dumosa *was sister to the rest of the Asian species plus* T. caroliniana. *This discordance may have resulted from an ancient hybrid origin of* T. dumosa *(Figure modified from Havill et al., in press).*

Since the two species in eastern North America have different ancestries, their susceptibility to HWA probably arose independently in each species. Perhaps this resulted from living in a region where there are only a few inconsequential sucking insects that specialize on hemlock and where there was more selective pressure from chewing insects. Many studies have shown that plants have different defensive reactions to sucking versus chewing insects. Before HWA was introduced, the major pest of hemlock was a defoliator, the hemlock looper caterpillar. Recent chemotaxonomic studies of hemlock species and cultivars growing at the National Arboretum, Morris Arboretum, and Longwood Gardens suggest that the two hemlocks in eastern North America have adapted their terpenoid chemistry to provide protection against chewing insects, which seems to have made them vulnerable to non-native sucking pests such as HWA and the elongate hemlock scale[12, 13]. Out of thirteen cultivars of *T. canadensis* examined, the two with white-tipped foliage, 'Albo-spica' and 'Snowflake' grouped closer to the Asian species than to the "wild" *T. canadensis*. Careful testing is still needed to examine whether these cultivars are more resistant to HWA and more susceptible to native chewing pests such as hemlock looper caterpillars.

Another surprising and very exciting discovery from the *Tsuga* phylogeny project involves two hemlocks growing at Arnold Arboretum (AA #1251-83). These trees were grown from seed collected on Ullung Island, South Korea in 1982 by an expedition from the Chollipo Arboretum. Ullung is a small, isolated volcanic island in the Sea of Japan—equidistant between Korea and Japan—that hosts many endemic plant species. Based on morphological characteristics, the hemlocks on Ullung Island have always been identified as *T. sieboldii*, the low-elevation Japanese species. DNA sequences from the trees growing in the Arboretum, however, consistently grouped, not with *T. sieboldii*, but with *T. diversifolia*, the other Japanese species that grows at higher elevations. To confirm this unexpected result, we obtained a fresh sample of Ullung hemlock from Dr. Nam Sook Lee at Ewha Womans University in Seoul. This sample, like those from the Arnold, independently verified that the Ullung hemlocks are closely related to, but distinct from, *T. diversifolia* rather than *T. sieboldii* as previously thought. A detailed study comparing the morphology of Ullung Island hemlock with *T. diversifolia* still needs to be done to decide whether it should be considered a new species.

**Adelgid Resistant Hemlocks**

Previously, it was reported that *T. chinensis* and *T. diversifolia* had high resistance to HWA. Researchers at the National Arboretum have been able to produce viable hybrid crosses between *T. chinensis* and *T. caroliniana*[14]. These hybrids have been established in a field trial to evaluate their HWA resistance and growth characteristics. Recent expeditions to China have resulted in collection of hemlock seed from five provinces and more than 20 accessions are growing in experimental nurseries at the National, Morris, and Arnold Arboreta. It seems that the cultivation of *T. chinensis* and its hybrids may be an option available to gardeners in the foreseeable future.

Without the resources and expertise at the Arnold Arboretum, the U.S. National Arboretum, Morris Arboreum, Longwood Gardens,

*A hemlock from Ullung Island, Korea growing at the Arnold Arboretum (AA #1251-83B). At 24 years of age, the tree was 8 meters tall by 6 meters wide. Ullung hemlocks have traditionally been identified as* T. sieboldii *based on morphology, but DNA analyses show that it is closely related to* T. diversifolia *and may be a new species (Photograph by P. Del Tredici, December 2007).*

Chollipo Arboretum, Hangzhou Botanical Garden, and the Royal Botanical Garden at Edinburgh, this research would not have been possible. By highlighting the vital contributions that botanical gardens have made to the development of ways to control this devastating pest, hopefully we have reinforced the need for their continued commitment to research.

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# Ancient and Notable Trees of Japan: Then and Now

*Richard Primack and Tatsuhiro Ohkubo*

Ernest Henry Wilson (1876–1930) visited Japan in 1914–1915 to collect woody plants for the Arnold Arboretum, principally conifers, azaleas and cherries. Many of the special plants that he brought back to the United States are still widely cultivated. During this expedition he photographed hundreds of trees and landscapes, which are now stored in the Arnold Arboretum archives and available online.

These photographs show the appearance of the trees and landscapes in Japan 93 years ago. In December 2006 and January 2007, we visited some of the same locations as Wilson, and tried to find the same trees. Most of the places that he visited were famous locations that were easy to track down. In most, but not all, cases the trees were still alive. Other sites were not described in sufficient detail to be readily located.

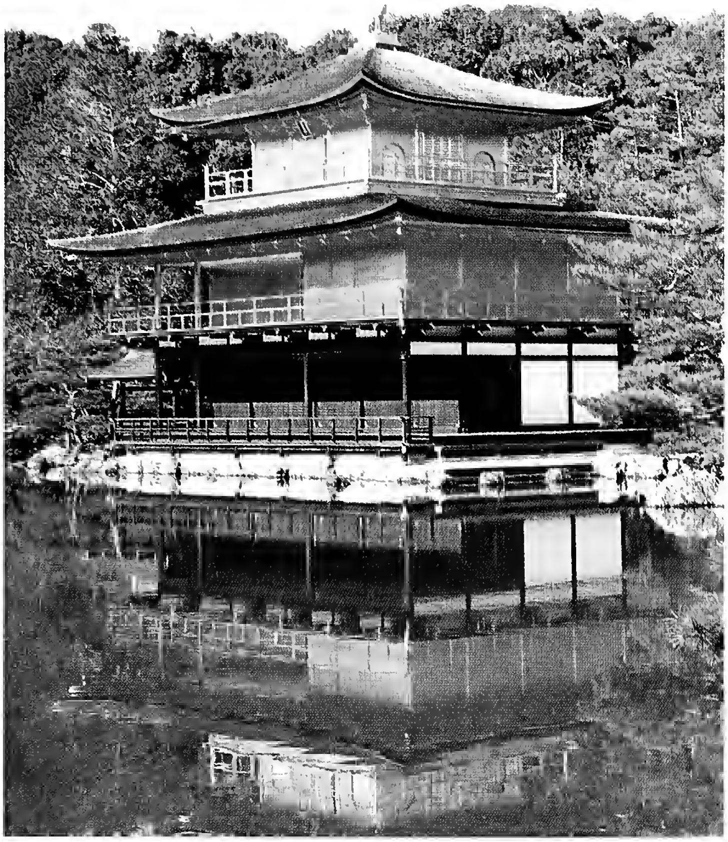
These trees and places have been associated with some of the major events in Japanese history, so the trees can be regarded as "witness trees" that can tell a story. And the trees themselves have a history in terms of how they have grown and been taken care of through this time. Let's now look at some of these trees as they were in the past and as they are today, starting with the famous Ship Pine of Kyoto.

**The Ship Pine of Kyoto.**

Kyoto was the capitol of Japan from A.D. 794 to 1185. Even after the government moved first to Kamakura and then Tokyo, Kyoto remained important to Japanese society for its many

*The Ship Pine of Kyoto* (Pinus parviflora) *in 1914, photographed by E. H. Wilson (#AAE-00292 from the Arnold Arboretum Archives). Note the latticework supporting the prow.*

R. B. PRIMACK



*The Golden Temple of Kyoto. Photographed in 2007.*

important Buddhist temples which are still in active use and frequetly visited by foreign tourists. The most well known of these is Kinkakuji Temple, also known as the Golden Temple because of the stunning metallic-yellow color of its main shrine. A small pond acts as mirror in front of the temple, creating an added effect and rocks are positioned deliberately to create a seacoast effect. This coastal imagery is further enhanced by the nearby Ship Pine, a white pine (*Pinus parviflora* Sieb. & Zucc.), known in Japanese as the "Rikushu-no-matsu", and is one of three famous pines in Kyoto. This tree was originally a bonsai trained in the shape of a ship, and belonged to the Shogun, or military ruler, Ashikaga, who was a great patron of the Temple.

After the Shogun's death in the mid-1300s, the ship pine was planted at this spot approximately 650 years ago. One of Wilson's photos from 1914 shows the tree planted in front of temple buildings. The lower branches have been trained in the shape of the hull and prow of a sailing ship, supported by a bamboo frame. The trunk of the tree appears as the mast, with approximately 22 side branches trained

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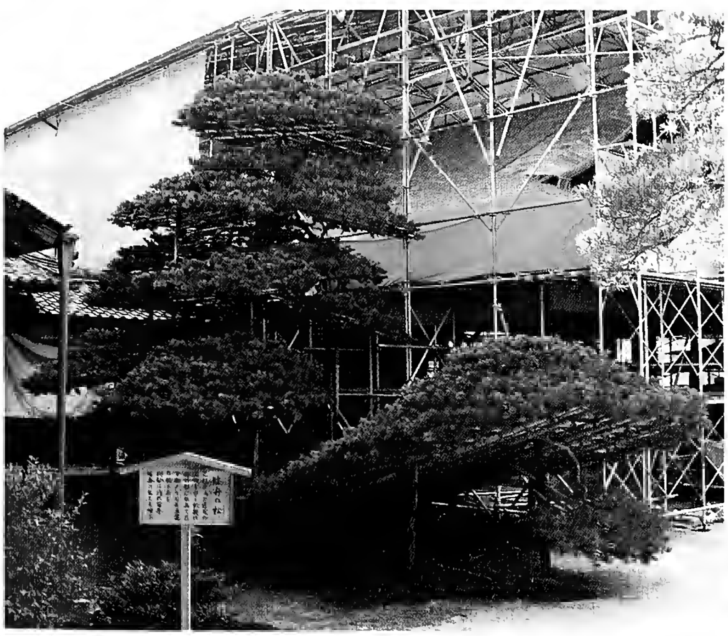

*The Ship Pine in 2007.*

R. B. PRIMACK

*Bamboo latticework supporting the prow of the Ship Pine. Photographed in 2007.*

as short, flattened surfaces suggesting sails. The horizontal branches are also supported by a framework of bamboo. Careful pruning of shoots over hundreds of years have been needed to create this precise shape.

Today the buildings in the background are still the same, showing the tree has remained in the same place, though the large building to the right is being renovated. The tree is approximately 20 feet (6 m) high and 30 feet (9 m) long. The horizontal "sail" branches and "prow" are still supported by bamboo frames. The Ship Pine is evidently in good health and essentially the same in shape after more than ninety years. The present pruning regime appears to be less precise that before, with the outlines of the prow and sails now appearing more diffuse.

**The Shogun's Ginkgo Tree**

The site of the present day Koishikawa Botanical Gardens, Graduate School of Science, The University of Tokyo was originally the medicinal plant garden of the Tokugawa Shogun, the military ruler that unified Japan in 1603. The large *Ginkgo* tree that grows there was planted approximately 300 years ago. In 1868 ownership of the garden was transferred from the Shogun to the new imperial Meiji government. This government was unpopular with many of the samurai, the traditional military class of Japan, because the Meiji government was eliminating their hereditary privileges in its drive to bring Japan into the modern age. To demonstrate their dislike of the new government, the samurai cut down some of the large trees on the day before the transfer was to take place. They started to cut down this ginkgo tree but did not complete their vandalism. However, even today evidence of the axe cuts remain at shoulder height on the trunk.

This tree is also linked to an important scientific discovery. In 1896, teaching assistant Sakugoro Hirase of the Botanical Institute of the Imperial University, using material collected from this tree, uncovered the previously

*E. H. Wilson's photograph of the Shogun's* Ginkgo *from 1914 (#AAE-03304 from the Arnold Arboretum Archives).*

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*The Shogun's* Ginkgo *tree in 2007.*


*E. H. Wilson's 1914 photograph of the black pine forest* (Pinus thunbergii) *on the Kamakura coast (#AAE-03392 from the Arnold Arboretum Archives).*

unknown sexual secrets of this unusual gymnosperm. He discovered that the male gametophyte, when it is mature, releases two large spermatozoids with multiple flagella, one of which fertilizes the ovule. This was a widely reported scientific discovery at the time, and a plaque at the base of the tree commemorates this finding.

Today the tree looks remarkably similar to its appearance in Wilson's photograph. Only the branches on the left side are now somewhat more pendent than before. The current tree height of 80 feet is virtually unchanged since Wilson's visit. It is remarkable that the tree survived at all, as the site was heavily damaged by firebombs dropped by American aircraft in World War II. And from 1945 to 1955 much of the surrounding garden area was used to grow food for the devastated population.

**Black Pines on the Kamakura Coast**

One of Wilson's photos shows an elegant group of Japanese black pines (*Pinus thunbergii* Parl.) growing on the grounds of the Kaihin Hotel near the Kamakura seashore. The trees are being bent to the right by the sea-winds and salt spray.

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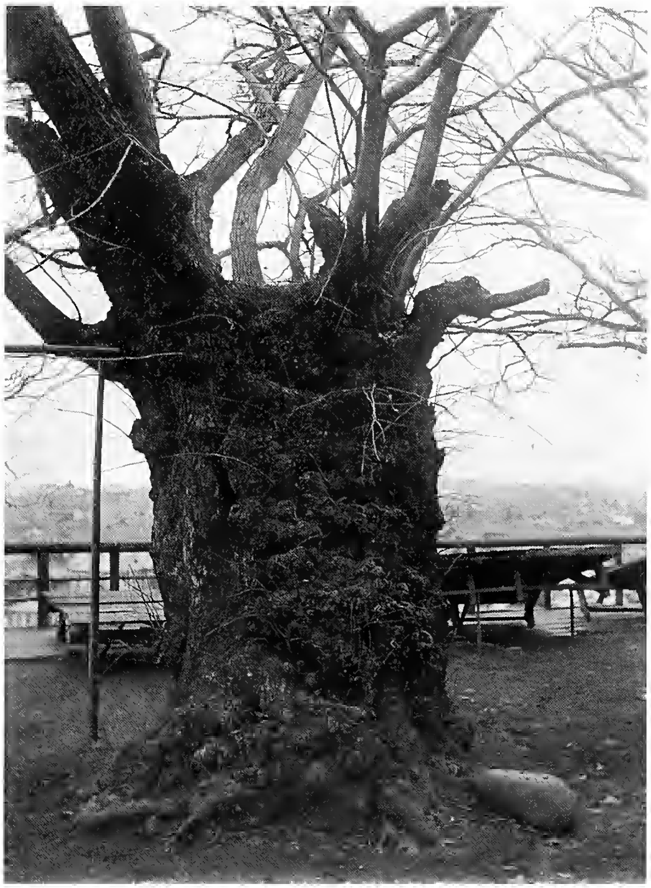
*Only a few of the black pines from 1914 remain in 2007, surrounded by a parking lot.*

Today the site is occupied by a tennis club. Sandwiched between tennis courts and houses, only four pine trees remain from the original stand, and have now become part of a parking lot. These trees are about 30 feet (9 m) tall



*The Chinese linden* (Tilia miqueliana) *growing on a hillside above Lake Biwa, photographed in 1914 by E. H. Wilson (#AAE-04480 from the Arnold Arboretum Archives).*

R. B. PRIMACK

*The Chinese linden in 2007.*

and 6 feet (2 m) in girth, with the bottoms of their trunks encased in asphalt. The fate of this coastal pine stand is typical—less than 1% of the original coastal pine stands remain intact as these sites are prime sites for the residential and industrial development.

**The Ancestor of Chinese Lindens in Japan**

Most of Wilson' pictures show well-formed trees. In contrast, the pictures he took at the Takakannon Gonshoji Temple near Kyoto show a Chinese linden (*Tilia miqueliana* Maxim.) with a massive knobby trunk, ending abruptly at perhaps 10 to 12 feet (3.7 m) high, out of which grows a dozen or so shoots. Behind the tree is a flattened ledge with benches. In the distance, a town can be viewed below with an indistinct horizon. According to the literature at the site, this tree was carried to Japan as a sapling by a Buddhist priest from China named Eshinsozu, who founded the temple in 904 A.D. This story would make the tree over 1100 years old. In Japan, the Chinese linden tree is held sacred to Buddhists in the same way that the Bo tree is held sacred by Buddhists elsewhere in tropical Asia. According to local tradition, this particular tree is not only the oldest Chinese linden tree in Japan, but it is regarded as the probable parent tree of all Chinese linden trees in Japan. Even today, pilgrims to the temple stop to collect seeds from this tree to plant back home.

The temple remains today perched on a steep hillside, above the pale blue waters of Lake Biwa, the largest lake in Japan. On the flat ground between the hills and the lake, lies the densely settled town of Otsu, though now with more tall buildings than shown in the old photo. Right in front of the temple is the same Chinese linden tree shown in the Wilson photos, but without the massive trunk. The 15 foot (5 m) tall tree consists of 16 vigorous shoots, the largest of which are covered with the distinctive helicopter-like fruit. A local resident told us that 40 years ago a typhoon broke off the trunk and washed away the bank beyond the tree. The tree base re-sprouted, as is typical for lindens, forming the tree that we see today, which is now on the edge of the road.

### The Giant *Ginkgo* at the Tsurugaoka Hachimangu Shrine in Kamakura

A massive ginkgo tree, in full leaf is shown in this photo from July 28, 1905, taken by John George Jack, another collector who worked for the Arnold Arboretum. To the right of the tree is a wide set of stairs leading upward to the Tsurugaoka Hachimangu Shrine, which is above and out of sight. There is a courtyard in the foreground and a traditional building on the right. A second picture shows a Japanese man standing between the base of the tree and the stairway. The immense size of the tree is indicated by the relative size of people in both pictures.

On January 2, 2007, the courtyard was packed with a dense crowd of people waiting to visit the shrine to say their New Year's prayers. Afterwards they buy a "Omikuji", or written prediction for the coming year, and have the chance to buy a special white arrow called "Hamaya" for keeping away unhappiness. Police and special officials were carefully regulating traffic up the temple steps to prevent injuries. As a result, we were unable to measure the size of the tree. A sign at the base of the tree today states that it is over 1000 years old, approximately 100 feet (32 m) tall and 23 feet (7 m) in girth. The ginkgo tree still dominates the courtyard area, though

*The giant* Ginkgo *tree at the Tsurugaoka Hachimangu Shrine, photographed by J. G. Jack in 1905 (#AAE-00114 from the Archives of the Arnold Arboretum).*

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*The giant* Ginkgo *at the New Year's celebration in 2007.*

*The base of the giant* Ginkgo *at the Tsurugaoka Hachimangu Shrine, photographed by J. G. Jack in 1905 (#AAE-00115 from the Arnold Arboretum Archives).*

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*The base of the giant* Ginkgo *tree in 2007.*

on this winter day the tree was leafless. The tree had been heavily pruned recently to help it regain a symmetrical shape following heavy typhoon damage three years ago. The trunk was encircled by a stylized rice straw rope called "Shimenawa", a traditional symbol showing the boundary of the shire sanctuary.

**Giant Witness *Ginkgo* in Tokyo**

In the crowded, chic Tokyo neighborhood of Azabu stands the Zenpukuji Temple, founded in 824 A.D. According to legend, a famous Buddhist priest visited the temple in 1232 A.D. and planted his staff in the ground. The staff later put forth buds and grew into the giant *Ginkgo* tree photographed in 1914 by Wilson. The tree was declared a national monument in 1926, and is among the oldest in Tokyo. Wilson records it as being 50 feet (16 m) in height and 30 feet (9 m) in diameter, which is probably close to its size today. The tree has seen lots of history: in 1859, the Temple was used as the first American embassy in Japan, and the assistant ambassador was assassinated nearby by angry samurai just few years later.

The basic shape of the tree is still the same as it was in the past. The main trunk is apparently formed by the fusion of multiple trunks which then broke off about 12 feet (4 m) from the ground. A secondary trunk formed from this main trunk, and was itself later broken off at about 36 feet (12 m) from the ground. There are now about ten additional secondary trunks developing both from the top of the trunk and the base of the tree. Many of the older branches are covered with "chichis" or "hanging breasts." These stalactite-like structures are downward growing shoots that are typical of ancient ginkgos throughout Asia. Some of these chichis are quite impressive, measuring more

*The* Ginkgo *tree at Zenpukuji Temple in Tokyo, as photographed by E. H. Wilson (#AAE-03739 from the Arnold Arboretum Archives).*

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*The massive trunk of the Zenpukuji* Ginkgo *in 2007.*

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*The cemetery grounds in 2007 with the* Ginkgo *in the background and a statue of a Buddhist priest to the left.*

*An unusual side branch of the Zenpukuji* Ginkgo *showing its prominent chichis (Wilson photo #AAE-03700 from the Arnold Arboretum Archives).*

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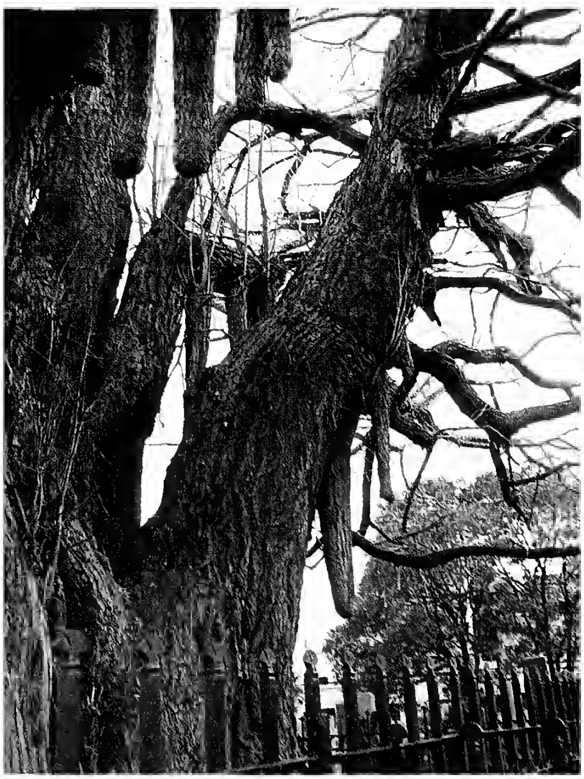


*The unusual side branch, shown above, photographed in 2007.*

than 6 feet (2 m) in length and 15 inches (37 cm) in diameter at the base. The trunk has many rotting holes and a bamboo is sprouting from the top of the split trunk. During World War II, the tree trunk was badly damaged by bombs, with burn marks still visible on the trunk.

In Wilson's photo, the area around the tree appears to be fairly open. However, today there is a wall blocking the view to the temple buildings on the left, there are trees planted in the courtyard, and there is a profusion of gravestones. Facing the main entrance to the cemetery is a greenish copper statue of a Buddhist priest, with a large sign that requests visitors to go to the temple to make a donation before paying their respects at family gravestones.

**The Ghosts of Ancient Trees at Nara**

Wilson photographed a series of ancient trees in Nara, the former capital near Kyoto. Nara Park near the city center is filled with winding paths, temples, and gardens. The park has a peculiar quality because of large numbers of tame deer that roam freely, and the black plastic netting which covers many tree trunks to prevent deer from stripping off the bark. We readily located the Kofukuji Temple and pagoda where a magnificent black pine had grown before and was photographed by Wilson. According to tradition, this tree was planted in the 9th century. Unfortunately the tree was gone, and a memorial plaque announced that the tree had died in 1937.

We next visited a bridge extending over a ravine, with a small shrine on the right side. A Wilson photo shows a giant Sugi tree (*Cryptomeria japonica* (L. f.) D. Don) on the left. On the right side a Chinese juniper (*Junipers chinensis* L.) leans slightly to the right with a Sugi tree growing out of its split trunk, and leaning slightly to the left. In 2007, the scene looked surprisingly similar, except that the damaged bridge is now being supported by a network of poles. Unfortunately all three trees are now dead though their trunks are still visible; two poles support the leaning trunk of the juniper tree.

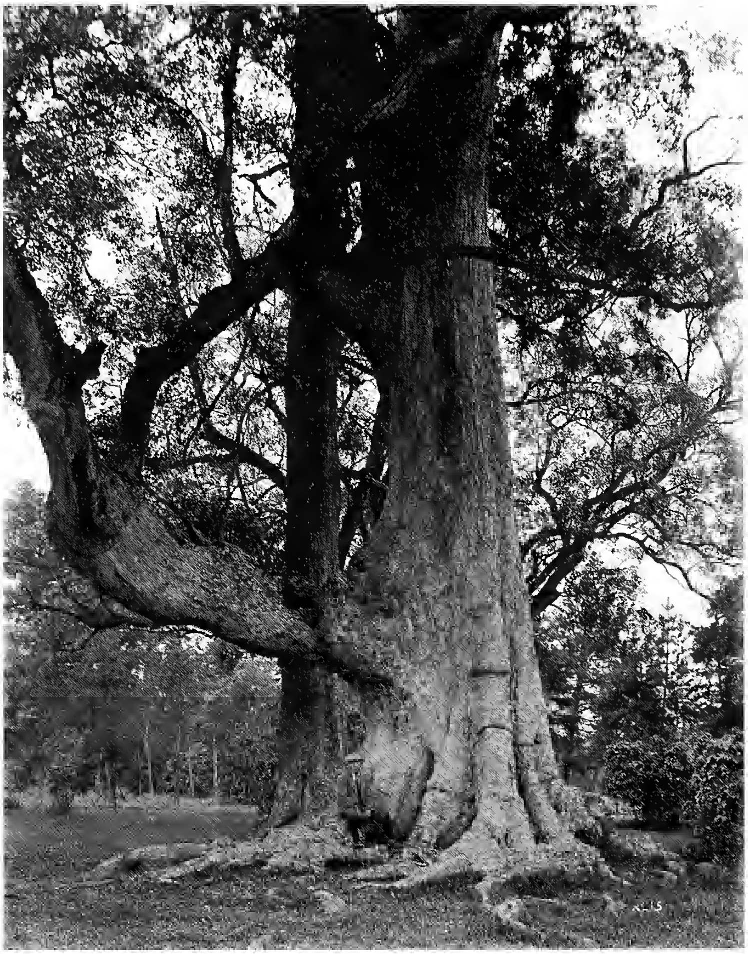
The final Wilson picture from Nara shows a massive oak (*Quercus gilva* Blume), described as 90 feet (27.4 m) in height and 30 feet (9.1 m) in diameter. The tree has large buttresses

*The magnificent pine of Nara photographed by E. H. Wilson in 1914 (#AAE-03350 from the Arnold Arboretum Archives). The tree died in 1937.*

*The bridge and shrine at Nara with the two* Cryptomerias *and one* Juniper *photographed by E. H. Wilson in 1914 (AAE-03351 from the Arnold Arboretum Archives).*

R. B. PRIMACK

*The* Cryptomeria *bridge in 2007 with the trunks of the dead trees still standing on either side of the small red hut.*



*A massive* Quercus gilva *at Nara photographed by E. H. Wilson in 1914 (#AAE-03359 from the Arnold Arboretum Archives).*

R. B. PRIMACK

*The presumed stump of Wilson's* Quercus gilva, *with massive buttresses similar to the ones visible in the original photo.*

coming out from the trunk and sweeping to the left. After considerable searching failed to locate this distinctive tree, we did locate a huge tree stump cut off at about 3 feet (1 m) from the ground. Based on the sheer size of the stump and the distinctive buttresses still present, this is almost certainly the remains of this ancient tree. In the end, none of the ancient trees from Nara that Wilson photographed are still alive.

## Japanese White Pines on the Rocky Island in Lake Towada

The Ebisudaikoku Island is named after two shrines, Ebisu and Daikokuten. They are the gods of wealth and commerce, two of the seven deities of good fortune. The island, which is located in Lake Towada, in northern Honshu, originated as part of central cone of the Towada volcanic caldera. On October 10, 1914, Wilson noted that Japanese white pine trees (*Pinus parviflora* S. & Z.) dominated the island and were between 45 to 50 ft (14–16 m) tall and 2 to 4 ft (0.6–1.3 m) in circumference. The pine canopies completely covered the Daikokuten shrine at that time and the understory vegetation was sparse. In today's photograph, taken on July 2, 2007, some of the past canopy trees have died. The heights of the pines that are still alive are remarkably similar to what they were in Wilson's day. The shrine buildings are now exposed to direct sunlight, and the understory shrubs are more abundant than in 1914. This is the typical pathway of vegetation succession following the death of canopy pines.

**Acknowledgements**

The authors wish to thank the many people in Japan who helped us to locate these trees, and the staff of the Arnold Arboretum who have taken care of these photos and made them accessible online.

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*Wilson's 1914 photograph of the Japanese white pines on the island in Lake Towada (#AAE-03642 from the Arnold Arboretum Archives).*

SHINGO NARA

*The island in Lake Towada, photographed on July 2, 2007.*

# The Search for Two Rare Maples

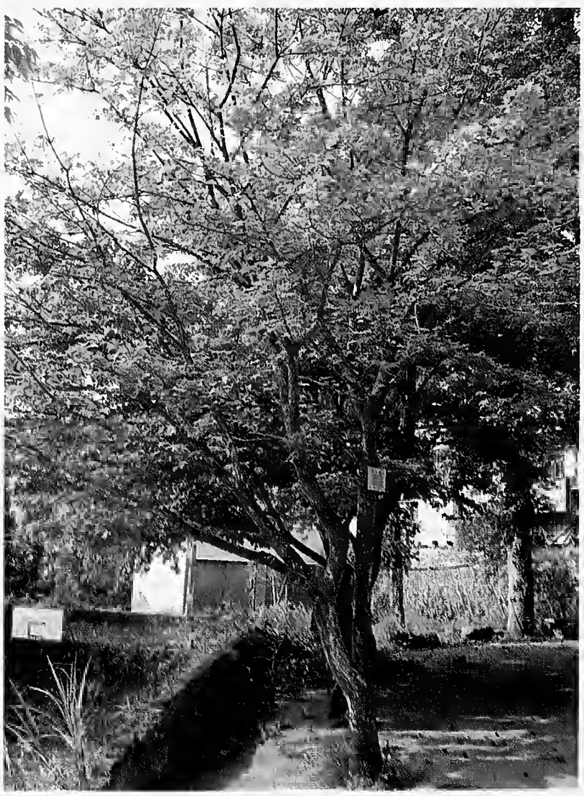
*Jianhua Li*

For most people in eastern North America, the first maple trees that come to mind are native species such as sugar maple *(Acer saccharum)*, red maple *(A. rubrum)*, or the box elder *(A. negundo)*. When it comes to introduced species, the most familiar ones are widely planted Japanese maple *(A. palmatum)* and Norway maple *(A. platanoides)*. From a worldwide perspective, maples occur across all temperate areas in the Northern Hemisphere, with a slight extension to the subtropics and tropics of Southeast Asia. Of the approximately one hundred and fifty species that have been described, over two-thirds of them occur in Asia. The vast majority of maples are deciduous, and justifiably famous for producing brilliant fall color, but a few of the Asian species are evergreen.

From an evolutionary perspective, the genus *Acer* has been around for at least 40 million years, during which time it has undergone extensive speciation and extinction. From a more modern perspective, the genus *Acer* was established by Linnaeus in 1753, and since then more than 200 species of maple have been described, of which about 150 are commonly recognized by botanists. Some of them have extremely wide geographic distributions, such as box elder which grows across most of North America, while others are restricted to a single, remote location. Because roughly two thirds of maples occur in China and because one of my research focuses has been on elucidating the maple "family tree," I have been collaborating with colleagues in China for the past few years to visit the areas where maples grow and to collect herbarium specimens and DNA samples. More recently, I have been anxious to obtain material of two very rare species—*Acer yangjuechi* and *Acer wardii*—to fill in some prominant gaps in my taxonomic study. Below is the story of my search of these elusive species in their native habitats.

### *Acer yangjuechi*

The species name of this maple, "yangjuechi," is derived from the local name of the plant, which literally translates as "sheep's horn" and refers to the similarity of the shape of seeds to the horns of a sheep. It was first described in 1979 based on specimens collected from Mt. Tianmu in Zhejiang Province in eastern China (Fang, 1979). It is similar to Miaotai maple *(A. miaotaiense)*, a species in southwestern Shaanxi and southern Gansu Provinces, but differs by virtue of its larger fruits and hairy branchlets and leaf undersides. Sheep-horn maple also resembles the Japanese species, *A. miyabei* but differs in its overall hairiness.



ALL PHOTOGRAPHS BY THE AUTHOR

*Figure 1.* Acer yangjuechi *in cultivation on Tian Mu Mountain, Zhejiang Provence, China.*

*Figure 2. The seeds of* Acer yangjuechi.

*Figure 3.* Acer acutum *on Tian Mu Mountain.*

*Figure 4.* Acer maximowiczianum *on Tian Mu Mountain.*

*Figure 5.* Stewartia sinensis *on Tian Mu Mountain.*

Upon arriving at the Mt. Tianmu Reserve in April 2007, we learned from our official guide, Mr. Mingshui Zhao, that only a few sheep-horn maples were still alive. Mt. Tianmu is located about 60 miles (100 kilometers) west of Hangzhou and is famous for the gigantic trees of *Ginkgo biloba* and *Cryptomeria fortunei* (Del Tredici et al., 1992). In an effort to preserve genetic resources of this species in case the plants disappear from natural or artificial causes, my students—Jinhuo Jiang and Mimi Li—and I spent a day with Mr. Zhao looking for specimens of the sheep-horn maple. Mr. Zhao had seen the species a few years before, but was not certain whether it still existed today. To make sure that we obtain genetic material of the species, we first visited two trees cultivated in the resort village located at the foot of the mountain (Figure 1). The trunk was grayish and covered with moss and the yellowish-green leaves had three to five lobes with coarsely toothed margins. The plants were covered with immature samaras with reddish wings spread out at a nearly horizontal disposition (Figure 2).

Around 8:30 in the morning, we took a tourist van up the mountain to the entrance of the nature reserve not far from the Old Temple, a landmark building on Mt. Tianmu at an elevation of about 900 meters. Near the entrance to the Temple we saw two other maple species, both young saplings without fruits. The first was the pointed-leaf maple *(A. acutum)*, which belongs to the Norway maple group which produced 6 to 7-lobed leaves with sharply toothed margins (Figure 3) and a drop of the milky sap oozes when the leaf stalk was broken. The other species was the Tianmu maple *(A. sinopurpurascens)* with beautifully veined 3 to 5-lobed leaves, which is similar to the devil maple *(A. diabolicum)* of Japan.

*Figure 6. Mr. Zhao next to the largest specimen of* Acer yangjuechi *on Tian Mu Mountain.*

*Figure 7. The crown of* Acer yangjuechi.

While the main path leads people up to the summit from the Old Temple, we followed the trail down the mountain and then veered off into the woods to look for the sheep-horn maple. Here we saw several saplings of another maple species with trifoliate leaves which were densely hairy on their undersides *(A. maximowiczianum)* (Figure 4). A few other plants were in bloom or fruiting including *Helwingia japonica, Stachyurus chinensis, Daphniphyllum macropodium, Arisaema sikokianum,* and an unidentified *Iris* species.

After eating our lunch in the woods, we climbed up to a mountain ridge and were greeted by some azaleas *(Rhododendron simsii)* blooming in various shades of red, white, and light blue. I was particularly pleased to see a large specimen of Chinese stewartia, *Stewartia sinensis,* that looked very much like the one growing at the Arnold Arboretum that had been sent from the Nanjing Botanical Garden in 1934 (Figure 5). Given that I have been working on the phylogeny of *Stewartia* for several years, it was particularly exciting to see this tree—covered with flower buds—growing in the wild.

From the mountain ridge we had to go downhill to find the sheep-horn maple. The understory vegetation was different here from the other side of the mountain, the dominant plant being a bamboo in the genus *Indocalamus.* Since bamboos are tall and form interlocking thickets, it took some effort to get through it. Mr. Zhao led the way but had to stop frequently to find his direction. Three years earlier he searched for the sheep-horn maple but ended up getting lost, so I kept my fingers crossed that we would have a better luck this time around. After about an hour or so of plowing through bamboo, Mr. Zhao shouted out that he found the tree. I pushed my way through the thicket and saw him standing next to a stately tree with a grey trunk (Figure 6). We searched the surrounding area for seedlings or saplings of sheep-horn maple but could only find those of a different species with three leaflets *(Acer henryi).* The lack of seedlings is probably due to a number of factors including intense competition from the bamboo and predation by insects.

After finishing our search of the area, I finally took a break to examine the old sheep-horn maple closely. The task filled me with a mixture of excitement and sadness because the tree, which was 20 meters tall with a diameter of 30 centimeters at the breast height, was decidedly unhealthy (Figure 7). The trunk had a gaping hole in it and insects have so damaged the foliage that it failed to produce any fruits. Luckily, we did manage to get a few undamaged leaves to preserve the genetic blueprint of this rapidly disappearing species. We left the area filled with a great sense of accomplishment, thankful that the time spent trekking around the mountain through bamboo thickets and winding pathways in the hazy and humid weather had not been wasted.

Upon our return to Hangzhou, Mimi Li, one of graduate students at Zhejiang University, obtained some DNA sequence data from both chloroplast and nuclear genomes of the sheephorn maple. Our preliminary analyses indicate that it is indeed closely related to the Japanese species *A. miyabei,* but we need to include another Chinese species, *A. miaotaiense,* in our analysis in order to determine what its closest relative is.

### *Acer wardii*

The quest for the next maple brought me to Yunnan Province in the southwestern part of China, an area long considered the botanical treasure land of the country. More than sixty species of maples occur naturally in Yunnan, and so it is no surprise that Ward's maple *(Acer wardii)* should also be one of them. This rare species, whose leaves have only three lobes, was named by W. W. Smith in 1917, to honor Frank Kingdon Ward (1885–1958) the English plant hunter who first collected it in Upper Myanmar (the country formerly known as Burma). The species also grows in Assam, India and in Yunnan and Xizang Provinces, China. Ward's maple was first introduced to England by George Forest at the end of 19th century. Unfortunately the plant did not survive, and it is probably still not in cultivation in the West.

In early May of this year I was fortunate to visit Mt. Gaoligong in northwestern Yunnan with a group of researchers from the Kunming Institute of Botany (KIB). Prior to the trip, I had gotten a few specks of leaf tissue of Ward's maple from Peter Wharton of the University of British Columbia Botanical Garden and had been able to extract DNA sequences of the sample for several genome regions. Despite this limited success, it was still unclear which group of maples *Acer wardii* was most closely allied with. Based on morphological features alone, it seemed to stand between the Japanese maple and the American stripe bark maple *(A. pensylvanicum).* The primary goal for my trip, therefore, was to collect specimens to further resolve the question of its affinity to other maples.

I flew to Kunming from Hangzhou on the afternoon of April 30 and early the next morning our van left for Mt. Gaoligong with 15 people on aboard, all from KIB except for myself and Dr. Jin Xiaohua, who was from the Beijing Institute of Botany. Since the week of May 1st was a vacation week in celebration of the World Labor Day the highway teemed with buses, cars, and vans. However, the bustling traffic did not dampen my spirits: I had not visited the area for about fifteen years and was excited at the prospect of seeing how everything had changed. Whereas before there was no highway between Kunming and Dali, the one-way trip took an arduous twelve hours, but with the new road, the time travel between these two cities

*Figure 8.* Acer oligocarpum.

*Figure 9.* Leycesteria formosa *in fruit.*

*Figure 10. The foliage of* Acer wardii.

*Figure 11. The distinctive leaves and unopened flower buds of* Acer wardii.

was reduced to four hours. Change was clearly happening as rapidly in Yunnan as it was everywhere else in China.

Be that as it may, it still took us nearly two days to get from Dali to Gongshan Xian, the town where we were to begin our hike. By the time we reached our destination, the long and tiring journey had taken its toll on me and I was feeling pretty sick. I was also worried that it would not get better and would hold up the rest of the group. Xiaohua suggested that I stay in the inn for the day to rest up while he went out to look for the maple with the guide. However, no one but me knew what the plant looked like and I hated to miss the opportunity to find the plant after coming such a long way. So we compromised by taking a taxi instead of hiking the first half hour of the trip.

We went down to the valley from the dirt road where the taxi dropped us off, crossed a suspension bridge (see inside front cover), and hiked along the river. Not far from the bridge we saw a Schneider maple *(A. schneiderianum)* with five, deeply lobed leaves. Several yards from it was a semi-evergreen maple, *A. oligocarpum* (Figure 8), with simple, entire leaves and aborted terminal buds similar to those of the Japanese maple. We found a plant of the Himalayan honeysuckle, *Leycesteria formosa* (Caprifoliaceae), with many young fruits (Figure 9) and we saw patches of a common orchid in bloom with greenish yellow flowers. We also found the giant *Cardiocrinum* lily in its vegetative state with large leaves and immature flower. By noon we were still four hours from where the specimen of *Acer wardii* had been collected and I did not feel any better. Following the guide's advice we decided to turn back. It was clearly a good decision since just climbing up the hill from the valley to where the taxi dropped us off took more than half an hour. It was getting dark when we got back to the inn.

The next morning we drove back to Liuku town for the night. The next day our van followed the winding mountain road to the summit pass called Pianmayakou where we saw many interesting plants including *Ranunculus* (buttercup), *Lindera* (spicebush), and *Arundinella* (bamboo) and the top of the mountain was covered with rhododendron thickets. After half an hour botanizing at the summit we went back to the winding road and drove downhill to the other side. About noon we got to the city of Pianma bordering Myanmar. Here we visited a museum housing a United States C-53 cargo aircraft which had been restored from wreckages that were discovered near the border in 1996. It was built as a memorial to the hundreds of US pilots who died while transporting supplies between New Dehli and Kunming (known as the "hump") during World War II. I found the display deeply moving because it reminded me of the great sacrifices the American people made in helping the Chinese defend their country against the Japanese invasion.

While our van took the others back to the pass where we had collected specimens in the morning, Lianming Gao (a researcher at KIB), Xiaohua, and I walked back up the mountain botanizing and collecting. My focus was again on finding *Acer wardii* since this area is part of Mt. Gaoligong. The maples were easy to spot because the reddish color of their emerging leaves made them stand out like flames against the mountain. Unfortunately, almost all of the maples we saw had leaves with five lobes. To my surprise and great joy, however, I spotted a small tree with red, three-lobed leaves next to a maple with five-lobed leaves growing on a ten-foot high cliff above us in full sun. Xiaohua climbed up and threw a small twig down to me. It was clearly *Acer wardii*, with each of its leaf lobes terminating with a long, sharp-pointed tip. The flowers were typical for a maple, but were not yet open. We saw a few more individuals in the area, which were absolutely beautiful under the blue sky with their reddish leaves (Figures 10 and 11). Finding *Acer wardii* was the highlight of my brief trip to Mt. Gaoligong, and seeing how beautiful it was in the wild makes me believe that Ward's maple would make a great ornamental tree, albeit somewhat tender and in need of protection in areas with a harsh winter.

Maples are one of the most diverse tree groups in the Northern Hemisphere and they play an important role in both natural and man-made forest ecosystems. It is important to conduct detailed studies on the diversity, geographic distribution, ecology, evolution, and biology of maples in their native habitats before they disappear forever. Such information will not only help to preserve and protect endangered species, but will also help people learn how to use maples in a sustainable manner.

**Acknowledgements**

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# A Golden Afternoon

*Michael Dosmann*

Nestled at the base of the conifer collection and straddling the banks of Bussey Brook stands one of the most picturesque plantings in the Arboretum: a grove of mature golden larches, *Pseudolarix amabilis*. In the winter, one marvels at their stately, flat-topped form; girthy branches defying gravity. Each spring, from small branch spurs, new leaves flush greenish-yellow before turning dark green by mid-summer. But, it is in autumn that the species takes on its true majesty, when the leaves seem to be on fire, becoming the intense golden-yellow that gives the species its common name.

*Pseudolarix* is a monotypic genus (i.e., it has but one species), and is a moderately rare tree of east-central China. It resembles the true larches (Larix) by having both long- and short-shoots (spurs) and deciduous leaves, however the male cones are borne in clusters at the ends of the short shoots as are the solitary female cones, which resemble miniature artichokes before disintegrating as they release their seeds.

Robert Fortune, the famous Scottish plant explorer responsible for innumerable horticultural introductions from Asia, first collected seeds of *Pseudolarix* in modern-day Zhejiang Province, China, in the autumn of 1853. Some of the massive trees he found in the wild reached impressive sizes, oftentimes exceeding 35 meters (115 feet) in height. Although he collected seeds, germination was very poor and most of the plants first in cultivation in the west were seedlings brought back in the infamous Wardian cases.

By the 1870s, cultivated European trees began producing seeds, and many nurseries in the UK were offering young plants for sale. However, it was not until May of 1891 that the Arboretum received its first plants from the English firm of Veitch and Sons. These two individuals, accessions 3656-A and 3565-B, were planted on opposite banks of Bussey Brook. They continue to thrive, and 3656-B stands tallest in the collection, with a height of 24.5 meters (80 feet) and a DBH of 80 centimeters (2.5 feet). In 1896, the Arboretum received seed from the Hunnewell Pinetum in Wellesley, Massachusetts, which was collected from a mature tree Horatio Hollis Hunnewell had purchased from Veitch back in 1866. Two plants of this 1896 seedlot, accessions 16779-A (see facing page) and 16779-B, also grow on the banks of Bussey Brook; 16779-B has the stoutest stem of any in the collection, with an impressive diameter at breast height of 91.4 centimeters (3 feet). A bit higher up on the slope stands accession 10764-A, another plant received from the Hunnewell's on April 22, 1921 with the moniker *Pseudolarix amabilis nana*. However, this tree did not live up to its dwarf name, for by 1946 it was at least 9 meters (30 feet) tall, prompting Heman Howard to note in the records: "nothing 'nana' about this plant." By coincidence, the Arboretum's archives contain a photograph taken by Alfred Rehder on June 21, 1921 of a 'dwarf' *Pseudolarix* growing in a container; most likely the same individual. Despite being 30 years younger than the two oldest specimens, this tree is nearly as tall, with a height of 21.1 meters (70 feet). The only wild-collected golden larches in the Arboretum came from Tian Mu Shan, Zhejiang Province, and are represented by 5 plants in accession 187-94. Plant A of this accession was planted in the Bussey Brook grove in 2000 and has grown very well, already reaching 8.2 meters (27 feet) in height.

The next time you come to the Arboretum, be sure to visit the grove of golden larches—each season reveals a bit of its personality. As you stroll Conifer Path and cross the bridge over Bussey Brook, you can admire their majesty and reflect upon their history.

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Michael Dosmann is Curator of Living Collections at the Arnold Arboretum.

# arnoldia

The Magazine of the Arnold Arboretum

DIRECTOR'S REPORT 20[illegible]–200[illegible]

*Zelkova serrata* (AA 1813-77) by Michael Dosmann

Between 1 July 2002 and 30 June 2007, 1,011 accessions comprising 2,075 plants were added to the Living Collections, bringing the total number of accessions and plants to 10,176 and 15,665, respectively. Of the new accessions, 53% were of wild origin and 42% were of garden origin, and 103 additions were of taxa new to the collection.

Below, the taxonomic profile of the Living Collections as of 30 June 2007. Numbers for infraspecific ranks correspond only to those accessions where rank is known.

| RANK | NUMBER |
|---|---|
| Families | 97 |
| Genera | 351 |
| Species | 2254 |
| Subspecies | 75 |
| Varieties | 401 |
| Formae | 84 |
| Cultivars | 1552 |
| Interspecific hybrids | 456 |
| Intergeneric hybrids | 19 |

Jon Hetman

# THE ARNOLD ARBORETUM OF HARVARD UNIVERSITY

## DIRECTOR'S REPORT: 2003–2007

*Robert E. Cook, Director*



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FRONT COVER: Weld Hill research facility, design sketch of Centre Street view (detail); KlingStubbins. BACK COVER: Model of Weld Hill research facility by GPI Models; photographs by Desroches Photography. *Top* main entrance and laboratory wing on the north side of the building; *Bottom* courtyard and greenhouses on the south side of the building.

*Quercus* (oak) collection by Jon Hetman

## Introduction

Early this spring, the Arnold Arboretum began construction of a new research and administration building at Weld Hill, a fourteen-acre parcel of land adjacent to the grounds of the Arboretum (see Figure 1). It will be the first major building added in nearly half a century. The Weld Hill facility, as we are calling it for now, will have nearly 44,000 square feet of floor area and cost approximately $42,000,000. Its greenhouses, growth chambers, and modern laboratories will provide state-of-the-art facilities for plant research.

The construction of the building marks a major milestone in the history of the Arboretum and a reaffirmation of our mission as a research institution at Harvard University. In this Director's Report, I will focus on a physical description of the building and its location, the decisions that led to its construction, and the implications of its

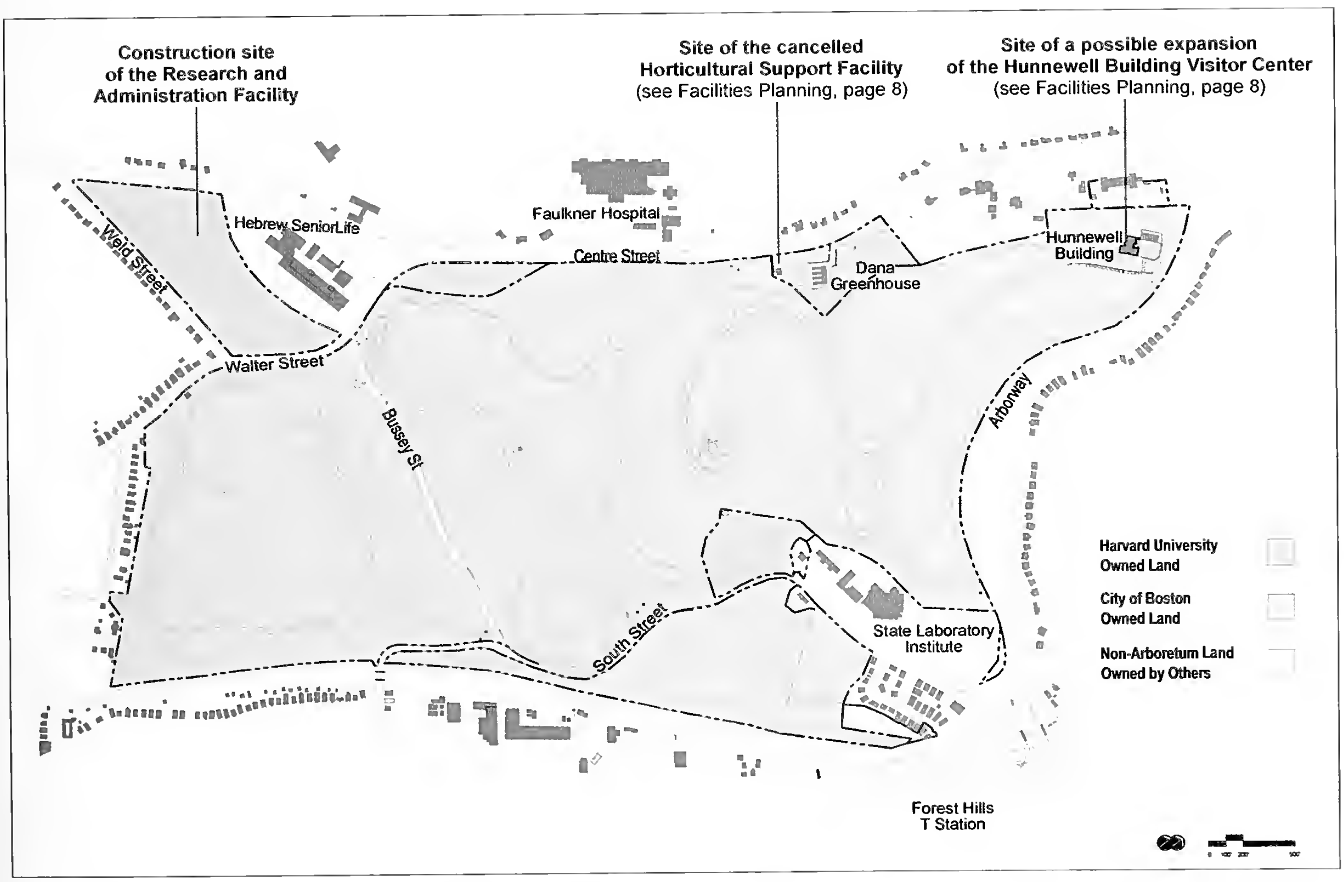



Figure 1. Map of the Arnold Arboretum, showing Harvard-owned land, City of Boston-owned land leased to Harvard, and the proposed facility additions (see Facilities Planning, page 8), by KlingStubbins.

operation on the future programs of the Arboretum. At the end of the report, I will return to the critical role that all the friends of the Arboretum have had in reaching this milestone.

## A Building in its Landscape

As is well known, most of the land of the Arboretum is owned by the City of Boston and open to the public as part of the Boston park system; however it did not begin this way. Through the generosity of James Arnold, and on land donated by Benjamin Bussey, Harvard University created the Arboretum as a private research department dedicated to the study of trees. Within a decade the first director, Charles Sprague Sargent, had developed a unique partnership with the City that captured his vision for the institution. It was to become both a non-public research station and a public museum. A decade later, in 1882, the Arboretum's land was given to the City to be operated as a park open to the public for education and enjoyment. At the same time, the land was leased back to the University, for a fee of one dollar a year and a renewable term of 1,000 years, to allow faculty and students to conduct research on the biology of trees. This partnership between Harvard and the City has successfully endured up to the present day. The Weld Hill building is simultaneously an affirmation of the partnership and the embodiment of Sargent's original vision.

Several considerations determined the choice of location for the facility. First, it was highly desirable that a new facility not subtract from the parkland available to the public; a location on the grounds would have had this effect. At the same time, however, researchers would highly value close proximity to the collection of trees upon which their research is conducted. Finally, in consideration of both cost and formal control of the facility's operation and construction, we preferred to site the building on land already owned outright by the University, close to but not within the historic public park.

In 1922 Charles Sargent, in his fiftieth year as director, purchased from a neighbor a fourteen-acre parcel of land lying across Walter Street and adjacent to the southwest boundary of the Arboretum (see Figure 2). The parcel displays significant topographic variation, from the drainage swale feeding Bussey Brook to a large

Lilac Sunday visitors by Eric Roth.

hilltop that reaches 172 feet above sea level. Over the subsequent eighty years, it was variously used for nurseries, tree plantations, and the planting of some specimen trees.

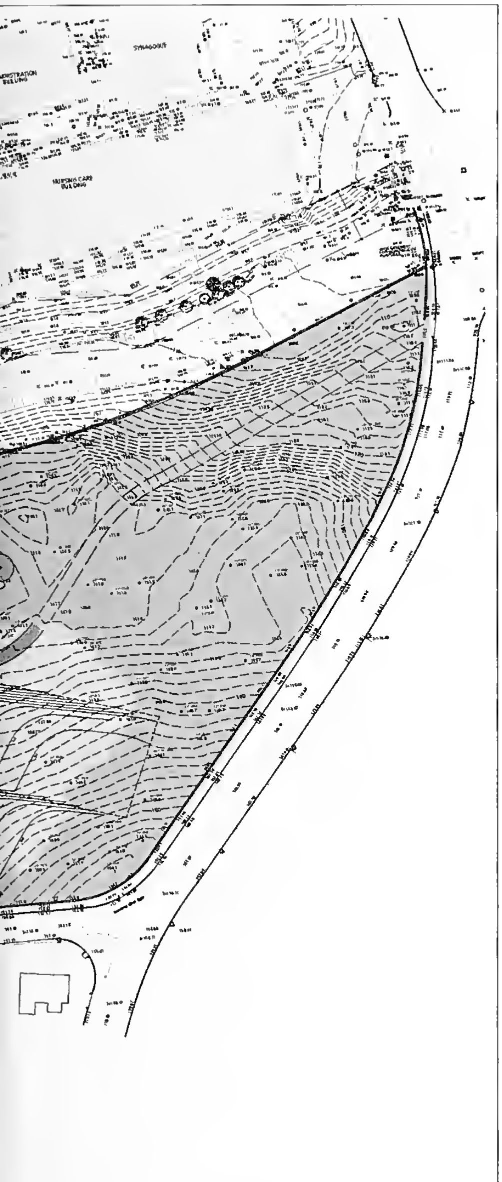
By 2002 Weld Hill's pastures and woodlots were no longer home to any significant collections and horticultural care had been reduced to an annual mowing of its meadows. To the north of Weld Hill, a major teaching and research hospital for the elderly, called Hebrew SeniorLife, had become an important partner of the Harvard Medical School. Following completion of our strategic plan in 2002 (see Director's Report 1999–2002), we decided that this parcel of land would become the home for a laboratory facility representing a major expansion of our capacity to conduct research.

The functional requirements were developed collaboratively with botanical faculty members in Harvard's Department of Organismic and Evolutionary Biology (OEB), with which the Arboretum has worked for more than a century. These requirements grew out of the Arboretum's commitment, described in the 2002 Director's Report, to make a strategic investment in scientific research.[1] Our goal for

[1] R. E. Cook. "The Future of Research at the Arnold Arboretum," *Arnoldia* 65(2): 23–39 (2007).

Figure 2. Site plan with topographic detail and building footprint for the Weld Hill facility, by Reed|Hilderbrand.

this investment was to match other major research units at Harvard University in providing the physical and financial capacity to support researchers of the highest quality. Nothing pleases high-quality researchers more than first-class research facilities. For plant scientists, this means the finest growing facilities (controlled climate greenhouses; growth chambers; nurseries and experimental gardens). And, if at all possible, it also means access to a broadly diverse collection of living



tree species of great maturity and known provenance from all over the world.

The scientific program of the building must support a sufficient number of scientists to form an intellectual community that interacts and collaborates closely. Toward that end we specified enough laboratory space to house eight senior researchers or faculty members, along with their post-doctoral trainees, their graduate students, their laboratory technicians, assorted undergraduates just getting started, and visiting scientists. We estimated the total to be about 40 full-time researchers.

In addition, as part of a larger facilities plan to address other needs at the Arboretum (see Facilities Planning, page 8), the new building would also accommodate the relocation of the Arboretum's administrative offices, presently housed in the Hunnewell Building. These offices include the director's and those of such functions as finance, facilities management, personnel, and research administration.

The space required for these purposes, together with the mechanical systems to heat and cool the facility, comes to approximately 43,500 square feet. Taking into account site conditions (topography, wetlands, utility easements, rock) and the necessary road and parking infrastructure, we envisioned that the facility would require less than a quarter of the entire fourteen acres of the Weld Hill site.

In collaboration with the architectural firm of Stubbins Associates (now KlingStubbins, Inc.), located in Cambridge, MA, we defined a set of principles for siting the building that would be consistent with the pastoral nature of the Weld Hill land and with the Olmsted

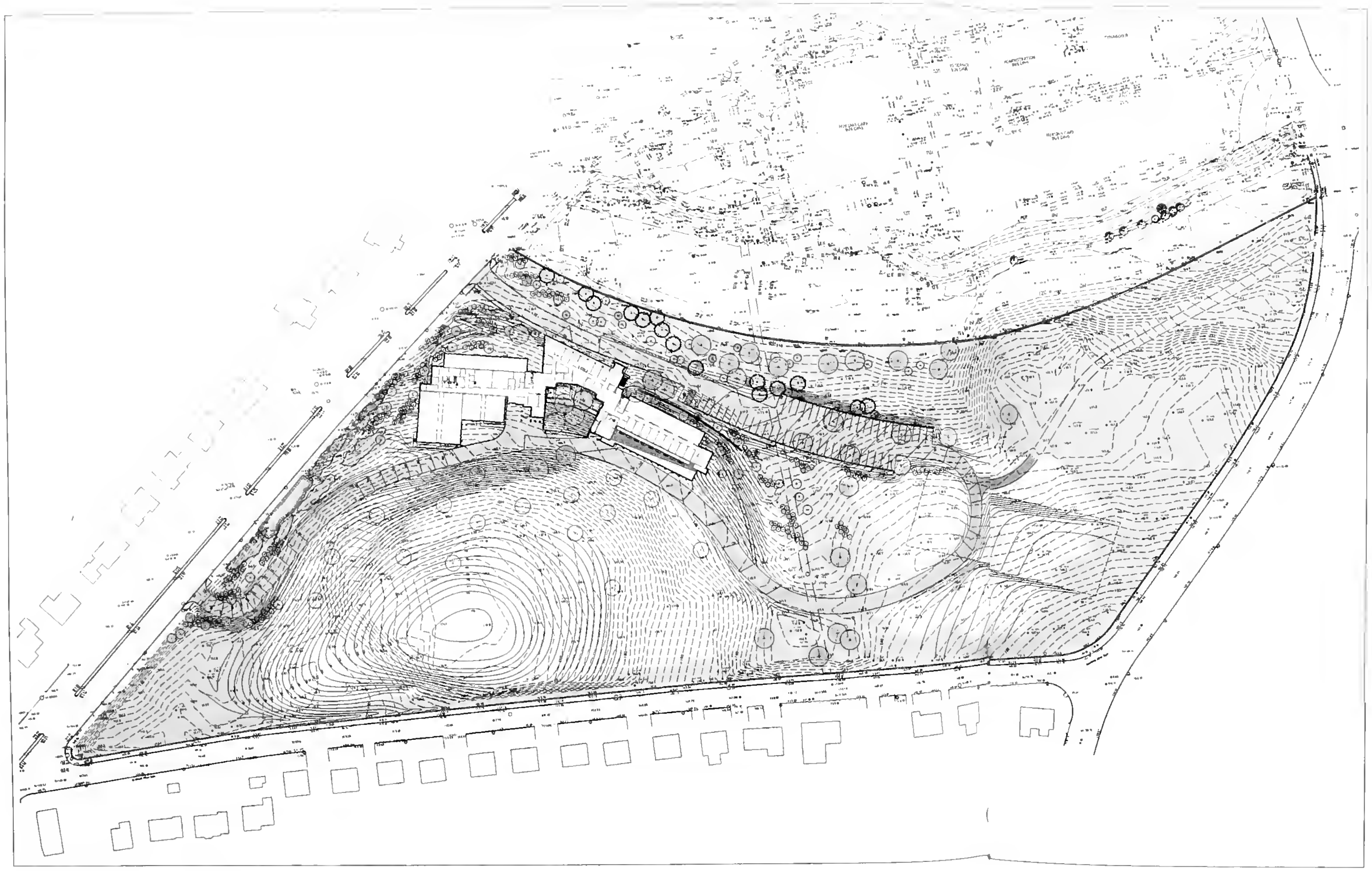


**Figure 2. Site plan with topographic detail and building footprint for the Weld Hill facility, by Reed|Hilderbrand.**

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## FACILITIES PLANNING

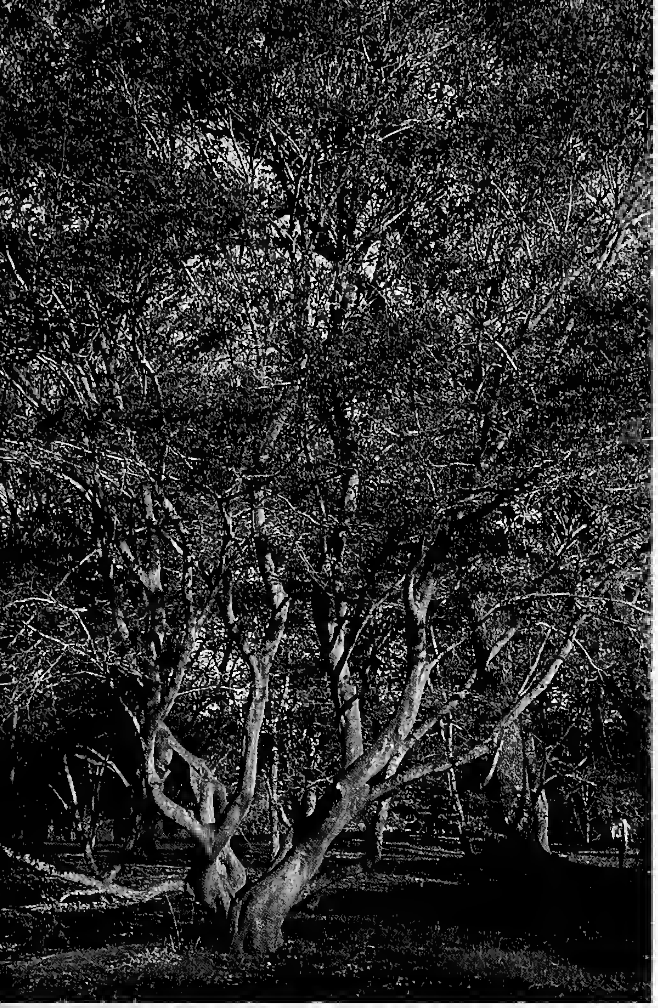
In 2004 the Arboretum developed a comprehensive facilities plan. At its center was the creation of the research facility that is described in this director's report. But the plan also projected the construction of facilities that would address two other needs. First, our primary maintenance facility, which houses grounds equipment adjacent to the Hunnewell Building, has reached the end of its useful life. In the plan we proposed a new facility that would be more centrally located in the vicinity of the Dana Greenhouse, thereby separating the traffic in tractors and trucks from the movement of pedestrians around the Hunnewell Building Visitor Center. Second, we wanted to expand our service to the public adding a new wing to the Hunnewell Building that would house our educational programs and visitor services and provide greater access to the horticultural library.

Thus the larger facilities plan envisioned three centers (see Figure 1). A new research and administration complex would be located at Weld Hill. The horticultural support facility would include a new maintenance building combined with the Dana Greenhouse. Finally, the Hunnewell Building, with a newly constructed public wing, would be the "public museum," dedicated to education and service.

However, late in 2005, after developing schematic designs for the maintenance facility at the Dana Greenhouse, we suspended any further work on it and, consequently, on any expansion of public programs at the Hunnewell Building as well. Our plan called for the removal of an 1820 farmhouse, in dilapidated condition and of no further use to the Arboretum, because its location precluded the construction of a maintenance facility on land owned outright by Harvard University rather than on land under lease from the City and historically part of the public realm. A small group of neighbors objected to our proposed removal for reasons of historic preservation. We made the strategic decision to focus our immediate energies on the construction of the Weld Hill facility.

design of the adjacent Arboretum landscape. These principles are: 1) to locate buildings on edges and in corners; 2) to concentrate buildings and circulation infrastructure near other buildings and infrastructure; and, 3) to reserve the higher elevations for pedestrians and use the lower, level land for nurseries. These principles, combined with the concern expressed by neighbors that they not "see" the building, led to its current planned location in the parcel's northwest corner on the lower slope of Weld Hill (see Figure 2).

Here the building will lie close to the existing hospital facility (Hebrew SeniorLife) and be terraced into the lower hillside such that the mass and height of the hill will screen the building from its neighbors to the south. The service road will enter the site from Centre Street and curve across and around the rising topography to meet the rear of the building at its highest floor, adjacent to the greenhouses, before descending to an exit on Centre Street. This siting effectively leaves the hill itself open for pedestrian enjoyment and reserves the eastern half of the parcel for woodlands, pastures, and gardens.



*Acer palmatum* f. *atropurpureum* (AA 22717-A), photo by Jim Harrison.

Thus the overall landscape will be characterized by its four quadrants. The northwest quadrant will hold the building and its circulation infrastructure; the pastures and distant views of the hilltop will continue to occupy the southwest quadrant; mature woodlands will remain throughout the northeast quadrant; and the southeast quadrant will display terraced nursery beds.

## A Home for Research

The facility itself will be a large, three-story central building with two wings to the east and west (see Figure 3). The basement floor of the central building will consist of a large room for mechanical equipment adjacent to the main entrance and the stairway leading to the administrative offices, computational facilities, and a large auditorium for meetings and lectures on the first and second floors.

The first floor of the east wing will have a large, open laboratory conducive to collaborative research, with individual work stations on the north side and specialized equipment rooms tucked into the hillside on the south. Above this, on the second floor, a series of offices will house senior researchers and faculty.

The west wing will be devoted to growing plants. On the first floor, several large rooms will be equipped with reach-in and walk-in growth chambers, as well as related laboratory support spaces. The second floor will have a large head house and loading dock to support twelve adjacent greenhouse modules.

My simple description of these spaces with their highly specialized equipment and technical capacity does not evoke the ambiance of the building—the way it will look and feel as it sits in its landscape. I wanted the building's occupants to feel very much at home despite the essentially institutional nature of their work. This is a challenge for a fairly large facility that one might initially envision as a steel and glass box like most laboratories being built today. The configuration of the interior spaces will be largely dictated by functional needs; any domestic qualities must evolve from the ingenuity of their occupants. Nevertheless, we have tried to communicate in the design of the building's exterior—its appearance and surface qualities—a sense of arriving at home as one approaches the front door.

The façade of the building will be constructed of basic, traditional, residential materials: stone, brick, and wood. The lowest level of the central building will be clad in light Kasota stone of a lemon hue. This stone base will rise to meet horizontal shiplap cedar siding covering the first and second floors, both of which will display horizontal bands of vertical windows (see Figure 3). The base of each wing will be articulated in brick that rises to meet cedar-clad walls and rows of windows. At the end of each wing and at the junctures with the central building will be large vertical brick "chimneys" to house mechanical ducts and other equipment. Most important, the roofs of the entire building will slope gently down to create substantial overhangs. They will be shingled with a dark synthetic slate, and the gutters, downspouts, and building accents will be made of copper.

The overall appearance of the building will recall the early prairie houses of Frank Lloyd Wright, particularly Taliesin East, his first studio and home in Wisconsin. With its central mass flanked by two recessed wings that recede into the slope of the hill; its strong horizontal lines defined by roof, windows, and base; and its cladding of natural materials, the building will be fully integrated with and defer to the surrounding pastoral landscape. The immediacy of the landscape will be reinforced on the south side of the central building by a courtyard sanctuary that visually connects the first-floor reception area to the summit of the hill (see Figure 3).

The design and engineering of the facility and its site will fully incorporate current principles of sustainable architecture. The roof shingles, for instance, will be made of recycled tires, and other materials

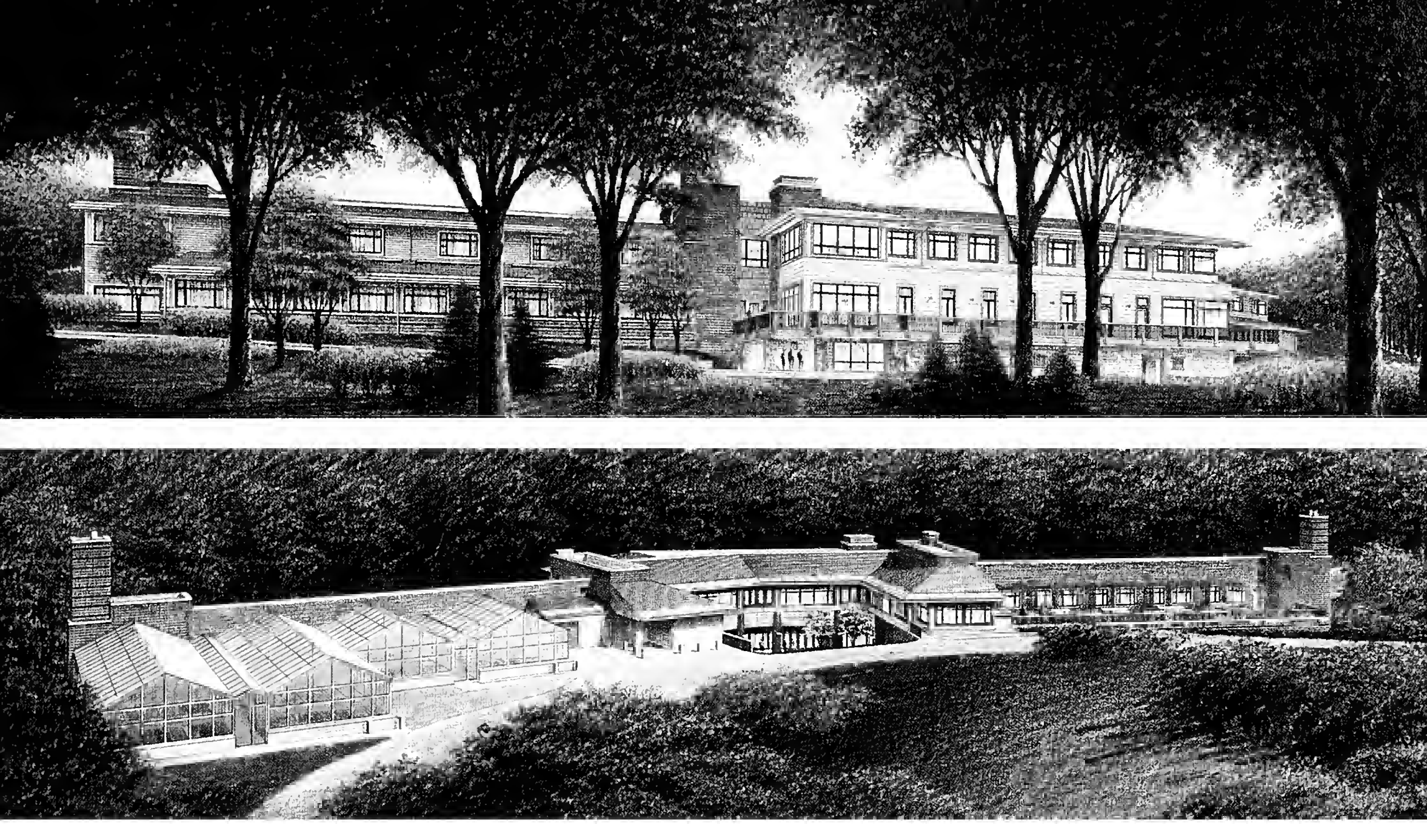


**Figure 3. Architectural rendering of the north (top) and south views of the Weld Hill facility, by KlingStubbins.**

throughout the building have been chosen to minimize their negative impact on the environment. Water flow from rain falling on the building and land will be managed to minimize any change to the hydrological conditions that prevailed prior to construction. Rooms will have ceiling fans and all windows will be operable to maximize natural circulation and encourage energy conservation. Finally, and most significantly, the building will be heated and cooled by a geothermal exchange system buried deep below the ground. This system—essentially a network of connected pipes buried in deep bore holes—will work like a very large radiator drawing heat from the earth in the winter and returning it in summer. There will be no basement furnaces or rooftop air conditioners.

## Building Research Capacity

Because of the challenges presented by the building's hillside location and its environmentally sensitive architecture, the Weld Hill facility is relatively expensive on a cost-per-square-foot basis. Can such an investment in research at the Arnold Arboretum be justified?

I believe the answer is yes. Elsewhere I have written extensively on the revolution sweeping the botanical sciences and the critical importance of the Arboretum's participation in this revolution.[2] Let me briefly review the reasons for our investment at this time.

In 2001 a landmark goal was reached in biomedical science when the Human Genome Project completed the sequencing of all human genes. Out of this work and related efforts with other species' genomes have come whole new approaches to basic research that are fundamentally transforming our understanding of biological organisms and their evolution. A new field of science, evolutionary developmental biology, has emerged that embodies many of the elements of this revolution. It seeks to understand how a sequence of genes inherited from two parents leads to the creation of a new organism and how this system of reproduction evolved over time. The methods of research in this new field, while drawing deeply on the sciences of molecular biology and biochemistry, have also given renewed importance to comparative biology, which analyzes the differences between species and studies their evolutionary history in order to bring insight to discoveries in developmental biology and genetics. All of these new approaches and their highly technical methodologies apply to the biology of plants as well as that of animals.

This has three major implications for the Arnold Arboretum. First, if the Arboretum is to maintain its scientific reputation for the long-term future, it must invest in the capacity to conduct this kind of research. The original trustees who created the Arboretum at Harvard University and the Arboretum's first director, Charles Sprague Sargent, would have surely agreed. Second, with its collections and endowment, the Arboretum has an exceptional opportunity to advance our understanding of plant biology, particularly that of trees. The herbarium and living collections, in addition to our incredible library collections, can only become more valuable as tools to further our understanding of comparative biology and the evolutionary history of botanical diversity. And, as noted earlier, the Arboretum needs research facilities of the highest caliber to preserve and enhance our future scientific reputation.

Should the Arboretum conduct applied research with more targeted goals typical at agricultural colleges and land-grant universities? I believe the answer is no, because the highest-quality research,

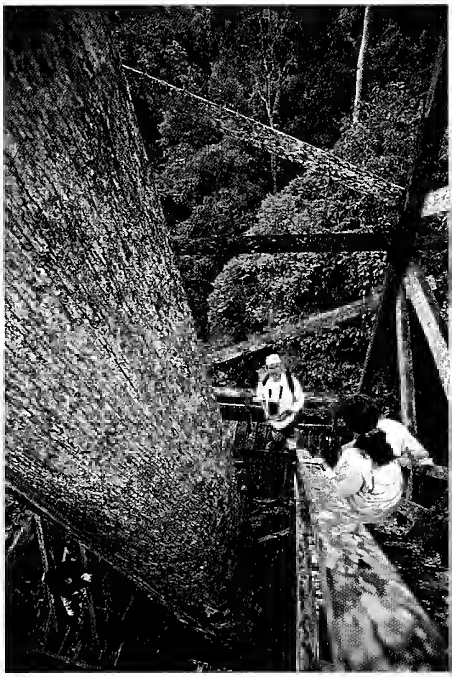
[2] Ibid.

## CURRENT INTERNATIONAL RESEARCH

Although the Arboretum is investing in a major research expansion at Weld Hill, it continues its international research in Asia through projects in southwest China, Kalimantan (Indonesian Borneo), and Papua New Guinea. Also of critical importance is our growing collaboration with the Smithsonian Institution. It was Charles Sprague Sargent, the Arboretum's first director, who first recommended an expansion of the Arboretum's mission to the tropical forests of Asia.[1] This tradition reached its apex in the spring of 2007 when Peter Ashton, Bullard Professor Emeritus and director of the Arboretum from 1979–1987, was awarded the Japan Prize for his lifetime devotion to research on the biology of Asian tropical forests (see Director's Report 1997–1999 for a full description of this work).

In 1983 Peter initiated a collaboration between the Smithsonian Institution's Tropical Research Institute (STRI) and the Arnold Arboretum which has since evolved into the Center for Tropical Forest Science (CTFS), a network of international partners around the world. This program supports long-term tropical forest research through a set of permanent, large-scale plots established in forests that differ in climatic conditions, soil types, and disturbance regimes. These research plots, located at twenty sites in fifteen different tropical countries in Asia, Africa, and Latin America, are united in maintaining a standardized monitoring methodology involving a complete census every five years of all trees larger than one centimeter in diameter, with each individual being mapped, tagged, measured, and identified to species. The first plot was established on Barro Colorado Island in Panama in 1980. In recent years the number of permanent plots has been expanding through support from the Arnold Arboretum, particularly in tropical Asia.

Recently the Center received grants to create a global earth observatory system for research on forest dynamics in response to climate change. This system will be based on the already existing permanent tropical forest plots and expanded to include new plots in temperate regions of the world. The grants will support measurement and monitoring of carbon flows and watershed dynamics in forests that are experiencing the impact of changes in global climate. The Center also maintains programs of field training, research grant support, and applied research into sustainable policies for the management and restoration of tropical forests.



**CTFS director Stuart Davies and Harvard biology professor Naomi Pierce at the CTFS tropical forest plot at Lambir National Park, Malaysia, photo by Christian Ziegler.**

In June of 2007 the headquarters of CTFS, and its director, Dr. Stuart Davies, relocated to the Harvard University Herbaria, with the Arnold Arboretum assuming full support for the twelve permanent plots in Asia. The CTFS program will continue to maintain the core of its operations at STRI in Panama.

[1] C. S. Sargent. "The First Fifty Years of the Arnold Arboretum," *Journal of the Arnold Arboretum* 3(3): 127–171 (January 1922).

of greatest long-term value to society, emerges out of the passions and interests of the highest-quality scientists asking basic research questions. Rather than defining a particular problem and hiring a scientist who will conduct prescribed research to solve it, I favor identifying the best scientists in very broad areas of endeavor—as defined by their previous research and their publications—and giving them the freedom to define their own research problems and priorities. Restricting individuals of this sort to a narrow specific problem usually leads to narrow findings and less valuable science. Open-ended research by very creative scientists is a better long-term investment strategy.

In fact, the Arboretum's capacity to make major advances in our basic understanding of plant biology is unique. There are many institutions with strong agricultural missions (Cornell comes to mind) that are much better positioned to apply massive scientific resources, underwritten by the Department of Agriculture, to the resolution of agricultural or horticultural problems by developing drought- or pest-resistant varieties of crop species, for example. Today, however, the distinction between applied and basic research has become increasingly blurred by the impact of the genomics revolution on our understanding of plant physiology and development. These days basic research in plant biology promises to contribute directly to imme-

Senior research scientist David E. Boufford collects herbarium specimens with the help of local Tibetans at an elevation of 3,780 meters, in Daofu Xian county of western Sichuan, China. In 2007, Arboretum researchers joined an international team for the fourth of five expeditions to China's Hengduan Mountain region, home to 30 to 40 percent of China's estimated 30,000 plant species. The group made 2,652 collections of vascular plants for a total of 17,861 herbarium sheets, and 752 collections of tissue samples for molecular analysis. In addition, members of the team photographed the plants and their habitats for the project's biodiversity website (http://hengduan.huh.harvard.edu), the largest collection of such documented and vouchered images of Chinese plants, photo by Susan Kelley.

diate societal problems in ways, and in a time frame, that are very hard to predict.

Let me cite as examples three major problems that currently confront us and suggest how basic research on woody plants might point to solutions: global climate change, remediation of severely polluted land, and energy independence. Early each year, as the days of spring grow longer, a magical phenomenon sweeps across vast tracts of land in the temperate regions of the world. The branch tips of a wide diversity of deciduous trees develop a covering of carbon-sequestering machines called leaves. Over time, this greening of a large part of the earth's surface has a huge impact on the overall carbon budget of the planet and, therefore, on its climate. Curiously, though, maple trees develop their leaves very early in spring, while for unknown reasons the leaves of oak trees emerge much later. Could basic research on the biology of leaf emergence and canopy development, particularly on the difference in the timing of these phenomena in oaks and maples, contribute to a greater understanding of global climate and how humans are changing it?

Consider the second example, remediation of land pollution. There are natural populations of plant species whose roots have adapted to growing in soils that have been severely contaminated by heavy metals, such as mercury. Could an investigation of the basic biology of root growth under these conditions suggest ways that this capacity might be introduced into a fast growing tree such as aspen, thereby allowing the mercury to accumulate in its wood for safe disposal?

Finally, the search for renewable energy has increasingly focused on potential fuels from plants (biofuels). Unfortunately, the strong and resilient structure of wood, with which any carpenter is quite familiar, resists the efficient extraction of energy to create a liquid form of fuel able to compete with gasoline. Could a better understanding of the biology of wood lead to a crop that efficiently yields its energy in a highly concentrated form of fuel?

In sum, I believe the Arboretum must seize the opportunity before it. We can become an international leader in the type of basic research that will be required to resolve fundamental problems facing today's world. Through the construction of research facilities on Weld Hill, we are taking a giant step toward achieving this goal.

## MANAGEMENT INITIATIVES FOR COLLECTIONS AND LANDSCAPE

The past five years have brought significant progress in strengthening operations at the Arnold Arboretum. Signaling an increased commitment to excellence in the care of the living collections as well as the landscape in which they grow, staff members completed a strategic plan with the explicit goal of attaining an exemplary level of quality in arboretum management.

To define excellence in the care and development of a botanical collection and landscape, Arboretum managers investigated four sister institutions that share our mission as centers of knowledge and investigation relating to woody plants: Holden Arboretum in Kirtland, Ohio; Morris Arboretum of the University of Pennsylvania, Philadelphia; Morton Arboretum, Lisle, Illinois; and the U.S. National Arboretum, Washington, DC. These investigations included interviews with staff, reviews of policies and management practices, and tours of facilities, equipment, and landscapes to explore common challenges and identify best practices across our profession.

**Arborist Robert Ervin gets a lift to collect seed from the upper branches of an *Abies* accession for use in the Arboretum's 'Tree of Life' investigations of gymnosperms, funded by the National Science Foundation, photo by Kathryn Richardson.**

In assessing the accomplishments and aspirations of our peer institutions, we identified three key initiatives that will significantly enhance the work of the Arnold Arboretum: Landscape Management, Collections Development, and Plant Health Management.

### *Landscape Management*

Our careful review of how landscape work is accomplished at sister arboreta underscored the benefits of assigning to each horticulturist the responsibility for specific collections and landscapes. As our professional peers have found, this site-specific focus yields substantial cumulative knowledge, enabling staff to provide increasingly effective horticultural care and to serve as "local" experts on soils, pests and disease, collections development, hardscape maintenance, and visitor needs and impacts.

In June 2006, following a history of more broadly deploying staff, Arboretum managers implemented this approach through a new Landscape Management Plan. After organizing our 265-acre landscape into 62 management zones composed of contiguous areas that share similar challenges, collections themes, and management priorities, we placed each zone under the care of a staff horticulturist. Now entering its second year of implementation, the new system is yielding substantial improvements, which will be amplified as horticulture manager Steve Schneider collaborates with our dedicated horticulturists to further refine care plans for collections, natural areas, and historic features.

In a second phase, to be completed in 2009, the Landscape Management Plan will expand to include curatorial initiatives, cultural resource management goals, and longer-term capital projects. The end result will be a comprehensive vision for the Arnold Arboretum landscape.

*Collections Development*

Our assessments also identified a strong need to develop a highly systematic approach to collections development. As we enter our 137th year, the Arboretum collections are distinguished by their maturity, with over 500 accessions that exceed 100 years in age. Through careful planning, the coming decades can bring a significant strengthening of our collections.

Priorities for future development include expansion of our national collections in *Acer, Carya, Fagus, Syringa, Stewartia,* and *Tsuga,* along with the acquisition of documented, wild-collected accessions to fill critical gaps, or augment specimens of lesser-known provenance. We will also create new research opportunities through increased representation of the disjunct genera of eastern Asia and North America and other taxa that can directly support the work of Arboretum scientists. Additional tasks include assessing space-constrained collections, particularly our plantings of shrubs, as well as implementing new curatorial policies for potentially invasive accessions.

In January 2007, Michael Dosmann, a recent graduate of Cornell University's doctoral program in horticultural science, joined the Arboretum staff in the new position of curator of living collections. A former Arnold Arboretum Putnam Fellow, Michael brings strong expertise in both hardy woody plants and collections management. In 2008, he will complete a collections development plan to guide the acquisition of new accessions and to set curatorial priorities for the next five years.

*Plant Health Management*

Not surprisingly, the larger environmental changes altering our world have affected the work of the Arnold Arboretum. Most notably, the human-mediated transport of organisms has made the management of hemlock woolly adelgid, winter moth, and other invasive species a challenge of expanding scope. At the same time, we have sought to more effectively manage the complex and changing ecosystem within which our diverse botanical collections grow. To address these and other needs, the strategic vision for horticulture called for a staff position dedicated to overseeing plant health.


**Horticultural staff relocates *Syringa* 'Purple Haze' (AA 36-2002) on Bussey Hill from its testing location at the Dana Greenhouse, photo by Steve Schneider.**

In the fall of 2007, Julie Coop, former grounds superintendent, was appointed plant health manager. Charged with implementing a comprehensive approach, Julie will coordinate integrated pest management activities and increased monitoring of critical environmental factors over time, including pest populations, soil pH, and soil moisture. This work will provide important opportunities to better understand the impacts of introduced organisms, climatic shifts, and other forces of long-term ecological change in the Arboretum environment.

These initiatives promise to bring the Arnold Arboretum to the forefront of professional practice, requiring significant investment but achieving the standards of excellence and innovation befitting an internationally respected botanical institution.

—*Richard Schulhof, deputy director*

## Sargent Fellows

Equally important as creating new facilities for research is the development of personnel policies to support the hiring of senior scientists at the Arboretum. Ordinarily at Harvard University faculty members are hired by academic departments to teach while also pursuing scholarly activities. Since the Arboretum is not an academic department—it is administered by the Vice President for Administration rather than being part of an academic school such as the Faculty of Arts and Sciences—we needed to create a new type of position that would attract highly qualified scientists. At the same time, a set of recruitment and retention policies different from those ordinarily associated with our administrative positions would be required. Scientists in a university setting usually have remarkable freedom to define their work schedules and to develop their research programs. The quality of their research is judged according to exactingly high standards set by the larger community of scientists rather than by the administrator who "supervises" them. Therefore the Arboretum's personnel policies must be crafted to encourage creativity rather than constrain it.

In 2003, working with Harvard botanical faculty members in Cambridge, I defined a new type of position: the Sargent Fellow. Over time, I envision that the Arboretum may have six or eight such Fellows managing their own research programs in the new Weld Hill facility. Initial appointments will be for a fixed term of time (two years, followed after evaluation by another five years). At the end of this time, Fellows will be considered for permanent appointments based on a review of the quality of their research by their peers.

In August 2003, the Arboretum appointed the first Sargent Fellow, Dr. Sarah Mathews. Sarah conducts research on the biology and evolution of systems in plants that sense environmental conditions and control plant development. She currently works in borrowed facilities at the Harvard University Herbaria in Cambridge and eagerly anticipates the construction of the Weld Hill facility. In 2004 I recruited a second Sargent Fellow, Dr. Maciej Zwieniecki, who is a plant physiologist interested in the physical and biological mechanisms that control the acquisition and movement of water and nutrients in very large trees.

Sargent Fellow Sarah Mathews collects foliage samples of *Thuja plicata* for DNA analysis as part of the 'Tree of Life' project, photo by Mark Beilstein.

As completion of the Weld Hill facility approaches, I will begin searching for a senior research director, who may also be a faculty member at Harvard. For this position I hope to attract an exceptional scientist who will oversee the development of a broad, long-term research program on the biology of trees.

## Balancing a Dual Mission

In making this major investment in research, does the Arboretum risk overshadowing its traditional mission to serve the public? For the Arboretum, administered as it is by one of the world's leading research universities, what is the proper balance between the scholarly activities that ordinarily define the mission of Harvard and the programs of education and visitor amenity that serve the general public?

During the Arboretum's first half-century, approximately ninety percent of the Arboretum's activity and expenditures would probably have been defined as research by its director, Charles Sprague Sargent. At that time public activities largely consisted of publishing the *Bulletin of Popular Information* (the predecessor of *Arnoldia*) and holding occasional public lectures by staff for local schoolteachers. This was also a time when research itself, especially exotic expeditions securing new species in distant lands and introducing them as landscape plants for the garden, was seen by the Arboretum's public—primarily affluent

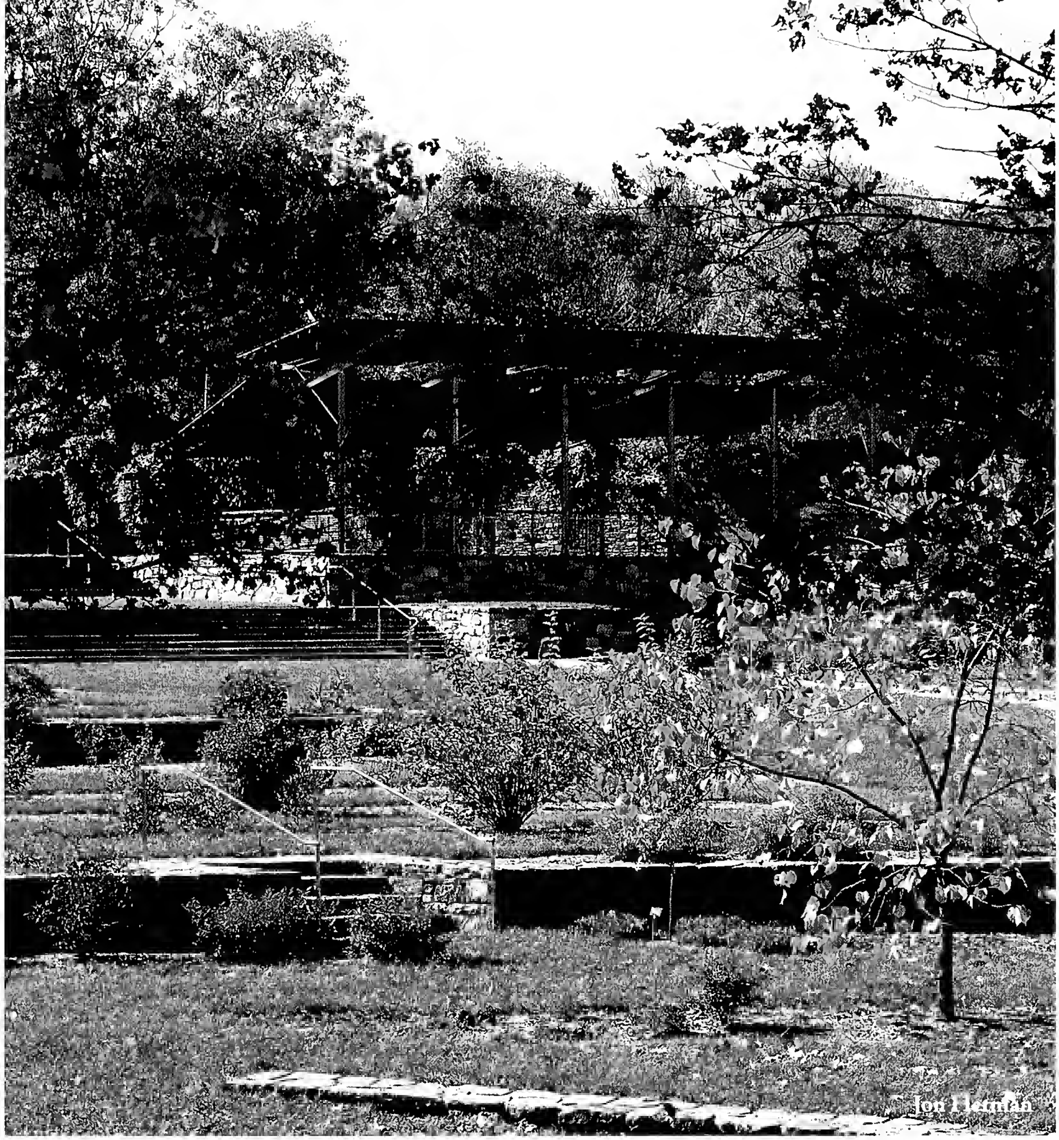
Bostonians during that period—as more obviously serving their interests (see Current International Research, page 13).

Over the last half-century, botanical research, particularly at Harvard, has become much less accessible to non-specialists, while the Arboretum's public has become much more diverse. When I became director in 1989, research as a percentage of the budget was below twenty percent and declining. As described in my most recent Director's Report, in 2002, the scientific reputation of the Arboretum was coasting on the impact of work done decades earlier, and current research activity was being conducted by a few scientists who were housed in Cambridge and distant from the collections here in Boston. If research at the Arboretum was to avoid extinction, a major investment would be required to modernize facilities, expand the scope of research, and fully engage the intellectual resources of the University in a collaborative effort. The Weld Hill facility and our Sargent Fellows program begin to address this need.

In the 1980s, at the same time that our research effort was contracting, our public service initiatives, including education programs for children and adults, as well as visitor services, were expanding significantly. Over the past decade and a half, we have increased our commitment to improved care for our collections and landscape (see Management Initiatives for Collections and Landscape, page 16). Large landscape projects, exemplified by the new Leventritt Shrub and Vine Garden, have richly enhanced the enjoyment of visitors. In 2002, we adopted the Landscape Institute (formerly administered by Radcliffe College as the Radcliffe Seminars Landscape Design Program), adding a major public program to our budget.

Over the next five to ten years, our investment in research is likely to increase to perhaps sixty percent of our budget, with the remaining forty percent supporting programs that serve the public. This seems about right to me. However, these two parts of our dual mission—as research institution and as public museum—have always been in some tension at the Arboretum, and they pose an unusual governance challenge for the University.

In general, research at Harvard is conducted within its schools, with the directors of research organizations reporting to a dean. This is how the Arboretum was governed from about 1930 to 1988 before



## LINDEN PATH AND THE LEVENTRITT GARDEN

In 2006, completion of a new path through collections of *Tilia* (linden), *Cercidiphyllum* (katsura), and *Lonicera* (honeysuckle) marked an important addition to the Arboretum's pedestrian circulation system. Linden Path, designed by the landscape architectural firm Reed|Hilderbrand Associates, provides a direct connection between Meadow Road and the Leventritt Garden, guiding visitors along a gently winding passage that features exceptional specimens of *Tilia* and *Cercidiphyllum*.

The Leventritt Garden, also designed by Reed|Hilderbrand, was recognized by the American Society of Landscape Architects with its 2007 Award of Excellence. Completed in 2002 and now a highly popular visitor destination, the Leventritt Garden provides a long-needed home for sun-loving shrubs and vines as well as new interpretive exhibits exploring botanical research, plant conservation, and horticultural introduction.

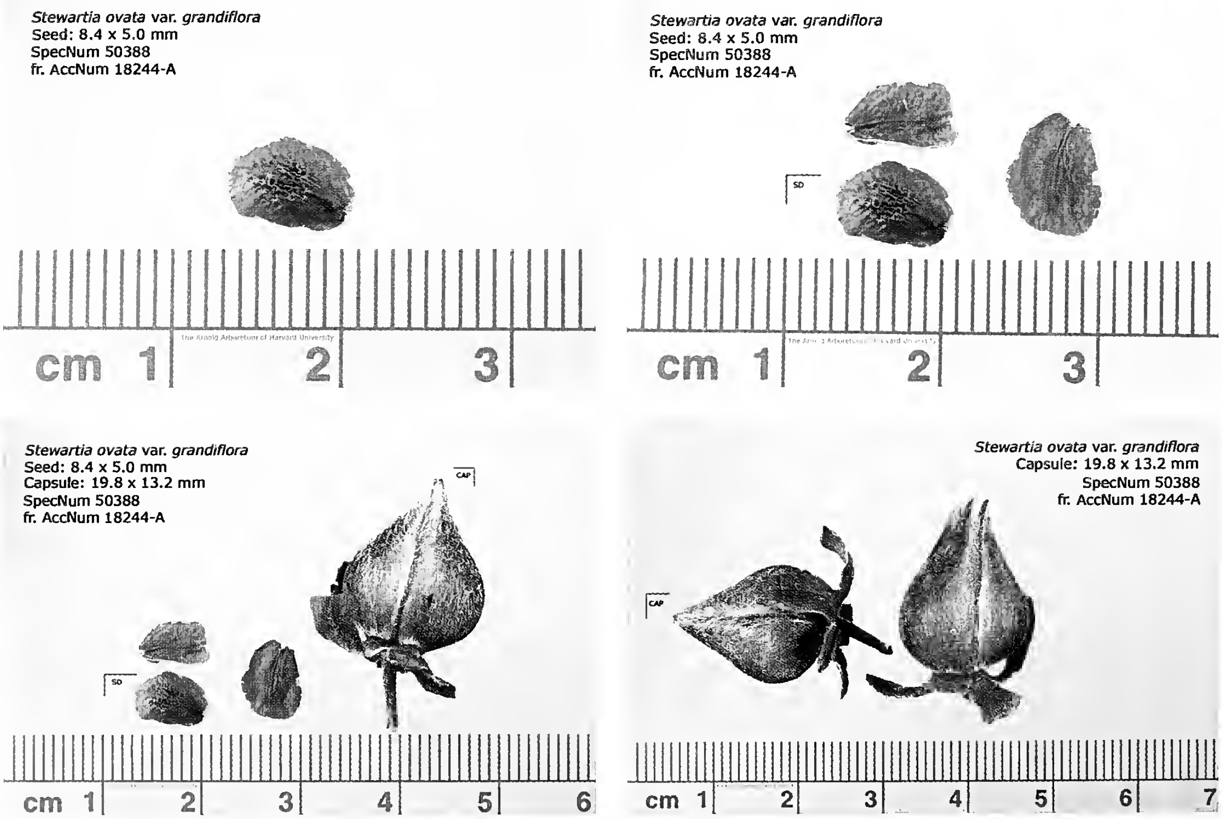
*—Richard Schulhof, deputy director*

## SEED HERBARIUM IMAGE PROJECT

Beginning in the 1960s, Arboretum propagator Al Fordham created a seed herbarium to facilitate the growing of unfamiliar species. Collecting the seed of several hundred rare and unusual taxa, Fordham envisioned a unique resource for the identification and propagation of woody plants from around the world. In 2004, his vision entered the digital age through the Arboretum's Seed Herbarium Image Project (SHIP). Made possible through the generous support of the J. Frank Schmidt Family Charitable Foundation, the Cabot Family Charitable Trust, and the Stanley Smith Horticultural Trust, SHIP uses high-resolution digital photography to document the morphology of seeds and selected fruit structures. The SHIP images, now available on the Arboretum's website, support scientists, horticulturists, and educators, particularly in propagation research and management of rare and endangered species.

The SHIP team is working to finish photographing the Arboretum's six national collections within the North American Plant Collections Consortium: *Acer* (maple), *Carya* (hickory), *Fagus* (beech), *Stewartia*, *Syringa* (lilac), and *Tsuga* (hemlock). Using new protocols and equipment developed for microphotography, SHIP will next document species within the Ericaceae (heath family).

—*Richard Schulhof, deputy director*




**Seed and fruit images of *Stewartia ovata* var. *grandiflora* created as part of the Seed Herbarium Imaging Project (SHIP) include a detail of a single seed, multiple seeds displaying alternate views and morphological variation, seeds shown with fruiting structure, and fruiting detail, photos by Julie McIntosh Shapiro.**

it was moved to administration within the Central Administration. At about the same time, other non-research organizations providing public service, like the University Art Museums and the American Repertory Theatre, were also moved to the Central Administration. Today, with the revitalization of our research mission and our major investment in research facilities and staff, we have become something of an anomaly in Central Administration and this creates some specific problems for the Arboretum.

First, there are no personnel policies for research scientists in the Central Administration of the University because research scientists at Harvard ordinarily receive academic appointment in one of the schools. Second, the Arboretum now manages seven federal research grants—another anomalous activity within Central Administration—and the number promises to grow. Finally, because neither the director of the Arboretum nor the researchers on its staff are members of a faculty, there is no link between long-range planning for research at Harvard, which happens in faculty meetings and committees, and long-range planning at the Arboretum which does not involve faculty.

The issue of governance for the Arboretum is further complicated by the administrative position of the Harvard University Herbaria (HUH), located five miles away in Cambridge. Nearly half the herbarium and library collections within this botanical unit are the property of the Arnold Arboretum and we pay for about 40% of the facility's operation. Yet its director reports through a school to the Dean of the Faculty of Arts and Sciences (FAS) and the administrative and personnel policies governing its operation are defined and executed by FAS.[3] Despite considerable similarity in their missions, these two botanical units are governed in very different parts of the University.

All of these factors have come together to frame a critical question: Should the Arboretum return to management by the Faculty of Arts and Sciences, consistent with its research mission? Or should it remain under the management of Central Administration, consistent with its public mission?

This matter should be resolved before a new director is chosen for either the Arboretum or HUH, but it presents a thorny challenge. In the case of the Arboretum, a governance structure that is dominated

[3] In July, 2005, I accepted a three year term as director of HUH in addition to my duties as director of the Arboretum.

## LANDSCAPE INSTITUTE

Since its relocation to the Arnold Arboretum in 2002, the Landscape Institute (formerly the Radcliffe Seminars Landscape Design Program) has undergone several changes that will prove critical to its future success as an educational resource for professionals working in landscape design and management, historic preservation, landscape history, and related fields. In 2006, the Institute moved from the Cronkhite Center, the program's home for more than seven years, to 29 Garden Street in Cambridge, just outside Harvard Square. The new facility, with its strikingly contemporary design, offers increased space and new possibilities for classes and special programs.

An equally significant transition began in early 2007 when Landscape Institute director John Furlong, following twenty-five years of strong leadership, announced his desire to step down to devote more time to private practice and teaching. Following a national search, Heather Heimarck assumed full-time duties as director in February 2008. Her background includes a Master in Landscape Architecture from the Harvard Graduate School of Design, work with several accomplished landscape architects, and the founding of Heimarck and Foglia, formerly HighMark Land Design, a firm specializing in green design, innovative use of plant materials, and new construction approaches. In keeping with the progressive spirit of the Institute, Heather's extensive practical experience and commitment to innovation promise important new directions in sustainable design, construction, and landscape horticulture. Looking to the future, the Landscape Institute will continue the work of Arboretum founding director Charles Sprague Sargent to strengthen the landscape professions, while also addressing burgeoning societal needs for leadership in environmental design and management.

*—Richard Schulhof, deputy director*

by either FAS or Central Administration risks undermining one part of our dual mission or the other. Put another way, if the dual mission of the Arboretum is to survive into the future, its governance structure must support integration of its research investment with the traditional mission of the University (research and undergraduate education) while also encouraging the public mission of the Arboretum to thrive.

### A New Model for the Arboretum

Thus our sizable investment in research will only succeed for the Arnold Arboretum if it also succeeds for the University. Effectively this means that the conduct of research must be governed as an integrated part of ordinary academic operations and coordinated through members of a school's faculty. In this case, the logical school is FAS, where the Arboretum resided prior to 1988. I believe the decision about how Arboretum research is to be managed will need to recognize this reality. The remaining question about Arboretum governance regards its public mission: what threats might it face in an academic context such as FAS?

Magnolia 'Elizabeth' (AA 120-78), photo by Jim Harrison

Three come to mind. First, a large bureaucracy exists within FAS to manage intelligent and ambitious professors who are powerful through their appointment and their relations with outside sources of funds (donors, government agencies, consultancies). Professors, in turn, are always creative in their efforts to circumvent a constraining bureaucracy. A small public museum governed by this sort of bureaucracy without the protection of a resident professor can suffocate through no one's ill intentions.

Second, public service will never be a high priority at major research universities beyond the normal public relations activity required by proximity to non-university neighbors. Put more positively, universities like Harvard provide "public service" for the long term: they develop tomorrow's leaders and increase our understanding of the world. In such a university, a unit providing direct services to the public can suffer from administrative and financial neglect simply because it is not a priority for senior administrators and deans.

Finally, unprotected public service operations in the midst of large academic schools can suffer financial predation from well-meaning but narrowly focused academics. Funds that are not being used to educate university students or support faculty research look to many professors like money being poured into a hole, money that could be more fruitfully spent on academic activities.

In view of these threats, three elements seem essential to protecting a university unit with a mission of direct public service—what we here call the public museum of the Arboretum. First, the public museum must have a clear identity and sufficient independence to establish its own brand of administrative culture, one that openly acknowledges a commitment to service. This requires real authority, particularly over budgets and personnel, even though in an academic setting this authority is normally vested in the dean and his or her administration.

Second, this independence can only work if the public museum is given a guaranteed base of financial support sufficient to carry on essential activities. This base of support must be ensured a reasonable rate of annual increase to sustain it against inflation in the future. While this will support the core program, special projects that enhance its facilities and programs will also require the public museum to raise money from the public, largely through philan-

## ENHANCING VISITOR EXPERIENCE

*A Time for Change*, a strategic vision authored by Bob Cook in 2002, voiced a strong commitment to improving the quality of information and orientation furnished to Arnold Arboretum visitors. After several years of planning, 2007 brought completion of a comprehensive wayfinding signage system that enables visitors to fully explore our 265-acre historic landscape and diverse botanical collection. Created by the environmental graphic design firm Roll Barresi, the system provides "you are here" maps, path markers, and other navigational aides to ensure confident and effective visitor wayfinding. In 2009, the system will be augmented by a new map brochure and temporary interpretive signs focused on seasonal information.

To provide leadership for visitor programs, Julie Warsowe, a graduate of Cornell University's program in public garden management, was appointed the Arboretum's first manager of visitor education in 2006. Julie recently completed a survey of Arboretum visitors that provides valuable information about the demographics, motivations, and interests of the broad community that utilizes our landscape. Survey data, compiled and analyzed by visitor research consultants People, Places and Design, will inform development of new interpretive programs, including plans for new exhibits in the Hunnewell Building Visitor Center.

# DIGITAL RESOURCES

## Plant Collections

- **Plant Inventory:** Search the Arboretum's living collections database by common or scientific name; http://arboretum.harvard.edu/plants/inventory.html
- **Interactive Map of the Arboretum:** Explore 31 plant collections and 76 featured plants; http://www.arboretum.harvard.edu/visitors/map.html?myURL=/visitors/visitors.html&myLayer=collections
- **Multisite Plant Inventories:** Search 24 living collections and conservation databases for participating botanical institutions, hosted by the Royal Botanic Garden, Edinburgh, Scotland, UK; http://rbg-web2.rbge.org.uk/multisite/multisite3.php

## Herbarium Collections

- **Cultivated Herbarium:** Search the Arboretum's herbarium collections by common or scientific name; http://arboretum.harvard.edu/plants/herbarium.html
- **Seed Herbarium:** Browse images from the Arboretum's seed herbarium; http://arboretum.harvard.edu/plants/herbarium.html
- **Joseph Rock's Type Specimens:** Access to 197 type specimens collected by Joseph Rock between 1923–1932 in western China and Tibet; http://www.arboretum.harvard.edu/library/tibet/herbarium.html
- **Maps of Joseph Rock:** Navigate 10 individual hand-drawn maps and related gazetteer illustrating plant explorer Joseph Rock's travels (1924–1927) in China;
  **Maps:** www.arboretum.harvard.edu/library/tibet/zoom/rock_maps.html
  **Gazetteer:** www.arboretum.harvard.edu/library/tibet/map.html

## Photographic Collections

- **The Arboretum Through Time:** Historical photographs of the Arboretum's landscape and collections; www.arboretum.harvard.edu/programs/views/intro.html
- **Botanical and Cultural Images of Eastern Asia, 1907–1927:** Archival images of Arboretum plant explorers and their field photographs from their exhibitions; www.arboretum.harvard.edu/programs/eastern_asia/overview.html
- **South Central China and Tibet: Hotspot of Diversity:** Images of natural history and ethnographic collections from Arnold Arboretum expeditions to China and Tibet between 1924 and the present; http://www.arboretum.harvard.edu/library/tibet/expeditions.html
- **Cienfuegos Botanical Garden, Cuba:** Archival and contemporary photographs of the former Atkins Institution, administered by the Arnold Arboretum from 1946 to 1959; http://www.arboretum.harvard.edu/programs/cuba/intro.html

## Other Resources

- **Arnoldia:** Searchable database of all volumes published during the last hundred years of the Arboretum's journal *Arnoldia* and its antecedent, *The Bulletin of Popular Information;* http://arnoldia.arboretum.harvard.edu
- **Silva:** All issues of the Arboretum's news magazine since its inception in 2005; http://arboretum.harvard.edu/aboutus/silva/current.html
- **Correspondence Index:** A work in progress referencing institutional correspondence from the 1880s to 1940; http://www.arboretum.harvard.edu/library/about_arc.html
- **OASIS:** Harvard's Online Archival Search Information System includes 42 finding aids to archival and manuscript records at the Arnold Arboretum Archives; http://oasis.harvard.edu
- **Hollis:** Searchable database containing more than 9 million records for more than 15 million items in the Harvard University Libraries; http://lib.harvard.edu/
- **Google Book Search:** Search the full text of all books available in Google Book Search, including some 3,000 titles from the Arnold Arboretum Library; http://books.google.com

thropy rather than earned revenue which usually creates too many conflicts in an academic culture.

Finally, a public museum in academia needs deeply committed leadership with a strong belief in its public mission, not only within its internal operation but also at more senior levels of the university. For the Arboretum, this certainly includes the director, who may be primarily focused on the health of the research mission. But it must also extend to the supervising administrator, whether in FAS (the dean) or in Central Administration (the provost or a vice president).

These governance issues are now being addressed in two ways. First, the provost has formally assigned them for deliberation to the University's senior committee for long-range planning for science and engineering. I anticipate resolution of the matter by the end of the fiscal year in June. Second, at the Arboretum we have begun to develop a new model of operation that more explicitly acknowledges the identity of our public museum functions traditionally serving our visitors and students.

## The Public Museum

Defining the programs at the Arnold Arboretum that provide public service is relatively easy in the case of educational programs and visitor services. Our educational programs are of two kinds. Children's education serves about 2,000 individuals under the age of ten each year. Adult programs include lectures and classes for the dedicated amateur and the more formal programs of the Landscape Institute, which can lead to a certificate indicating professional-level achievement.

The services for visitors might be characterized as providing access to information. They include the traditional functions of our horticultural library and our visitor's center, both of which serve people walking in through the door. But they have also been expanded to include the vast amount of information we are now making available through the Internet (see Digital Resources, page 28). Because digital access provides valuable information to anyone anywhere in the world at any time, these efforts promise to continue growing in the years to come.

## SCHOOL PROGRAMS

Over the course of several years, Arboretum friends Henry and Nod Meyer have generously supported explorations of the natural environment for urban children. Thanks to their encouragement, Arboretum field study programs have grown significantly in depth and focus, now hosting over 2,000 children annually with a special commitment to elementary schools in Boston and Chelsea, and to local Head Start centers. Among these initiatives is a new field study that invites Boston students to investigate the dramatic changes caused by hemlock woolly adelgid on the Arboretum's Hemlock Hill. The new program, developed in collaboration with Boston teachers and titled "A Changing Ecosystem," supports the fifth-grade science curriculum through a case study in biological invasion that powerfully conveys the dynamics of ecological change.

Kris Snibbe/Harvard News Office © 2012 President and Fellows of Harvard College

A second initiative serves pre-schoolers attending neighborhood Head Start centers. Over the past three years, visiting children from Hyde Park, Jamaica Plain, and Roslindale were led by trained volunteers in exploring flowers, fruit, bark, soil, and other aspects of plants and landscape. Designed in collaboration with specialists in early childhood education, the program provides children with a range of new outdoor experiences, builds vocabulary, and encourages curiosity about the natural world. In coming years, we will increase our training for Head Start instructors in inquiry-based teaching methods and also offer family activities that foster parental participation in pre-school education. In addition to supporting public education, these efforts seek to strengthen neighborhood connections and promote greater enjoyment of the Arboretum by the diverse communities of Boston.

—*Richard Schulhof, deputy director*

Horticultural technologist Scott Grimshaw cuts invasive undergrowth of *Rubus* spp. growing along Oak Path, photo by Richard Schulhof.

One might ask, does the Arboretum's program in horticulture also provide "public service"? While the living collections are of great value for research, they and the grounds are given a much higher level of care than would be the case if they were grown solely for the use of scientists. A planting for purely scientific use would look like an agricultural field, with long rows of trees enclosed by a tall fence, rather than an open, beautiful landscape inviting the visitor to linger. I therefore see our strong commitment to horticultural excellence on the grounds as a public service, though that commitment is shared with our obligation to serve the needs of researchers today and tomorrow. This dual function of the living collections is the essence of Charles Sprague Sargent's original vision for the Arboretum.

Last summer we reorganized the Arboretum into two programmatic entities, research and public museum, supported by a central administration consisting of the director's office and the functions of finance, information technology, and facilities (see Organizational Chart, page 32). As noted earlier, the research program will be headed by a director of research and will include all senior research staff, as well as the post-doctoral fellows and technicians in their laboratories. The public museum will include the functions of horticulture, education, and information access for visitors. It is now headed by my deputy director, Richard Schulhof.

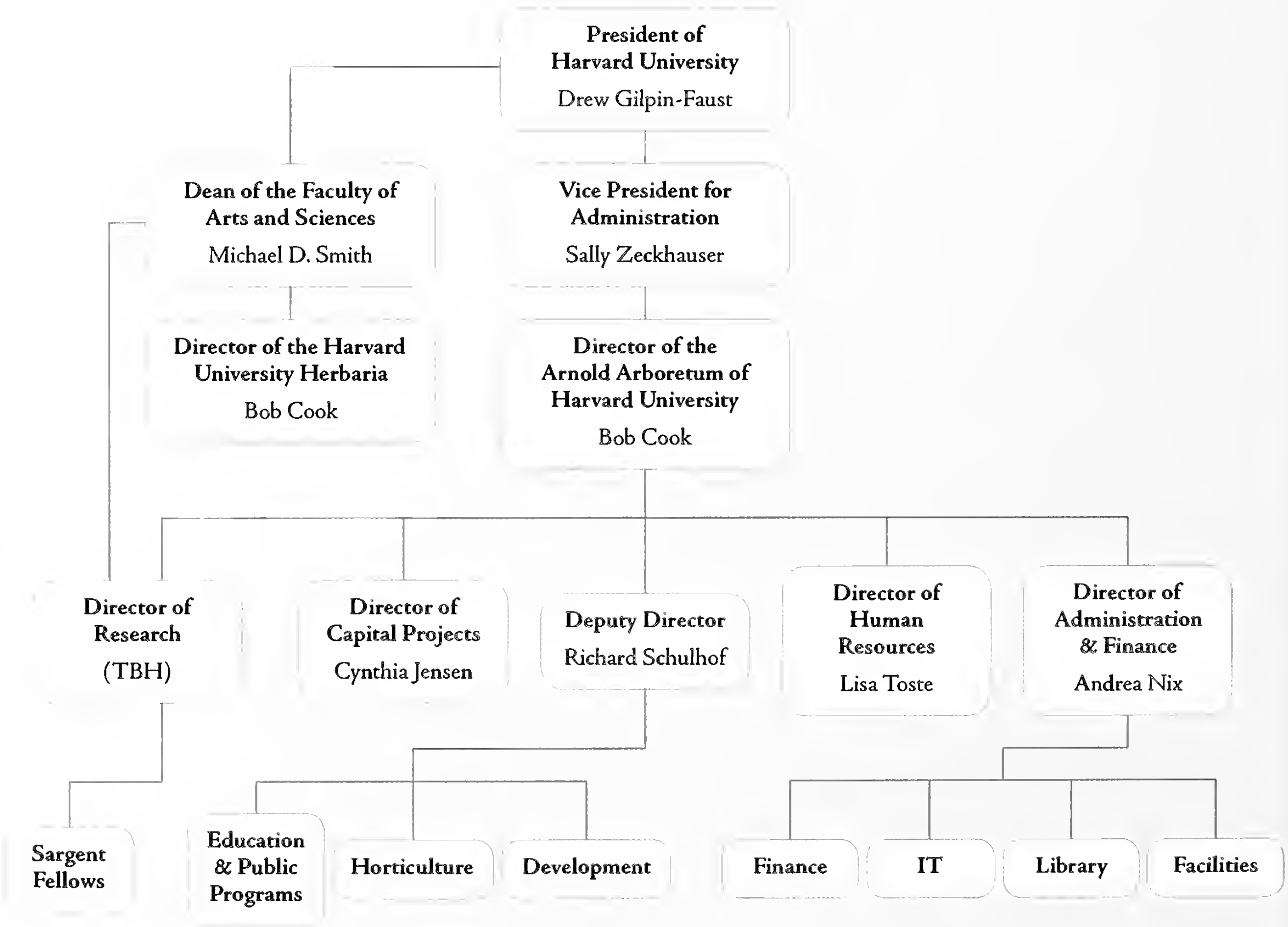
Anticipating its need for financial security, we have identified a core budget for the public museum that for the current fiscal year amounts to $9,375,000 (out of a total Arboretum budget of $13,770,000; see Summary of Operations, page 33). We have also projected a four-percent rate of budget increase for future years. Finally we have transferred the Arboretum's membership and development program from administration (reporting to the director) to the public museum (reporting to the deputy director).

## The Arboretum and its Friends

One may question the change in the reporting relationship of the development department. Shouldn't it support the entire institution, not solely the public museum?

Ever since its creation in 1872, the Arboretum has benefited from very generous friends and their generosity has arrived with remarkably few restrictions beyond a specification that their gifts should support the Arboretum (as opposed to Harvard University). I believe this pattern of giving reflects unusual trust on the part of our friends in the wisdom of past directors.

### ARNOLD ARBORETUM OF HARVARD UNIVERSITY ORGANIZATIONAL CHART



## SUMMARY OF OPERATIONS

This chart indicates our overall financial performance for the past six years. As we have taken on new capital projects and invested in research, our overall budget has moved from overall surpluses to deficits in the past two years which have been covered by reserves. With respect to income trends, the appointment of Sargent Fellows after 2003 has led to increases in research grants, and renewed efforts in membership have brought in increasing numbers of gifts. The large jump in education income in 2003 represents the assumption of administrative responsibility for the Landscape Institute and its educational programming; it is offset by equal increases in expenditures. With respect to expenses, salaries and services are the major categories increasing, along with debt service reflecting the completion of the Leventritt Garden in 2005. Expenses will continue to increase in coming years as we expand our investment in research.

| | Actual FY 2002 | Actual FY 2003 | Actual FY 2004 | Actual FY 2005 | Actual FY 2006 | Actual FY 2007 |
|---|---|---|---|---|---|---|
| **Income** | | | | | | |
| Endowments | 7,666,661 | 8,226,848 | 8,244,215 | 8,360,913 | 9,042,906 | 9,590,265 |
| Membership/Gifts | 644,972 | 497,892 | 376,947 | 292,612 | 307,663 | 442,613 |
| Enterprise | 116,774 | 115,463 | 323,496 | 239,770 | 334,377 | 346,373 |
| Grants | 112,446 | 39,422 | 194,647 | 410,335 | 455,040 | 566,553 |
| Education/Publications | 70,799 | 605,748 | 607,701 | 675,098 | 753,989 | 636,561 |
| **Total Income** | **8,611,652** | **9,485,373** | **9,620,006** | **9,845,844** | **10,754,143** | **11,434,580** |
| **Expenses** | | | | | | |
| Salaries/Benefits | 4,162,438 | 4,393,437 | 5,000,632 | 5,801,809 | 6,219,559 | 6,526,842 |
| Supplies/Equipment | 429,101 | 460,973 | 554,039 | 560,997 | 600,118 | 562,473 |
| Facilities/Operations | 717,645 | 881,689 | 724,302 | 800,482 | 1,143,790 | 1,505,463 |
| Services | 771,907 | 1,058,734 | 1,296,032 | 1,131,235 | 1,931,237 | 1,990,992 |
| University Subvention | 256,483 | 264,092 | 292,123 | 317,134 | 346,520 | 378,988 |
| Travel | 66,934 | 107,962 | 142,577 | 235,863 | 182,432 | 201,637 |
| **Total Expenses** | **6,404,508** | **7,166,887** | **7,882,705** | **8,714,636** | **10,283,824** | **11,018,610** |
| **Excess (Loss)** | **2,207,144** | **2,318,486** | **1,737,301** | **1,131,208** | **470,319** | **415,970** |
| **Debt Payment** | **312,416** | **304,434** | **393,609** | **609,450** | **566,729** | **568,962** |
| **Total Excess (Loss)** | **1,894,728** | **2,014,052** | **1,343,692** | **521,758** | **(96,410)** | **(152,992)** |

The research program of the Arboretum, now and as expanded in the near future, will be fully integrated into the University's overall research endeavors in the botanical sciences. As such it will benefit from the fundraising energies of the University, which are traditionally focused on alumni. Fundraising for the public museum will face the significant challenge of operating nimbly in the shadow of Harvard's larger fundraising program which is unlikely to support public service as a priority. Because most members of the Arboretum are unusually committed to the horticultural and educational work of the institution, they give their support to ensure the continuing excellence of these programs. Therefore I believe that the work of our development staff should primarily sustain the long-term survival and growth of the public mission.


Beech Path, photo by Eric Roth

So a bargain can be struck. The University will commit itself to ensuring the health and well-being of the Arboretum's research mission, at the same time permitting the Arboretum to raise funds for its parallel mission of public service. But the Arboretum will need help achieving this second goal. Our members and friends, who have always been deeply loyal to our public purposes, will be asked to increase their critical support for this equally important part of our mission. It is a bargain that can secure the continuing fulfillment of Charles Sargent's remarkable vision.

*Robert E. Cook*
1 May 2008

## ARNOLD ARBORETUM WEATHER STATION DATA—2007

| | Avg. Max. Temp. (°F) | Avg. Min. Temp. (°F) | Avg. Temp. (°F) | Max. Temp. (°F) | Min. Temp. (°F) | Precipitation (in.) | Snowfall (in.) |
|---|---|---|---|---|---|---|---|
| Jan. | 40.0 | 23.1 | 31.55 | 69 | 2 | 2.74 | 1.5 |
| Feb. | 33.0 | 16.1 | 24.55 | 49 | 7 | 2.15 | 7 |
| Mar. | 46.4 | 25.8 | 36.1 | 70 | 4 | 4.78 | 7.7 |
| Apr. | 52.8 | 36.4 | 44.6 | 87 | 27 | 7.91 | 0 |
| May | 71.4 | 49.5 | 60.45 | 93 | 33 | 3.16 | 0 |
| June | 77.0 | 57.4 | 67.2 | 95 | 47 | 3.1 | 0 |
| July | 81.7 | 63.6 | 72.65 | 91 | 53 | 3.44 | 0 |
| Aug. | 81.7 | 61.2 | 71.45 | 95 | 50 | 0.4 | 0 |
| Sep. | 76.6 | 55.9 | 66.25 | 94 | 43 | 1.67 | 0 |
| Oct. | 66.8 | 47.9 | 57.35 | 87 | 32 | 2.59 | 0 |
| Nov. | 50.3 | 31.5 | 40.9 | 68 | 20 | 3.11 | 0 |
| Dec. | 36.4 | 20.5 | 28.45 | 54 | 8 | 5.93 | 26.7 |

| | |
|---|---|
| Avg. Maximum Temperature | 59.5° |
| Avg. Minimum Temperature | 40.7° |
| Avg. Temperature | 50.13° |
| Total Precipitation | 40.98" |
| Total Snowfall | 42.9" |
| Warmest Temperature | 95° on August 4 |
| Coldest Temperature | 2° on January 26 and 27 |
| Last Frost Date | 32° on April 9 |
| First Frost Date | 32° on October 9 |
| Growing Season | 183 days |

2007 was a year of highly changeable weather at the Arnold Arboretum. The first half of January brought record warmth, even inducing a scattering of cherries into early bloom. But on January 16 winter finally arrived in the Northeast and temperatures plummeted. The first 16 days of January averaged 12 degrees above normal while the second half of the month averaged 5 degrees below normal. The winter cold extended well into March and April and was coupled with heavy rains and street flooding during both months. Spring and early summer precipitation provided adequate levels of moisture for a very good growing season up to the end of July, which began a period of extremely dry weather in the Northeast. Fortunately temperatures did not soar during this dry spell which helped to limit the negative impact of the drought. However it was dry enough to delay and significantly reduce fall planting from Arboretum nurseries to the grounds. September and October were pleasantly mild and quite sunny. Although poor fall color had been predicted (in part because of the drought), the foliage at the Arboretum ended up putting on quite a colorful show. November remained on the dry side and brought the onset of winter with below average temperatures. To close the year, December was very cold and snowy, with snow accumulation coming close to breaking the record for Boston. Unlike the very mild late fall/early winter of 2006, this period in 2007 reminded us how tough our winters can be. Throughout this variable year of weather, visitors and staff continued to appreciate the beauty of the Arnold Arboretum through all the seasons.

## STAFF OF THE ARNOLD ARBORETUM*

### ADMINISTRATION

Rose Balan, Staff Assistant

Donna Barrett, Accounting Assistant

Kenneth Clarke, Horticultural Technologist (resigned 9.30.05)

Robert Cook, Director, Arnold Professor

Ann Marie Countie, Computer Services Manager

William Hays, Biological Database Applications Programmer (resigned 6.3.06)

Andrew Hubble, Network Systems Manager

Cynthia Jensen, Director of Capital Projects (hired 1.3.05)

James Macklin, Director of Collections and Informatics (hired 3.20.06)

Frances Maguire, Director of Administration and Finance

Andrea Nix, Director of Administration and Finance (hired 4.30.07)

Karen Pinto, Staff Assistant

Christopher Preheim, Executive Assistant (hired 9.11.05)

David Russo, Facilities Manager

Lisa Toste, Director of Human Resources (hired 7.1.02)

Sylvia Winter, Landscape Project Manager (hired 9.2.03)

### DEVELOPMENT/INSTITUTIONAL ADVANCEMENT

Sheila Baskin, Development Assistant

Anne Jackson Bell, Events Manager (resigned 7.27.06)

Ronda Brands, Development Assistant (hired 7.1.05 and resigned 1.5.07)

Jon Hetman, Development Manager

Wendy Krauss, Development Assistant (hired 1.24.07)

Michele Levy, Director of Communications (hired 2.6.07)

Julie Anne McNary, Senior Development Officer (hired 2.6.05 and resigned 8.26.05)

Heidi Norris, Development Officer (hired 2.7.06)

Robert Surabian, Director of Development (hired 8.9.04)

Michaela Tally, Events Manager (hired 2.26.07)

*(1 July 2002 through 30 June 2007)

### PUBLIC & PROFESSIONAL PROGRAMS

Sheryl Barnes, Webmaster

Kirstin Behn, Staff Assistant (resigned 6.17.05)

Ellen Bennett, Manager of Horticultural Information (resigned 1.10.03)

Sonia Brenner, Staff Assistant (resigned 6.1.07)

Lois Brown, Editorial Assistant (hired 9.25.05)

John Furlong, Director of the Landscape Institute (program transferred from Radcliffe 7.1.02)

Ann-Marie Greaney-Williams, Administrative Coordinator (hired 7.1.02)

Leah Kane, Staff Assistant (hired 5.2.05)

Karen Madsen, Editor of Arnoldia

Sandra Morgan, Staff Assistant (resigned 5.3.07)

Caroline Richardson, Manager of Horticultural Information (hired 5.19.03 and resigned 12.15.05)

Nancy Sableski, Manager of Children's Education

Micah Schatz, Arboretum Assistant (less than half time); (hired 3.27.04 and resigned 4.22.07)

Richard Schulhof, Deputy Director (hired 9.30.02)

Pamela Thompson, Manager of Adult Education

Julie Warsowe, Manager of Visitor Education (hired 7.5.06)

Sheryl White, Staff Assistant

Laura Wilson, Staff Assistant (hired 7.10.02)

### HERBARIUM

David Boufford, Senior Research Scientist

Maria del Carmen Chavez-Ortiz, Curatorial Assistant (hired 8.1.05 and resigned 7.31.06)

Lihong (Wendy) Duan, Curatorial Assistant (transferred to J.P. Library 1.2.05); Staff Assistant (hired 10.31.05)

Jennifer Fonda, Curatorial Assistant (hired 11.9.04)

Susan Hardy Brown, Curatorial Assistant

Edith Hollender, Arboretum Assistant (less than half time)

Henry Kesner, Curatorial Assistant (hired 10.5.04)

Walter Kittredge, Curatorial Assistant

Jude Mulle, Curatorial Assistant (resigned 9.30.02)

Melanie Schori, Editorial Assistant (resigned 10.10.03)

Emily Wood, Manager of Systematic Collections

**LIBRARY**

Beth Bayley, Library Assistant (hired 5.1.04)

Sheila Connor, Horticultural Research Archivist

Carol David, Library Assistant (resigned 6.1.04)

Lihong (Wendy) Duan, Staff Assistant (transferred from Herbarium 1.2.05)

Marla Gearhart, Library Assistant (hired 11.29.04)

Judy Green, Project Image Cataloger (hired 4.1.01 and resigned 6.30.02)

Joseph Melanson, Library Assistant (resigned 12.6.04)

Lisa Pearson, Library Assistant (hired 7.8.02)

Cathleen Pfister, Library Assistant

Christy S. Robson, Catalog Librarian

Gretchen Wade, Reference/Collection Development Librarian

Judith Warnement, Librarian of Harvard University Botany Libraries

Winifred Wilkens, Library Assistant (retired 9.6.03)

**LIVING COLLECTIONS**

Thomas Akin, Assistant Superintendent of Grounds (resigned 10.24.03)

John Alexander, Plant Propagator

James Allen, Arboretum Assistant (less than half time)

Jesse Batty, Grounds Crew Term (9.4.05–9.21.06)

Stacy Berghammer, Apprentice (resigned 12.2.02)

Jessica Blohm, Gardener (hired 9.10.04 and resigned 7.15.06)

Laura Tenny Brogna, Landscape Project Manager (resigned 7.19.04)

Julie Coop, Manager of Horticulture

John DelRosso, Head Arborist

Peter Del Tredici, Director of Living Collections (transferred to Research 7.1.03)

Kristin DeSouza, Apprentice (hired 8.29.04 and resigned 9.19.05)

Michael Dosmann, Curator of Living Collections (hired 1.2.07)

James Doyle, Gardener/Arborist Apprentice (hired 9.29.03 and resigned 1.5.07)

Ralph Ebener, Grounds Crew Term (10.3.04–10.21.05)

Charlotte Enfield, Grounds Crew Term (10.30.05–4.29.06)

Robert Ervin, Arborist (hired 7.8.02)

David Falk, Horticulture Term (9.5.06–1.5.07)

Robert Famiglietti, Horticultural Technologist

Kirsten Ganshaw, Horticultural Technologist

Donald Garrick, Horticultural Technologist (resigned 7.8.03)

Bethany Grasso, Horticultural Technologist (resigned 1.14.04)

Scott Grimshaw, Horticultural Technologist (hired 5.17.04)

Dennis Harris, Horticultural Technologist

Eric Hsu, Putnam Fellow (hired 10.31.05 and resigned 9.23.06)

Irina Kadis, Curatorial Assistant

Wesley Kalloch, Horticultural Technologist (hired 4.24.06)

Susan Kelley, Curatorial Assistant (transferred to Research 1.1.04)

Jennifer Kettell, Horticultural Technologist (hired 11.17.03)

Alice Kitajima, Apprentice (hired 9.30.02 and resigned 9.21.03)

Jianhua Li, Botanical/Horticultural Taxonomist (transferred to Research 1.1.04)

Daniel March, Apprentice (resigned 8.23.02)

Brendan McCarthy, Horticultural Technologist (hired 3.20.07)

Bruce Munch, Horticultural Technologist

Chloe Nathan, Grounds Crew Term (9.4.05–3.3.06)

James Nickerson, Horticultural Technologist (resigned 10.8.04)

James Papargiris, Horticultural Technologist, appointment as Working Foreperson

Thomas Por, Arborist (resigned 9.9.05)

Kyle Port, Manager of Plant Records

Chris Rice, Horticultural Technologist (hired 6.1.04 and resigned 10.28.05)

Kathryn Richardson, Curatorial Assistant (hired 6.7.04)

Kelly Ruth, Horticulture Term (9.3.06–1.26.07)

Nima Samimi, Gardener (hired 2.16.07)

Stephen Schneider, Associate Manager of Horticulture

Rita Schwantes, Grounds Crew Term (10.3.04–11.15.04)

Julie Shapiro, Curatorial Assistant (hired 4.9.06)

Maurice Sheehan, Horticultural Technologist, Working Foreman (retired 10.31.03)

Kyle Stephens, Arborist Apprentice/Arborist (hired 10.2.06)

Kevin Stevens, Apprentice (hired 9.13.05 and resigned 7.28.06)

Sara Straate, Curatorial Assistant (resigned 9.16.02)

Siobhan Sullivan, Horticulture Term (9.3.06–3.3.07)

Aneiage Van Batenburg, Apprentice (hired 9.29.03 and resigned 8.31.04)

Mark Walkama, Horticultural Technologist

Thomas Ward, Manager of the Greenhouse

Victoria Woodruff, Gardener (hired 9.29.03 and resigned 8.5.04)

### INSTITUTE FOR CULTURAL LANDSCAPE STUDIES

**(incorporated into Public and Professional Programs)**

Phyllis Andersen, Director of the ICLS (retired 6.30.04)

### RESEARCH

Kobinah Abdul-Salim, Mercer Fellow (appointed 12.1.02–5.31.03)

Jennifer L. Baltzer, CTFS-AA Asia Post Doctoral Fellow (appointed 4.4.05–3.31.2007)

Mark Beilstein, Mercer Fellow (hired 12.18.07)

Jonathan Bennett, Research Fellow (appointed 8.1.03–7.31.04)

Tim Brodribb, Putnam Fellow (appointed 6.1.05)

Zhiduan Chen, Mercer Fellow (appointment ended 8.31.02)

Stuart Davies, Science Director of the CTFS-AA Asia Program (resigned 9.30.05); Director of Asian Programs (re-hired 7.1.07)

Peter Del Tredici, Senior Research Scientist (transferred from Living Collections 7.1.03)

Michael Dosmann, Putnam Fellow (appointment ended 8.31.02)

Rodger Evans, Mercer Fellow (hired 1.2.07 and resigned 4.30.07)

Kenneth Feeley, CTFS-AA Asia Post Doctoral Fellow (appointed 6.1.05)

Margaret Frank, Research Assistant (hired 6.18.07)

Lianming Gao, Mercer Fellow (hired 6.26.07)

Phyllis Glass, Staff Assistant (hired 5.27.03 and resigned 6.1.05)

Anna Gorska, Post Doctoral Fellow (hired 3.1.06)

Barbara Gravendeel, Mercer Fellow (hired 10.19.05 and resigned 10.18.06)

Jocelyn Hall, Mercer Fellow (appointed 9.1.03–1.31.06)

Maria Jaramillo, Mercer Fellow (appointment ended 6.30.03)

Zhen Jiao, Mercer Fellow (hired 3.20.06) (resigned 9.14.06)

Susan Kelley, Botanical Project Manager (transferred from Living Collections 1.1.04)

David King, CTFS-AA Asia Post Doctoral Fellow (appointed 1.1.03–12.31.04)

Jeremy Ledger, Research Assistant (hired 7.15.02 and resigned 1.23.04)

Ethan Levesque, Research Assistant (hired 12.2.03 and resigned 5.23.07)

Jianhua Li, Senior Research Scientist (transferred from Living Collections 1.1.04)

Wenbo Liao, Mercer Fellow (appointed 3.1.05–8.15.05)

Stuart Lindsay, Mercer Fellow (appointment ended 9.30.02)

Tatyana Livshultz, Mercer Fellow (appointed 7.16.03–10.15.05)

Laura Lukas, Arboretum Assistant (hired 1.7.05, less than half time); Research Assistant (hired 10.9.05 and resigned 1.14.06)

Andrew Marshall, Mercer Fellow (appointed 8.1.04–8.1.06)

Sarah Mathews, Sargent Fellow (appointed 8.11.03)

Joel McNeal, Post Doctoral Fellow (appointed 2.22.05–1.26.07)

David Middleton, Tropical Plant Systematist (resigned 12.31.04)

Rebecca Pradhan, Mercer Fellow (appointed 9.1.02–6.30.03)

Richard Primack, Putnam Fellow (hired 7.1.06)

Hardeep Rai, Post Doctoral Fellow (hired 5.1.07)

Sabrina Russo, CTFS-AA Asia Post Doctoral Fellow (appointed 9.1.03–12.31.05)

Lawrence Sack, Putnam Fellow (appointed 8.1.02–7.31.03)

Sonali Saha, Putnam Fellow (appointed 10.8.02–8.31.04)

Mariya Schilz, Research Assistant (hired 8.20.06)

Suzie Shoup, Research Assistant (hired 3.29.04 and resigned 11.13.06)

Stephanie Stuart, Research Assistant (hired 11.28.04 and resigned 8.4.05)

Wayne Takeuchi, Tropical Forest Biologist

Nina Theis, Putnam Fellow (appointed 1.12.04–8.31.05)

Donna Tremonte, Research Assistant (hired 1.5.04 and resigned 8.31.06)

Sonia Uyterhoeven, Putnam Fellow (appointed 1.1.02–2.1.03)

Ellen VanScoyoc, Staff Assistant (resigned 6.30.03)

James E. Watkins, Mercer Fellow (hired 9.1.06)

Campbell Webb, Tropical Forest Biologist (hired 9.1.05)

Kyle Williams, Post Doctoral Fellow (appointed 1.12.04–1.12.07)

Qing Ye, Post Doctoral Fellow (hired 3.27.06)

Jipei Yue, Mercer Fellow (appointed 10.1.04–5.31.05)

Lihua Zhou, Putnam Fellow (appointed 10.1.02–3.31.03)

Maciej Zwieniecki, Sargent Fellow (appointed 6.6.04)

**RESEARCH AFFILIATES**

Glenn Steven Adelson, Arnold Arboretum Associate (appointed 9.1.06)

Ihsan Al-Shehbaz, Arnold Arboretum Associate (appointed 4.1.05)

Phyllis Andersen, Arnold Arboretum Associate (appointed 8.1.04)

Peter Ashton, Charles Bullard Professor of Forestry, emeritus

Jennifer Baltzer, Arnold Arboretum Associate (appointed 4.1.07)

Mark Beilstein, Arnold Arboretum Associate (appointed 8.8.06–12.17.07)

Gordon Burleigh, Arnold Arboretum Associate (appointed 7.19.06–10.31.06)

Mabel Cabot, Arnold Arboretum Associate (appointed 11.1.05)

Thomas Campanella, Arnold Arboretum Associate (appointment ended 1.31.03)

Chin-Sung Chang, Arnold Arboretum Associate (appointed 9.15.06)

Chua Siew Chin, Arnold Arboretum Associate (appointed 3.1.06)

Stuart Davies, Arnold Arboretum Associate (appointed 10.1.05; hired 7.1.07)

Michael Dosmann, Arnold Arboretum Associate (appointed 4.1.04–3.31.06; hired 1.2.07)

Peter J. Franks, Arnold Arboretum Associate (appointed 12.1.02–11.30.03)

Irwin L. Goldman, Arnold Arboretum Associate (appointment ended 1.31.03)

Jocelyn Hall, Arnold Arboretum Associate (appointed 2.1.06–6.30.06)

Richard Howard, Professor of Dendrology, emeritus (died 9.18.03)

Shiu-Ying Hu Hsu, Botanist, emerita

Alice Ingerson, Arnold Arboretum Associate (appointed 7.1.02–6.30.05)

Yu Jia, Arnold Arboretum Associate (appointed 1.1.06)

David King, Arnold Arboretum Associate (appointed 1.1.05–9.30.05)

James LaFrankie, Arnold Arboretum Associate (appointed 9.1.02–8.31.05)

Timothy Laman, Arnold Arboretum Associate (appointment ended 6.30.04)

Tatyana Livshultz, Arnold Arboretum Associate (10.16.05–12.31.05; hired 3.1.06)

Richard H. Ree, Arnold Arboretum Associate (appointed 2.1.03)

Kenichi Shono, Arnold Arboretum Associate (appointed 1.1.05 –12.31.05)

Stephen Spongberg, Curator, emeritus

George Staples, Arnold Arboretum Associate (appointed 8.1.03–7.31.04)

Hang Sun, Arnold Arboretum Associate (appointed 1.1.06)

Kim Tripp, Arnold Arboretum Associate (appointment ended 4.30.03)

Sonia Uyterhoeven, Arnold Arboretum Associate (appointed 2.1.03–1.31.05)

Keith Vanderhye, Arnold Arboretum Associate (appointed 9.1.03–8.31.04)

Campbell Webb, Arnold Arboretum Associate (appointment ended 8.31.05)

Kyle Williams, Arnold Arboretum Associate (appointed 1.13.07)

Carroll Wood, Jr., Professor of Biology, emeritus

Zhuliang Yang, Arnold Arboretum Associate (appointed 1.1.06)

Donglin Zhang, Arnold Arboretum Associate (appointment ended 8.31.02)

# PUBLISHED WRITINGS OF THE ARNOLD ARBORETUM STAFF

**J. H. Alexander**

2002. Paraphyletic *Syringa*: evidence from sequences of nuclear ribosomal DNA ITS and ETS regions. *Systematic Botany* 27: 592–593 (with J. Li and D. Zhang).

2002. Phylogenetic relationships of Empetraceae inferred from sequences of gene *matK* and nuclear ribosomal DNA ITS region. *Molecular Phylogenetics and Evolution* 25: 306–315 (with J. Li et al.).

**P. Andersen**

2002. The Institute for Cultural Landscape Studies of the Arnold Arboretum of Harvard University. In *Restoring the Landscape: Policies for a New Sustainable Regional Project*, ed. Francesca Leder. Ferrara, Italy: Facolta di Architettura di Ferrara.

2003. The Arnold Arboretum and the Early Years of Landscape Design Education in America. *Arnoldia* 62(3): 2–9.

2003. Spirit of Place (roundtable discussion). Architecture Boston 6(6): 8–17.

2003. Book review: *Sacred Places: American Tourist Attractions in the Nineteenth Century*, J. F. Sears. *ArchitectureBoston*, 6(6): 61.

2004. Book review: *Becoming Cape Cod: Creating a Seaside Resort*, J. C. O'Connell. *ArchitectureBoston*, 7(3): 49.

**J. L. Balzer**

2007. Geographical distributions in tropical trees: can geographic range predict performance and habitat association in co-occurring tree species? *Journal of Biogeography* 34: 1916–1926 (with S. J. Davies et al.).

2007. Determinants of whole-plant light requirements in Bornean rain forest tree saplings. *Journal of Ecology* 95: 1205–1221 (with S. C. Thomas).

2007. Physiological and morphological correlates of whole-plant light compensation point in temperate deciduous tree seedlings. *Oecologia* 153: 209–223 (with S. C. Thomas).

**J. R. Bennett**

2006. Phylogeny of the parasitic plant family Orobanchaceae inferred from phytochrome A. *American Journal of Botany* 93: 1039–1051 (with S. Mathews).

**D. E. Boufford**

1992–2006. *Harvard University Herbaria Databases: Botanists, Publications, Specimens*. http://www.huh.harvard.edu/databases (with K. N. Gandhi).

1998–2007. *Biodiversity of the Hengduan Mountains Region, China*. http://hengduan.huh.harvard.edu/fieldnotes (with Z. W. Ge et al.).

2002. Plant databases and the study of Asian Plants (1). *Ouroboros* 7(1): 10–13.

2002. Plant databases and the study of Asian Plants (2). *Ouroboros* 7(2): 13–15.

2003. Hengduan Mountains: International Hotspot of Biodiversity. In *Xiuyuanjieying*, ed. H. S. J. Wenji. Hong Kong: Commercial Press.

2003. A checklist of the vascular plants of Taiwan. In *Flora of Taiwan*, 2nd ed. Vol. 6. Taipai: National Taiwan University (with H. Ohashi et al.).

2003. *Flora of Taiwan*, 2nd ed. Vol. 6. Taipei: National Taiwan University (with C. F. Hsieh et al.).

2003. Rubus Linnaeus. In *Flora of China*, Vol. 9, eds. C. Y. Wu and P. H. Raven. Beijing: Science Press; St. Louis: Missouri Botanical Garden (with L. D. Lu).

2003. Phylogenetic position of *Schnabelia*, a genus endemic to China: evidence from sequences of cpDNA matK gene and nrDNA ITS regions. *Chinese Science Bulletin* 48(15): 1576–1580 (with S. H. Shi et al.).

2004. Mountains of Southwest China. In *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Ecoregions*, 2nd ed., ed. R. A. Mittermeier et al. Mexico City: CEMEX Conservation International (with P. P. van Dijk).

2004. Japan. In *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Ecoregions*, 2nd ed., ed. R. A. Mittermeier et al. Mexico City: CEMEX Conservation International.

2005. Cornaceae. In *Flora of China*, Vol. 8, ed. D. Y. Hong and P. H. Raven. Beijing: Science Press; St. Louis: Missouri Botanical Garden (with Q. Xiang).

2005. Aucubaceae. In *Flora of China*, Vol. 8, ed. D. Y. Hong and P. H. Raven. Beijing: Science Press; St. Louis: Missouri Botanical Garden (with Q. Xiang).

2005. Helwingiaceae. In *Flora of China*, Vol. 8, ed. D. Y. Hong and P. H. Raven. Beijing: Science Press; St. Louis: Missouri Botanical Garden (with Q. Xiang).

2005. Mastixiaceae. In *Flora of China*, Vol. 8, ed. D. Y. Hong and P. H. Raven. Beijing: Science Press; St. Louis: Missouri Botanical Garden (with Q. Xiang).

2005. Toricelliaceae. In *Flora of China*, Vol. 8, ed. D. Y. Hong and P. H. Raven. Beijing: Science Press; St. Louis: Missouri Botanical Garden (with Q. Xiang).

2005. *Circaea lutetiana* L. sensu lato (Onagraceae) reconsidered. *Harvard Papers in Botany* 9(2): 255–256.

2005. Polyploidy in the flora of the Hengduan Mountains Hotspot, Southwestern China. *Annals of the Missouri Botanical Garden* 92: 275–306 (with Z. L. Nie et al.).

2005. The Botanical Collections: Proceedings of the symposium *Siebold in the 21st Century*, Bulletin No. 41. Tokyo: University Museum, University of Tokyo (with H. Ohba).

2006. Angiospermae; Dicotyledonieae; Archichlamideae. *Flora of Japan*, Vol. IIa, ed. K. Iwatsuki et al. Tokyo: Kodansha, Ltd (with K. Iwatsuki and H. Ohba).

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2007. Rhizophoraceae. In *Flora of China*, Vol. 13, ed. Z. Y. Wu et al. Beijing: Science Press; St. Louis: Missouri Botanical Garden (with H. N. Qin).

2007. Botanical Expedition to southern Gansu Province, China, May 2007. *Newsletter of Himalayan Botany* 40: 5–14 (with Y. Jia et al.).

2007. *A Selection of Plants from Iriomote Island, Japan*. Nantao, Taiwan: Endemic Species Research Institute and Research Center for Biodiversity, Academia Sinica (with C. Peng et al.).

2007. *Meconopsis wilsonii* subsp. *wilsonii* (Papaveraceae) rediscovered. *Acta Botanica Yunnanica* 29: 286–288 (with T. Yoshida and H. Sun).

2007. Atlas of the flora of New England: Cyperaceae. *Rhodora* 109: 237–360 (with R. A. Angelo).

2007. *The Genera of Vascular Plants of Korea*. Seoul: Academy Publishing Company (with C. Park, et al.).

2007. Two New Species of *Wikstroemia* (Thymelaeaceae) from Western Sichuan, China. *Rhodora* 109: 448–455 (with Y. H. Zhang and H. Sun).

**Z. Chen**

2003. Phylogeny of the Dipsacales s.l. based on chloroplast trnL-F and ndhF sequences. *Molecular Phylogenetics and Evolution* 26: 176–189 (with W. Zhang et al.).

2004. Regional differences in rates of plant speciation and molecular evolution: a comparison between eastern Asia and eastern North America. *Evolution* 58: 2175–2184 (with Q. Xiang et al.).

2004. Phylogenetics and biogeography of *Alnus* (Betulaceae) inferred from sequences of nuclear ribosomal DNA ITS region. *International Journal of Plant Science* 165: 325–335 (with J. Li).

2005. Phylogenetics of *Betula* (Betulaceae) inferred from sequences of nuclear ribosomal DNA. *Rhodora* 107: 69–86 (with J. Li and S. Shoup).

2007. Phylogenetic relationships of diploid species of *Betula* (Betulaceae) inferred from DNA sequences of nuclear nitrate reductase. *Systematic Botany* 32(2): 357–365 (with J. Li and S. Shoup).

2007. Phylogenetic and biogeographic diversification of Berberidaceae in the Northern Hemisphere. *Systematic Botany* 32(4): 731–742 (with W. Wang et al.).

2007. Mitochondrial matR sequences help to resolve deep phylogenetic relationships in rosids. *BMC Evolutionary Biology* 7: 217–231 (with X. Zhu et al.).

**S. Connor**

2003. Shrubs and Vines at the Arnold Arboretum: A History. *Arnoldia* 62(2): 3–15.

2003. A picture is worth… *The Public Garden* 18(4): 39–41.

2004. In the Library: *Hortus Nitidissimis*. *Arnoldia* 63(1): 32.

2005. The Nature of Eastern Asia: Botanical and Cultural Images from the Arnold Arboretum Archives. *Arnoldia* 63(3): 34–44.

**R. E. Cook**

2003. *The Director's Report of the Arnold Arboretum: 1999–2002*. *Arnoldia* 62(1).

2006. Botanical collections as a resource for research. *The Public Garden* 21(1): 18–21.

2007. The Future of Research at the Arnold Arboretum. *Arnoldia* 65(2) 23–29.

**J. Coop**

2003. Sun-loving shrubs and vines for the Leventritt Garden. *Arnoldia* 62(2): 20–26 (with P. Del Tredici et al.).

**S. J. Davies**

2002. *The 52-Hectare Forest Dynamics Plot at Lambir Hills, Sarawak, Malaysia: Tree Distribution Maps, Diameter Tables, and Species Documentation*. Diliman, Philippines: Center for Integrative and Development Studies, University of the Philippines (with H. S. Lee et al.).

2003. Effects of nutrient addition, mulching and planting-hole size on early performance of *Dryobalanops aromatica* and *Shorea parvifolia* in enrichment plantings in Sarawak, Malaysia. *Forest Ecology and Management* 180: 261–271 (with A. Vincent).

2003. Coadaptation and coevolution of *Macaranga* trees and their symbiotic ants. In *Genes, Behaviours and Evolution of Social Insects*, ed. T. Kikuchi et al. Sapporo, Japan: Hokkaido University Press (with T. Itino and T. Itioka).

2003. The trees of Pasoh Forest: stand structure and floristic composition of the 50-hectare forest research plot. In *Pasoh: Ecology and natural history of a Southeast Asian lowland tropical rain forest*, ed. T. Okuda et al. Tokyo, Japan: Springer (with M. N. Nur Supardi et al.).

2003. Lambir forest dynamics plot, Sarawak, Malaysia. In *Forest Diversity and Dynamism*, ed. E. Losos and E. Leigh. Chicago: The University of Chicago Press (with H. S. Lee et al.).

2003. Book review: *A Manual for Forest Plantation Establishment in Malaysia*, ed. B. Krishnapillay. *Journal of Tropical Forest Science* 15(2): 365–367.

2004. Habitat heterogeneity and niche structure of trees in two tropical rain forests. *Oecologia* 139: 446–453 (with M. D. Potts et al.).

2004. Soil-related habitat specialization in dipterocarp rain forest tree species in Borneo. *Journal of Ecology* 92: 609–623 (with P. Palmiotto et al.).

2004. Evolution of host affiliation in *Crematogaster* (Formicidae) inhabitants of *Macaranga* (Euphorbiaceae). *Evolution* 58: 554–570 (with S. P. Quek et al.).

2004. Lambir Hills Forest Dynamic Plot, Sarawak, Malaysia. In *Forest Diversity and Dynamism: Findings from a Network of Large-Scale Tropical Forest Plots*, ed. E. Losos and E. G. Leigh. Chicago: University of Chicago Press (with H. S. Lee et al.).

2004. Sinharaja 25-hectare plot: comparisons with other forests in the CTFS network. In *Ecology of Sinharaja Rain Forest and the Forest Dynamics Plot in Sri Lanka's Natural World Heritage Site*, ed. C. V. S. Gunatilleke et al. Columbo, Sri Lanka: WHT Publications.

2004. Palanan forest dynamics plot, Philippines. In *Forest Diversity and Dynamism*, ed. E. Losos and E. G. Leigh. Chicago: The University of Chicago Press (with L. L. Co et al.).

2005. Tropical tree $\alpha$-diversity: results from a worldwide network of large plots. *Biologiske Skrifter* 55: 565–582 (with R. Condit et al.).

2005. Tree growth is related to light interception and wood density in two mixed dipterocarp forests of Malaysia. *Functional Ecology* 19: 445–453 (with D. A. King et al.).

2005. Edaphically-associated variation in performance correlates with species' distribution patterns in a Bornean rainforest. *Journal of Ecology* 93: 879–889 (with S. E. Russo et al.).

2005. *Forest Trees of Bukit Timah, Singapore: Population Ecology in a Forest Fragment.* Singapore: Simply Green (with J. V. LaFrankie et al.).

2005. Soil-related floristic variation in a hyperdiverse dipterocarp forest. In *Pollination Ecology and the Rain Forest (Sarawak Studies)*, ed. D. Roubik et al. New York: Springer Science (with S. Tan et al.).

2006. Regeneration of native plant species in restored forests on degraded lands in Singapore. *Forest Ecology and Management* 237: 574–582 (with K. Shono and Y. K. Chua).

2006. Spatial associations of humus, nutrients, and soils in mixed dipterocarp forest at Lambir, Sarawak, Malaysian Borneo. *Journal of Tropical Ecology* 22: 543–553 (with I. C. Baillie et al.).

2006. The role of wood density and stem support costs in the growth and mortality of tropical trees. *Journal of Ecology* 94: 670–680 (with D. A. King et al.).

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2006. Competitive dominance in a secondary successional rain forest community in Borneo. *Journal of Tropical Ecology* 22: 53–64 (with H. Semui).

2006. Contrasting structure and composition of the understory in species-rich tropical rain forests. *Ecology* 87(9): 2298–2305 (with J. V. LaFrankie et al.).

2006. Comparing tropical forest tree size distributions with the predictions of metabolic ecology and equilibrium models. *Ecology Letters* 9: 589–602 (with H. C. Muller-Landau et al.).

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2006. Nonrandom processes maintain diversity in tropical forests. *Science* 311: 527–531 (with C. Wills et al.).

2006. Growth and mortality are related to adult tree size in a Malaysian mixed dipterocarp forest. *Forest Ecology and Management* 223: 152–158 (with D. A. King et al.).

2006. *Forest Trees of Palanan, Philippines: A Study in Population Ecology*. Diliman, Philippines: Center for Integrative and Development Studies, University of the Philippines (with L. L. Co et al.).

2007. The role of gap-phase processes in the long-term biomass dynamics of four old-growth tropical forests. *Proceedings of the Royal Society UK* 274: 2857–2864 (with K. J. Feeley et al.).

2007. Geographical distributions in tropical trees: can geographical range predict performance and habitat association in co-occurring tree species? *Journal of Biogeography* 34: 1916–1926 (with J. L. Baltzer et al.).

2007. Decelerating growth in tropical forest trees. *Ecology Letters* 10: 461–469 (with K. J. Feeley et al.).

2007. The geography of diversification in mutualistic ants: a gene's-eye view into the Neogene history of Sundaland rain forests. *Molecular Ecology* 16: 2045–2062 (with S. P. Quek et al.).

2007. Do current stem size distributions predict future population changes? An empirical test of intraspecific patterns in tropical trees at two spatial scales. *Journal of Tropical Ecology* 23: 191–198 (with K. J. Feeley et al.).

2007. Performance of 45 native tree species on degraded lands in Singapore. *Journal of Tropical Forest Science* 19: 25–34 (with K. Shono and Y. K. Chua).

2007. Determinants of tree species distributions: comparing the roles of dispersal, seed size, and soil specialization in a Bornean rain forest. In *Seed Dispersal: Theory and its Application in a Changing World*, ed. A. J. Dennis et al. Wallingford, UK: CAB International (with S. E. Russo et al.).

**P. Del Tredici**

2002. Phylogenetic relationships of Empetraceae inferred from sequences of chloroplast gene *matK* and nuclear ribosomal DNA ITS region. *Molecular Phylogenetics and Evolution* 25: 306–315 (with J. Li et al.).

2002. Phylogenetic relationships and biogeography of *Stewartia* (Camellioideae, Theaceae) inferred from nuclear ribosomal DNA ITS sequence. *Rhodora* 104: 117–133 (with J. Li et al.).

2003. *Stewartia* 'Scarlet Sentinel'. *Arnoldia* 62(2): 16–22.

2003. Plant introduction, distribution and survival: a case study of the 1980 Sino-American Botanical Expedition. *BioScience* 53: 588–597 (with M. Dosmann).

2003. Classification and nomenclature of weeping katsuras. *The Plantsman*, N.S. 2: 21–27 (with M. Dosmann et al.).

2004. *Parthenocissus tricuspidata* 'Fenway Park.' *Arnoldia* 62(4): 29–30.

2004. Neocreationism and the illusion of ecological restoration. *Harvard Design Magazine* 20: 87–89.

2004. Chinese hemlock, *Tsuga chinensis*, at the Arnold Arboretum: introduction, cultivation, and resistance to hemlock Woolly adelgid, *Adelges tsugae*. *Journal of Arboriculture* 30(5): 282–286 (with A. Kitajima).

2004. Identification of a heath-leaved cypress cultivar based on sequences of nuclear ribosomal DNA. *HortScience* 39(6): 1217–1219 (with J. Ledger et al.).

2004. Phylogenetics of Calycanthaceae based on molecular and morphological data, with a special reference to divergent paralogues of the nrDNA ITS region. *Harvard Papers in Botany* 9(1): 69–82 (with J. Li et al.).

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2005. Capturing and cutivating *Chosenia*. *Arnoldia* 63(3): 18–27.

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2006. Brave new ecology. *Landscape Architecture* 96 (February): 46–52.

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2007. The role of horticulture in a changing world. In *Botanical Progress, Horticultural Innovation, and Cultural Changes*, ed. M. Conan and W. J. Kress. Washington, DC: Dumbarton Oaks.

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2007. The Arnold Arboretum: a botanical bridge between the United States and China from 1915 through 1948. *Bulletin of the Peabody Museum of Natural History* 48(2): 261–268.

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**M. Dosmann**

2003. Sun-loving shrubs and vines for the Leventritt Garden. *Arnoldia* 62(2): 20–26 (with P. Del Tredici et al.).

2003. Classification and nomenclature of weeping katsuras. *The Plantsman* N.S. 2: 21–27 (with S. K. Andrews et al.).

2003. Plant introduction, distribution, and survival: a case study of the 1980 Sino-American Botanical Expedition. *BioScience* 53: 588–597 (with P. Del Tredici).

2004. *Grewia biloba*. *The Plantsman* N.S. 3: 94–96.

2005. The Sino-American Botanical Expedition of 1980: a retrospective analysis of success. *HortScience* 40(1): 8–9 (with P. Del Tredici).

2006. The (un)natural and cultural history of Korean goldenrain tree. *Arnoldia* 64(1): 16–30 (with T. H. Whitlow and H. D. Kang).

2006. Research in the garden: averting the collections crisis. *Botanical Review* 72(3): 207–234.

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2007. The Arnold Arboretum's living collections: a repository for research. *Arnoldia* 65(2): 30–39.

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**K. Feeley**

2006. Succession and biomass dynamics of old-growth tropical forests. *Proceedings of the Royal Society of London* B. 274: 2857–2864 (with S. J. Davies et al.).

2007. Decelerating growth in tropical forest trees. *Ecology Letters* 10: 461–469 (with S. J. Wright et al.).

2007. Do current stem size distributions predict future population changes? An empirical test of intraspecific patterns in tropical trees across two spatial scales. *Journal of Tropical Ecology* 23: 191–198 (with S. J. Davies et al.).

**J. Hall**

2005. The evolutionary dynamics of genes controlling floral development. *Current Opinion in Plant Biology* 8: 1–6 (with E. M. Kramer).

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Richard Schulhof

Adult Education: 2007

Classes Offered: 112
Enrollments: 1040

Visitor Education: 2007

Free Tours: 57
Free Tour Participants: 548
Paid Tours: 35
Paid Tour Participants: 612
Visitor Center Attendance: 27,575


Ann Greaney-Williams

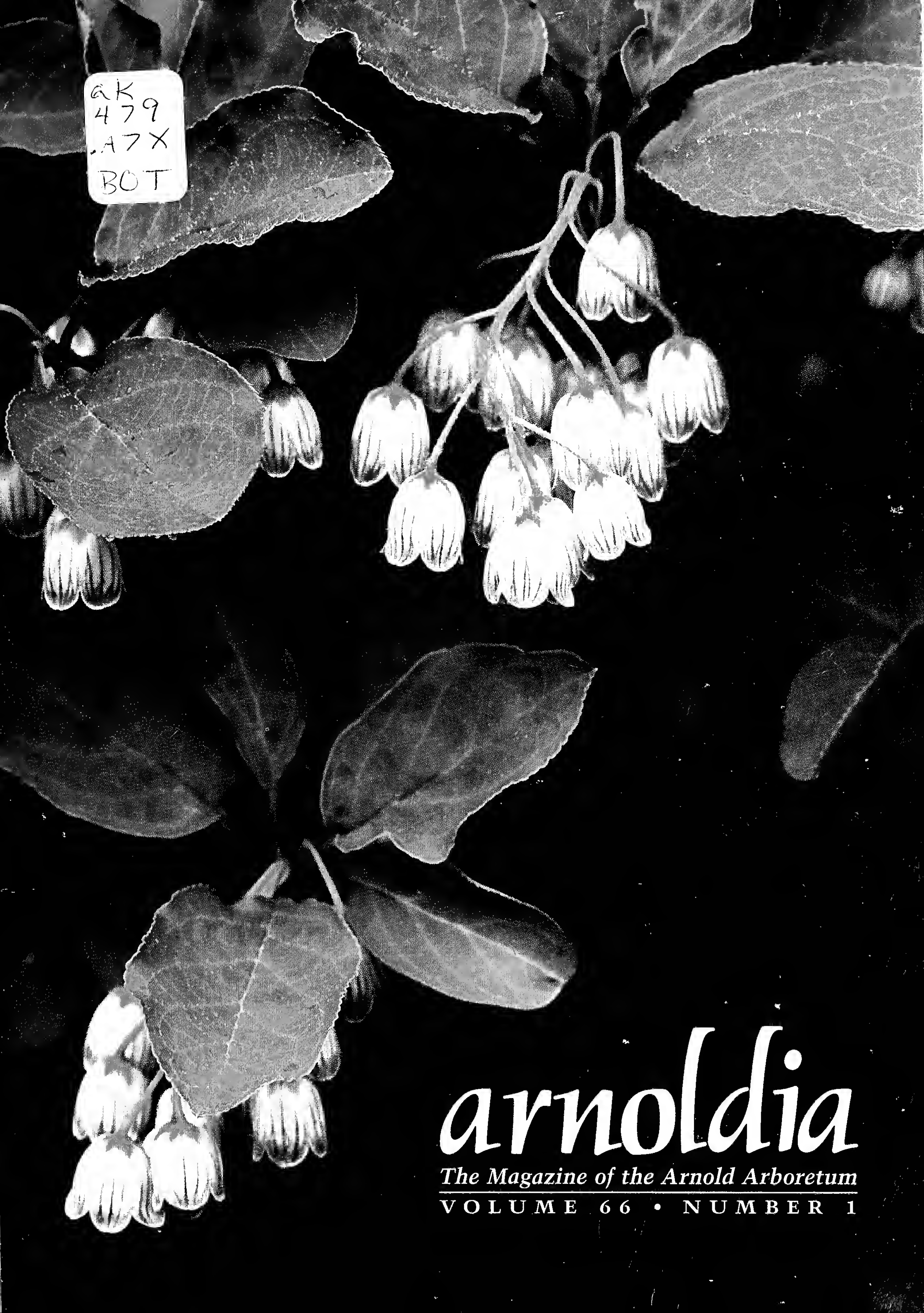
Landscape Institute: Spring/Summer/Fall 2007

Courses Offered: 70
Enrollments: 938
Certificates Granted: 18

Children's Education: Spring/Fall 2007

Programs Offered: 60
Participating Classes: 116
Students Served: 2,098







# arnoldia

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The ARNOLD ARBORETUM of HARVARD UNIVERSITY

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*Front cover:* The delicate bell-shaped flowers of *Enkianthus campanulatus* 535-93, one of eight accessions of this species at the Arboretum. For in-depth information on how and why accessions are added to the Arboretum collections, read curator Michael Dosmann's article on the Living Collections Policy. Photo by Nancy Rose.

*Inside front cover:* Swamp azalea *(Rhododendron viscosum)* typically bears white or very pale pink flowers when it blooms in June, but this form (*R. viscosum* f. *rhodanthum*) is noted for its striking bubblegum-pink flowers. Accession 638-62-A, shown here, grows in the recently renovated Azalea Border along the Arboretum's Meadow Road. Photo by Michael Dosmann.

*Inside back cover:* The majestic silver maple (*Acer saccharinum*, accession 12560-C) near Meadow Road is featured in this issue's plant profile. The tree was around 100 feet tall when photographed in April 1988 by Istvan Rácz and Zsolt Debreczy.

*Back cover:* This hand-colored emulsion-on-glass lantern slide, made around 1920 by photographer John Horace McFarland, shows two women in fashionable cloche hats walking on a path through the ferns and towering eastern hemlocks of the Arboretum's Hemlock Hill. From the Archives of the Arnold Arboretum.

# The Chinese *Parrotia:* A Sibling Species of the Persian *Parrotia*

*Jianhua Li and Peter Del Tredici*

The Persian ironwood *(Parrotia persica)* has a well-deserved reputation as a beautiful garden plant—mainly because of its exfoliating bark and gorgeous fall color—but also as a tough species that tolerates drought, heat, wind, and cold (Dirr 1998). Less well known is the fact that Persian ironwood has a sister species, the Chinese ironwood *(Parrotia subaequalis)* (Figure 1), growing about 5600 kilometers (3500 miles) away in eastern China. Remarkably, this species was correctly identified only sixteen years ago (Deng et al. 1992a).

The Persian and Chinese ironwoods are members of the witch hazel family (Hamamelidaceae), and in order to appreciate their uniqueness and evolutionary history we need to first examine one of their more familiar relatives, the witch hazels *(Hamamelis)*. There are five species of witch hazel distributed throughout the temperate regions: *H. mollis* in eastern China, *H. japonica* in Japan, and *H. virginiana, H. vernalis, H. mexicana* in North America. The genus shows the intercontinental disjunct distribution between eastern Asia and North

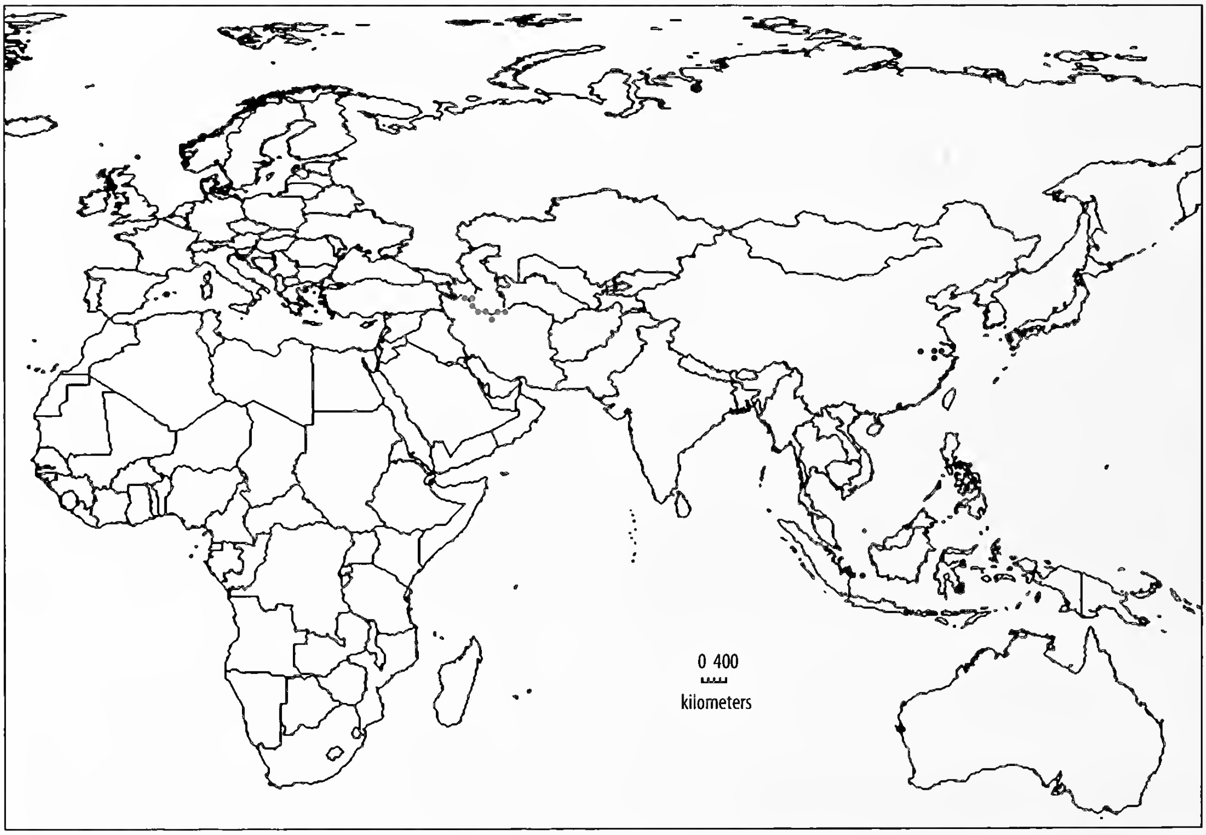


**Figure 1. Geographic distribution of *Parrotia persica* (in green) and *P. subaequalis* (in red). Note that the scale bar is 400 kilometers.**

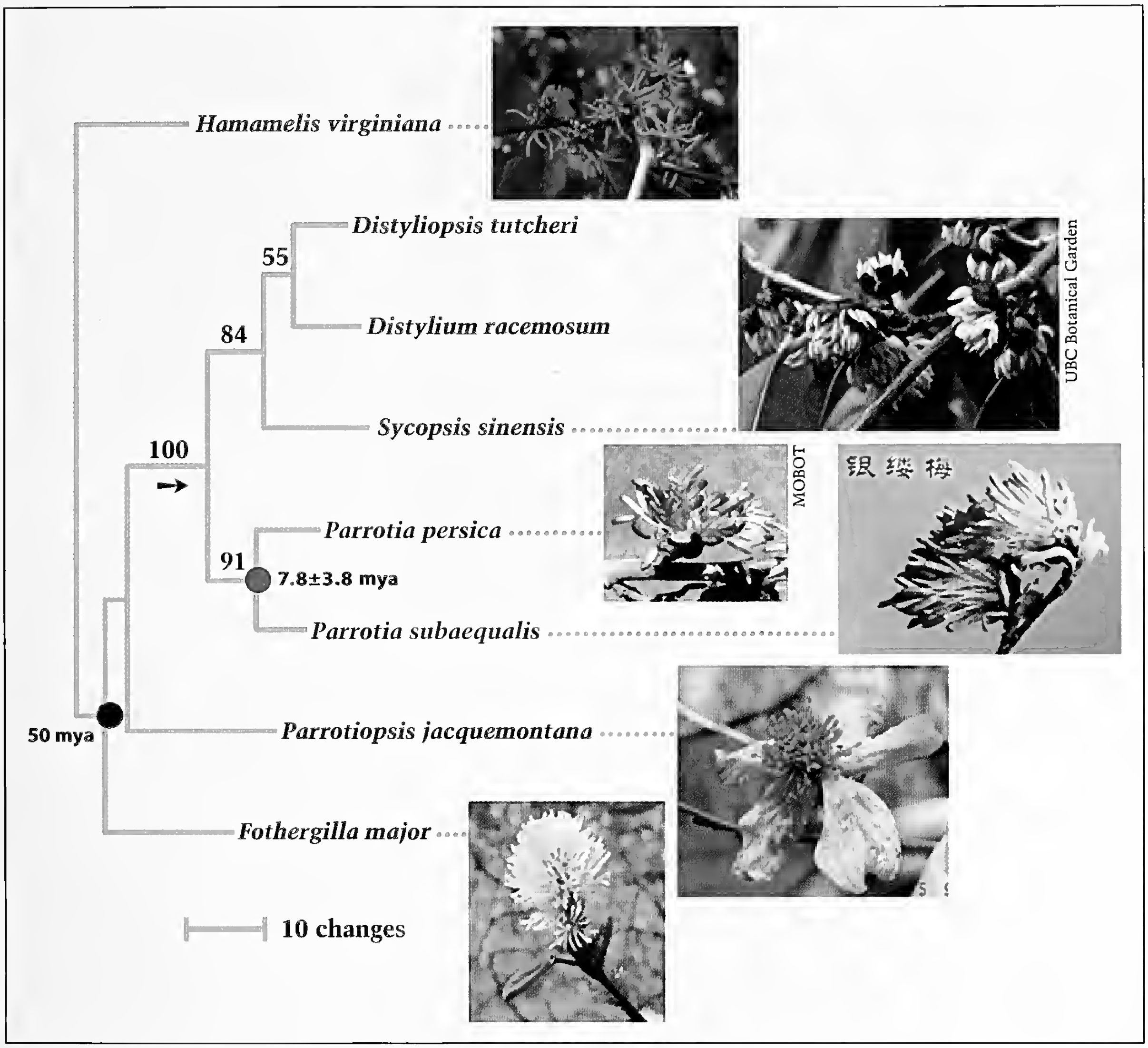


**Figure 2. Evolutionary relationships of *Hamamelis* and petalless genera, showing shift (the arrow) from insect to wind pollination. Black dot indicates the fossil calibration point and the red dot shows the divergence time of the two *Parrotia* species.**

**The scale bar represents ten changes in nucleotide composition as measured along the horizontal branches of this phylogenetic tree. Changes in nucleotide composition indicate genetic evolution over time.**

**The numbers that appear over several of the branches indicate the percentages of statistical support for those groupings. Higher numbers indicate stronger evidence of support.**

**(mya=million years ago)**

America that has fascinated many scientists since the time of Asa Gray (Gray 1846).

Witch hazels have four ribbonlike petals (Figure 2) that come in a variety of colors from yellow to reddish copper. Six other genera in the witch hazel family have similar ribbonlike petals and occur in Southeast Asia, Africa, Madagascar, and northeastern Australia. These genera have traditionally been considered closely related to one another and to *Hamamelis* because they have the same number of similarly shaped petals.

But recent DNA analysis has determined that the genera with four ribbonlike petals do not form a closely related natural group because they are positioned on different branches in the

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**Figure 3. The foliage of a specimen of *Parrotia subaequalis* growing at the Nanjing Botanical Garden.**

the only known species in the genus. In 1960 Professor H. T. Chang of Sun Yat-sen University described a new species of *Hamamelis—H. subaequalis—* based on a fruiting specimen that had been collected twenty-five years earlier from Yixing county of Jiangsu province, China. Its main distinguishing feature was that it produced much smaller leaves than the Chinese witch hazel *(H. mollis)* (Figure 3) (Chang 1960). The fact that the plant described as *H. subaequalis* was not re-collected until 1988—some 53 years after its initial collection—led to speculation that the plant had gone extinct in the intervening years.

witch hazel family tree. Interestingly, in each branch of this family tree the most advanced genera are those that have lost their petals, a trait that is generally believed to correlate with the transition from insect to wind pollination (Li et al. 1999). During this evolutionary transition period, a few genera in the *Hamamelis—Parrotia* lineage developed showy parts other than petals with which to attract insect pollinators. For example, *Parrotiopsis* of the western Himalayas possesses showy leaflike bracts beneath the inflorescences, while *Fothergilla* species in the eastern U.S. have conspicuous white stamen filaments (Figure 2). In contrast, *Parrotia* flowers lack not only petals but also showy bracts and stamen filaments. Instead, their anthers are elongated, a characteristic common to wind-pollinated species including the most advanced genera in Hamamelidaceae. Thus, the shift from insect to wind pollination is complete in the evolutionary branch leading to *Parrotia, Sycopsis, Distyliopsis,* and *Distylium* (Figure 2).

## Taxonomic History of the Chinese *Parrotia*

The first recorded species of *Parrotia—P. persica*—was described by C. A. Meyer in 1831 and named in honor of F. W. Parrot, a German naturalist and traveler. For a long time it was

In the fall of 1988, Miaobin Deng and colleagues at Jiangsu Institute of Botany discovered a natural fruiting population of *H. subaequalis* in the town of Yixing. After three years of continually monitoring the population, their patience was rewarded when the plants finally flowered again (Deng et al. 1992b). At that point it became clear that *H. subaequalis* lacked petals, making it dramatically different from *H. mollis* (Figure 4). They proposed a new genus—*Shaniodendron*—to accommodate the species which they named *S. subaequale* (Deng et al. 1992a). Dr. Riming Hao, who studied the floral morphology of *Shaniodendron*, pointed out that *Shaniodendron subaequale* was quite similar to *Parrotia persica,* but he did not place it within the genus *Parrotia* (Hao et al. 1996). In 1996, Dr. Yinlong Qiu sent some DNA of *Shaniodendron* to Jianhua Li, then a PhD candidate at the University of New Hampshire working on the systematics of the witch hazel family. He obtained nuclear DNA sequence data from the sample and, after comparing it with other genera of the family, determined that *Shaniodendron* was a sibling species to *Parrotia persica* (Li et al. 1997). After seeing the DNA results, Hao used this evidence to propose the merger of *Shaniodendron* with *Parrotia* (Hao and Wei 1998). Nevertheless, it seems that this

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**Figure 4. The flowers of *Parrotia subaequalis* as shown on a sign posted at the Yixing Caves Scenic Area.**

treatment may take some time for people to accept since recent studies continue to use the name *Shaniodendron subaequale* (Fang et al. 2004; Huang et al. 2005), despite the fact that the plant is listed as *Parrotia subaequalis* in the *Flora of China.*

*Parrotia persica* and *P. subaequalis* are very similar from growth habit to morphology. Both trees display exfoliating bark, have obovate leaves with bluntly toothed margins, and grow in moist habitats along streams. They bear four to seven flowers clustered in a head inflorescence subtended by broadly ovate, brownish bracts. Each flower has five sepals but no petals and four to fifteen stamens with long anthers (Figure 4). Their fruits are woody capsules consisting of two chambers, each with two brown seeds (Figure 5). *Parrotia subaequalis* can be easily distinguished from *P. persica* by its lanceolate stipules and sepals fused into a shallow saucer-shaped calyx (Hao et al. 1996).

### When did *Parrotia persica* and *P. subaequalis* diverge?

Recent DNA work in Jianhua Li's laboratory has shown that witch hazels *(Hamamelis)* are more primitive than the petalless genera in Hamamelidaeeae. The evolutionary sequence of the petalless genera appears in the order of *Fothergilla, Parrotiopsis, Parrotia, Sycopsis,* and *Distyliopsis* plus *Distylium,* and the two species of *Parrotia* are grouped together (Figure 2).

Fossils can provide evidence for the minimum age of the lineage to which they belong. Unfortunately, fossil information is often unavailable for a specific taxon. Nevertheless, if DNA molecules evolve at a constant rate, that is, a certain number of nucleotide changes per million years, we can use the total number of changes between the two species to estimate how long ago they diverged. Our statistical tests indicated that the evolution of the nuclear genes we have used to reconstruct the evolutionary history of these genera followed a clockwise manner. The next thing we needed was to calibrate the ticking rate of the molecular clock using one or more known fossil dates. Luckily, Radtke et al. (2005) found a fossil leaf that could be unequivocally assigned to *Fothergilla,* specifically *F. malloryi.* This fossil leaf is part of the Republic Flora of northeastern Washington State, dating to the late Eocene (about 50 million years ago), and thus provides a minimum separation age of *Fothergilla* from the branch leading to other genera (Figure 2). Based on the molecular clock calibrated using the fossil, our estimates suggest that the two species of *Parrotia* diverged around 7.5 million (plus or minus 3.8 million) years ago, during the Lower Miocene. This divergence time is consistent with the geological evidence

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**Figure 5. Fruit and seed of *Parrotia subaequalis.***

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**Figure 6.** ***Parrotia subaequalis*** **cultivated as penjing at the Nanjing Botanical Garden.**

that the cooling temperature in the Lower Miocene plus the uplifting of the Himalayas and the mountains of western China from 55 million years ago to the Middle Miocene may have restricted biological exchanges between central Asia and eastern China (Yin and Harrison 2000; Sun and Wang 2005).

Forests in the Caspian region of central Asia and those in eastern Asia are both relics of the widespread Tertiary vegetation (Wolfe 1975; Hosseini 2003; Sun and Wang 2005). Besides *Parrotia*, the two regions share many other woody plant genera including *Acer, Albizia, Buxus, Castanea, Carpinus, Diospyros, Fagus, Pterocarya, Quercus, Sorbus, Taxus*, and *Zelkova*. From an evolutionary and biogeographical standpoint it would be interesting to determine whether central Asian species within these genera are siblings of the eastern Asian species, and if so, whether their separation time agrees with that between the two *Parrotia* species.

### *Parrotia subaequalis* in China

According to Chengxin Fu, Riming Hao, and various accounts in the literature, there are five populations of *Parrotia subaequalis* in eastern China: two each in Jiangsu and Zhejiang provinces (Huang et al. 2005) and one in Anhui (Shao and Fang 2004). Professor Fu's team is currently conducting a survey to determine the levels and patterns of the genetic diversity in Chinese *Parrotia* populations. The results will provide a scientific foundation for designing conservation strategies. Regeneration of *Parrotia subaequalis* populations will be challenging because of the species' alternate-year fruit production, serious habitat competition from bamboos, and increasing human activities. It is essential to take immediate action and institute stricter measures to protect the species.

Peter Del Tredici first saw two plants of *Parrotia subaequalis* on October 8, 1994. They were being cultivated in containers as penjing (bonsai) in a lath-house at the Nanjing Botanical Garden. At that time, the foliage had turned a beautiful, rich, deep red (Figure 6). According to the Director of the Garden, Professor Shan-an He, the plants had been collected in Jiangsu province at the Yixing Caves Scenic Area, which is located about 120 kilometers (75

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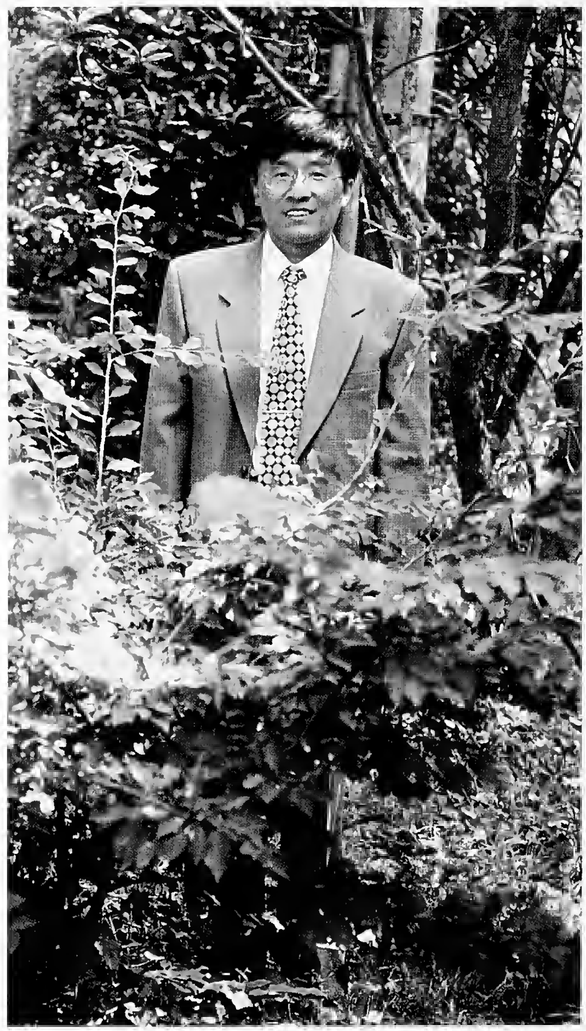

**Figure 7. Dr. Hao Riming of the Nanjing Botanical Garden with a plant of** ***Parrotia subaequalis*** **grown from a cutting.**

miles) southwest of Nanjing on the east side of Tai Lake. Both specimens had massive trunks and the larger of the two was about 50 centimeters (20 inches) tall by 70 centimeters (28 inches) across. The form of their trunks, along with their extensive yet well-healed wounds, suggested that both plants were very old. When Peter returned to the Nanjing Botanical Garden in September of 1997, he didn't see the penjing specimens but saw one young plant—recently propagated from a cutting and about 2 meters (6.6 feet) tall—growing out on the grounds of the garden (Figure 7).

On September 1, 2004, we [Del Tredici and Li] had the good fortune to be able to visit the Yixing Caves Scenic Area (known as Shan Juan Park) with Professor Cheng-xin Fu and Ying-xiong Qiu of Zhejiang University. Upon entering the park, the group immediately encountered a large specimen of *Parrotia subaequalis* growing on a steep slope above a small pond at the mouth of the largest of the karst caves. The plant was hard to miss because it was identified with a large sign with a close-up color photograph of the plant in bloom (Figure 4). The tree, which was about 6 meters (20 feet) tall, had two main trunks, the largest of which was 24 centimeters (9.4 inches) in diameter (Figure 8). The bark appeared to be at the peak of its exfoliation, with patches of fresh greenish white bark showing where sections of the old bark had sloughed off. There were no fruits on the plant—the species typically flowers only every other year—but there were numerous seedlings growing beneath it.

A second large specimen was spotted about 30 meters (100 feet) away, on a slope in a mixed woodland with bamboo and other trees. We observed at least two cases where the exposed roots of this plant were producing vigorous young suckers, a phenomenon which had not been reported in the literature (Figure 9). Interestingly, sprouting from the base of the trunk was not observed on any of the trees.

Later that afternoon, the group drove to Longwang Shan in Anji Xian, in northern Zhejiang Province, about 90 kilometers (56 miles) south of the Yixing Caves. This relatively small mountain is considered part of the larger Tian Mu Shan range that forms the border with

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**Figure 8. The trunk and foliage of a *Parrotia subaequalis* specimen growing at the Yixing Caves Scenic Area.**

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**Figure 9. Root suckers from a mature specimen of *Parrotia subaequalis* at the Yixing Caves Scenic Area.**

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**Figure 10. *Parrotia subaequalis* on Longwan Shan, 9.5 meters (31 feet) tall with a diameter at breast height of 38 centimeters (15 inches).**

Anhui Province. After spending the night in comfortable accommodations at the research station, we hiked partway up the mountain to about 650 meters (2,130 feet) elevation and located two specimens of *Parrotia subaequalis* growing near the side of a stream, amidst a pile of boulders. The larger of the two trees was about 9.5 meters (31 feet) tall with a trunk diameter at breast height of 38 centimeters (15 inches) (Figure 10). Its bark was exfoliating in a dramatic way—shedding jigsaw-puzzle-shaped plates of old, blackish brown bark to expose conspicuous patches of greenish white bark below (Figure 11). The second specimen had a double trunk, was about 8 meters (26 feet) tall, and its bark was not exfoliating as dramatically as the larger plant. Neither was producing any sprouts from the base of its trunk or any root suckers. Unfortunately there were no fruits on either plant, although there were curious hard, round, gall-like structures about a centimeter or so in diameter on many of the leaves of the smaller, double-trunked plant. Some of the notable associates growing with *Parrotia subaequalis* on Longwang Shan were *Fortunearia fortunei, Styrax confusus, Pterostyrax corymbosum, Cornus controversa, Stewartia rostrata,* and *Stewartia sinensis.* We were told that the *Parrotia subaequalis* population at Longwang Shan consisted of about twenty individuals at that time.

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**Figure 11. This specimen of *Parrotia subaequalis* (same plant seen in Figure 10) shows a very knobby trunk, indicating that it has lost many lower branches over time.**

## *Parrotia subaequalis* at the Arnold Arboretum

The Arnold Arboretum has two established plants of *Parrotia subequalis*. So far, both of them have survived two winters outdoors and they are now about 1.5 meters (5 feet) tall. On June 23, 2005, during their first growing season at the Arboretum, seven cuttings between 5 and 10 centimeters (2 to 4 inches) long were taken from the two plants. A month later, on July 25, another nine cuttings were taken from the plants. All sixteen cuttings were treated with a five-second dip in an aqueous solution of 5,000 parts per million KIBA, stuck in flats filled with a mix consisting of half sand and half perlite, and placed in the high-humidity greenhouse under intermittent mist and fog. Remarkably, all sixteen of the cuttings rooted and three of them are planted in the nursery.

With five plants now growing outdoors, the Arboretum is in a position to begin evaluating the horticultural potential of *Parrotia subequalis*. Successful establishment at the Arboretum also facilitates continued research on the genetics, physiology, reproductive biology, and conservation of this rare and evolutionarily important species.

#### Acknowledgments

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Jianhua Li and Peter Del Tredici are senior research scientists at the Arnold Arboretum.

# Curatorial Notes: An Updated Living Collections Policy at the Arnold Arboretum

*Michael S. Dosmann*

Museums, by definition, collect things, and in the case of botanical gardens and arboreta, those things are plants. In this quest to collect, curators must exercise discipline and prudence in determining what new things to acquire as well as which ones to remove. Garden collections can be notably challenging to curate because of the overwhelming breadth of possible biodiversity to accumulate. Thus, it is essential for curators to make use of a collections policy—a tool which defines the scope of the collection. The collections policy is mission-driven; it defines short- and long-term goals and establishes the direction of collection building. While the specifics of what items to collect may occasionally be included in the collections policy, they are typically outlined separately in a detailed collections development plan. Likewise, the tactics of curation, such as the means of acquisition, intricacies of database management, standardization of nomenclature, or tasks related to plant maintenance, are best housed within a separate procedural manual.

### Collections policy history at the Arboretum

Since its inception, the Arboretum has built its living collection of plants with the aid of a collections policy, although the policy's content and application have varied considerably over the years. The indenture signed by the President and Fellows of Harvard College and the Trustees of Mr. James Arnold on the 29th of March, 1872, included the original collections policy:

> "The Arnold Arboretum... shall contain, as far as is practicable, all the trees, shrubs, and herbaceous plants, either indigenous or exotic, which can be raised in the open air at the said West Roxbury..."

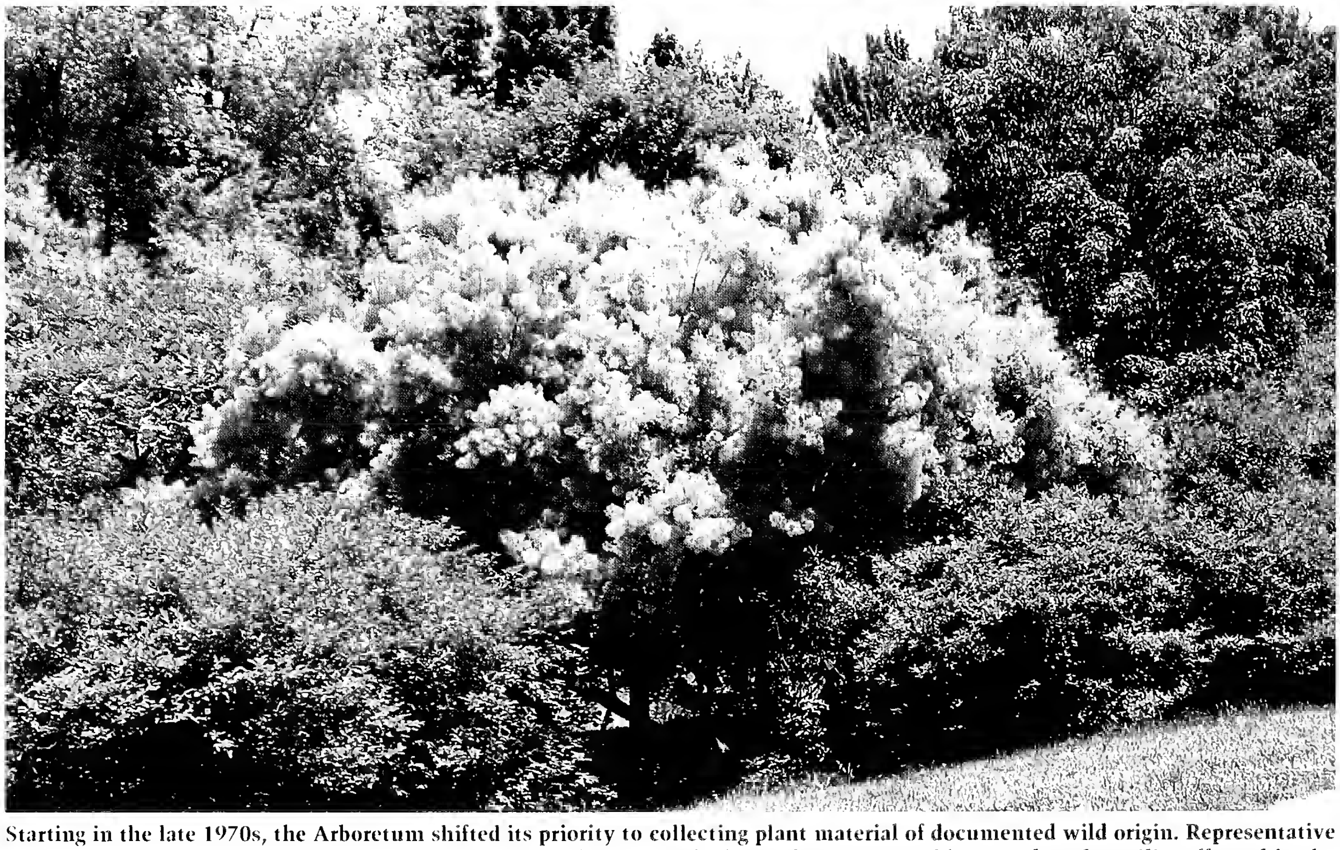
It was simple, direct—and too broad for Charles S. Sargent, the Arboretum's first curator and director. While he followed the spirit of the indenture's charge with aplomb, acquiring as many taxa as possible, the focus quickly shifted almost solely to woody plants, leaving most herbaceous plants out of the permanent collections. His keen interest in the floras of North America and eastern Asia, no doubt influenced by his mentor Asa Gray, led to substantive biogeographic collections from these locales. And Sargent's fascination with ornamentals resulted in the acquisition of many horticultural plants, including great numbers of botanical formae and varieties that are now considered cultivars.

Sargent (1922) estimated that during the Arboretum's first half-century some 6,000 taxa grew in the collections. But space became limited in the 265-acre landscape, and the collections became crowded. The problem became acute in the years following Sargent's death in 1927; in the absence of his careful direction the collections multiplied unchecked. To respond to this dilemma, landscape architect Beatrix Farrand was hired in 1946 by Karl Sax, Arboretum director at the time, to create a restorative plan. In her assessment (Farrand 1946), she questioned whether "the comparatively small acreage of the Arboretum can wisely accommodate all the species and varieties of woody plants of the temperate regions." The recommendation that she and the Administration came up with was that the collections grown in Jamaica Plain would be "the best and most ornamental"; research plants that lacked the desired showiness, yet had scientific merit, would be transferred to the Case Estates in Weston, where they could be lined-out in experimental nurseries. This strategy's execution was left to Donald Wyman, the Arboretum's horticulturist. Wyman undoubtedly sighed in relief with this decision. He acknowledged (Wyman 1947) the difficulty of maintaining an expanding number of plants solely at Jamaica Plain given the institutional reticence to modify any collections following Sargent's death (particularly those that Sargent had a hand in building). In theory, this split-site solution allowed the living collections to

HERBERT W. GLEASON, ARCHIVES OF THE ARNOLD ARBORETUM

**Arboretum planting space was already filling up when this photograph was made in May of 1930, a few years after Sargent's death. The photo shows Korean azalea (*Rhododendron yedoense* var. *poukhanense*) and other plants on Bussey Hill.**

PHOTOS BY MICHAEL S. DOSMANN



**Starting in the late 1970s, the Arboretum shifted its priority to collecting plant material of documented wild origin. Representative plants collected on expeditions made during this period include (clockwise from upper left): *Weigela subsessilis* collected in the Republic of Korea in 1977, *Sorbus yuana* collected in the People's Republic of China during the Sino-American Botanical Expedition in 1980, and *Cotinus coggygria* from the 1980 expedition to the Russian Federation (then the U.S.S.R.).**

remain comprehensive—as per the original collections policy of 1872—while providing focus to the two sites: research collections in Weston and ornamental collections in Jamaica Plain.

For the next 30 years, this practice continued and the Arboretum landscape in Jamaica Plain accrued great numbers of ornamental taxa, particularly cultivars under evaluation. This swing was reinforced by the post-war proliferation of cultivars introduced by the nursery industry, the institutional goal of becoming a showcase of horticultural material, and practically complete cessation of plant exploration efforts. It is important to note that while the collections policy did not shift, per se, its method of realization did.

In the late 1970s, a shift again took place—this time with an eye towards documentation, the prime metric used to assess a collection's value. While material of cultivated origin may carry with it notable documentation, its value is generally eclipsed by material of wild origin, particularly once it has been verified to identity. Thus, in a new living collections policy, priority shifted away from ornamental and toward botanical taxa (Spongberg 1979). While the emphasis was placed upon botanical taxa of wild origin, provisions were in place to accession or maintain garden-origin plants (as temporary placeholders), as well as cultivars—provided they were of historic significance (i.e., those with Latinized epithets proposed prior to 1953). This policy change coincided with the reinstated tradition of field collection of germplasm, both domestically and abroad. As a result, many new acquisitions of documented wild origin again crossed the Arboretum's threshold, particularly in Jamaica Plain. With respect to the practice of growing material in both Jamaica Plain and Weston, Peter Ashton (1979) reflected that the two-site strategy had come at a cost: the loss of valuable germplasm which did not survive the transfer from Jamaica Plain to Weston, including original introductions of species by E. H. Wilson and other explorers. The ambitious goal of acquiring everything—maintained in two separate sites—was too lofty, particularly with the resources available, and Jamaica Plain was deemed the primary repository.

This formal policy direction was sustained for the next decade, and then reaffirmed in 1991 (Living Collections Long-Range Planning Committee 1991). As in the 1979 version, the goal stated that "the living collections of the Arnold Arboretum were to consist of a scientific collection of entities tied to botanical, not horticultural nomenclature." Because the emphasis was placed on names and not necessarily taxonomy, a great deal of space in the new policy was dedicated to the "problem of cultivars and their relationship to taxa of infraspecific botanical rank."

### The need for a collections policy update

Shortly after joining the staff as Curator of Living Collections in January of 2007, I convened the Living Collections Committee to review the Arboretum's existing living collections policy and place it in context with current, as well as future, institutional needs. After thorough discussion and assessment, we restructured the policy with several broad goals in mind:

- The policy needs to describe the entire scope of our living collection, including collections that previously had not been highlighted such as the Larz Anderson Bonsai Collection and plants in our natural areas. It should also articulate levels of commitment, or priority (i.e., high to low), depending upon the type of collection. This would allow us greater flexibility as well as focus in collections development.
- The policy should not perpetuate the hierarchy between wild-origin and cultivated material. Instead, the emphasis should be placed on the level of documentation associated with individual accessions, as well as their programmatic use(s) in furthering the mission of the institution. This is particularly important when we consider the immense research potential of the collections (Dosmann 2007).
- The policy must be clear and usable, yet not burdened by too many details; the policy was not intended to be a procedural manual. Instead, we appended it with a list of operational definitions to aid in interpretation.

Here is the result: the current living collections policy for the Arnold Arboretum. Notice that in spirit, it has remained true to the original plan of 1872; additional details have been added for clarity and for establishing organization and a sense of priority. Interspersed within the official policy below are text boxes and figures that provide illustrative examples and additional information.

# Living Collections Policy

***Policy reviewed and approved on 10 September, 2007***

## MISSION STATEMENT

The Arnold Arboretum of Harvard University discovers and disseminates knowledge of the plant kingdom to foster greater understanding, appreciation, and stewardship of the Earth's botanical diversity and its essential value to humankind.

## I. INTRODUCTION

### A. PURPOSE OF THE LIVING COLLECTIONS POLICY

The Living Collections Policy of the Arnold Arboretum guides the development, management, and enhancement of the institution's Living Collections, and applies to all plants outlined below under Scope of the Living Collections. The Living Collections Policy is written and administered by the Living Collections Committee, which comprises the Curator of Living Collections (Chair of the Committee), Deputy Director, Manager of Horticulture, Manager of Plant Records, Manager of the Dana Greenhouses and Nursery, and Senior Research Scientist; it is further reviewed and approved by the Director. The Living Collections Policy is reviewed every five years and revised as needed. Operational procedures related to implementation of this and related policies are detailed in the Arboretum's *General Procedures for Managing the Flow of Plants through the Department of Horticulture* (January 2007).

### B. PURPOSE OF THE LIVING COLLECTIONS

The Living Collections of the Arnold Arboretum are essential to achieving its mission as a research institution dedicated to improving the understanding, appreciation, and preservation of woody plants. As a national and international resource for research in the various fields of plant biology and beyond, the Arboretum's Living Collections are actively developed and managed to support scientific investigation and study, as well as key educational and amenity roles.

### C. LEGAL AND ETHICAL CONSIDERATIONS

Activities related to the development, management, and use of the Arnold Arboretum's living collection comply with all relevant local, state, federal and international laws. This includes compliance with all necessary documentation and phytosanitary require-

NANCY ROSE

***Phellodendron amurense* (Amur corktree; fruit shown at left) is currently monitored for its invasive potential in the Arboretum. Spontaneous trees have been removed, and female trees lacking sufficient documentation have been deaccessioned as a means of limiting seed production. However, other individuals of documented origin—some representing unique provenances—remain in the collection because of their high scientific value.**

NANCY ROSE

RUPERT TAYLOR

**Nearly 500 plant genera are common to both North America and eastern Asia. Many representatives of this disjunct group are included in the Arboretum's collection, including two strikingly similar *Cornus* species, *Cornus alternifolia* from North America (left) and *Cornus controversa* from eastern Asia (right).**

ments during acquisition and distribution activities. All taxa are evaluated for their potential invasiveness, and should invasive or potentially invasive plants be retained for their scientific value, additional management procedures are put into place for containment purposes; they are not distributed for horticultural use.

## II. SCOPE OF THE LIVING COLLECTIONS

The Living Collections are divided into three primary collection categories: Core, Historic, and Miscellaneous Collections; within each are secondary collections. This organization allows priority to be assigned to all extant, as well as potential, accessions within each category, thus guiding collections development, management, and enhancement. It should be noted that none of the primary, or secondary, collections are mutually exclusive and that many accessions fall into multiple categories.

### A. CORE COLLECTIONS

The Core Collections are of highest priority and receive the greatest focus with respect to development, management and enhancement. In general, these collections are intrinsic to the mission of the institution through their research use, and preference is placed on material of documented wild origin. Exceptions to provenance requirements are made only in specific cases when the value is significant enough to warrant accessioning. By and large, these collections are regarded as obligatory.

1. **Biogeographic Collections**
   Collections representing the floras of eastern North America and eastern Asia have been an important traditional focus, strongly supporting research related to the floristic relationships between these two regions. In particular, eastern North American-Asian disjunct taxa receive high priority with respect to collections development.

2. **NAPCC Collections**
   As part of its commitment to the North American Plant Collections Consortium (NAPCC), the Arboretum maintains and develops collections of botanical taxa

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**Interspecific diversity is attained by growing as many species as possible within each of these high-priority genera. To increase intraspecific diversity, we strive to acquire germplasm from multiple provenances of each species so that we may illustrate genetic variation as a function of geographic source.**

Japanese beech ***(Fagus crenata)*** **is just one of the species of beech grown as part of the NAPCC collection.**

within the following genera: *Acer, Carya, Fagus, Stewartia, Syringa* and *Tsuga*. Because they serve as national germplasm repositories, development and maintenance maximizes both inter- and intraspecific diversity.

3. **Conservation Collections**
   As part of its commitment to the Center for Plant Conservation (CPC), the Arboretum maintains and develops collections of the following species: *Amelanchier nantucketensis, Diervilla rivularis, Diervilla sessilifolia, Fothergilla major, Ilex collina, Rhododendron prunifolium, Rhododendron vaseyi, Spiraea virginiana,* and *Viburnum bracteatum*. These species, as well as other taxa of conservation value outside the scope of CPC, are developed and maintained with the goals of preserving as high a level of intraspecific diversity as is practicable.
4. **Synoptic Collections**
   Collections of documented wild-origin species that together provide a synoptic representation of the woody flora of the North Temperate Zone are maintained and developed. Emphasis is first placed on generic diversity, and then inter- and intraspecific diversity as is practicable.

**The goal of a synoptic, or comprehensive, collection is to include the broadest possible representation of the item or group being collected. At the Arboretum this means seeking the greatest breadth across all families that contain woody plants. The Arboretum's synoptic collections cannot contain every woody species, let alone every botanical variety or subspecies, so representative genera and species are selected based on institutional priorities and available space.**

## B. HISTORIC COLLECTIONS

The Arboretum's early contributions to plant exploration and horticultural improvement are manifested in a number of Historic Collections. In general, these collections are obligatory and maintained, but not actively developed except in cases where authentic material of Arboretum origin can be repatriated or the material is sufficiently unique to warrant accessioning.

1. **Arnold Arboretum Accessions**
   Plants collected by early Arboretum staff (e.g., C.S. Sargent, E. H. Wilson, J.G. Jack, J. Rock) may lack sufficient documentation, or be of garden origin. However, because they represent important historical chapters in the development of the institution, they are maintained in the Living Collections. In some cases, these accessions may represent genotypes no longer extant in the wild because of local extinction and thus have high conservation value.
2. **Nurseries and Horticulturists**
   Accessions derived from historically significant nurseries, botanical institutions and horticulturists (e.g., H. J. Veitch, T. Meehan, M. Vilmorin) may lack full documentation, but are maintained in the Living Collections. These often represent the initial introductions of species into cultivation and are, in all probability, wild-collected. In some cases, these accessions may represent genotypes no longer extant in the wild because of local extinction and thus have high conservation value.
3. **Distinctive Cultivar Collections**
   Early in its development, the Arboretum established diverse collections of garden selections now regarded as cultivars within various plant groups (e.g., dwarf conifers, *Malus, Rhododendron, Syringa*). Because of their period and oftentimes comprehensive nature, these collections are maintained but not developed.

NANCY ROSE

**In 1885, C. S. Sargent described the goals of the Peters Hill landscape as housing "a collection for investigation which need not necessarily be permanent." Otherwise known as discretionary collections, these have often reflected the research interests of staff scientists. Prior to the substantial *Malus* collection (shown above), which grew through the work of director Karl Sax and horticulturist Donald Wyman, Peters Hill was home to extensive *Crataegus* collections—a long-term research project of Sargent.**

ARCHIVES OF THE ARNOLD ARBORETUM

***Hydrangea paniculata* 'Praecox' is an old cultivar with a Latinized epithet. Originally collected in Japan by C.S. Sargent in 1892, this Arnold Arboretum introduction is noted for its precocious floral displays, blooming at least a month before typical plants of the species.**

**4. Cultivars with names proposed prior to 1953**

The Living Collections contain a number of historic cultivars with Latinized names that were proposed in a botanical context prior to 1953. While not developed, these are maintained, particularly when they represent material unique in cultivation.

**5. Arnold Arboretum Cultivar Introductions**

Throughout its history, the Arboretum has selected and introduced a number of clones for ornamental use, many of which were initially regarded as botanical formae but are now recognized as cultivars. Because they arose at the Arboretum, they are maintained and development occurs only to repatriate genotypes lost by the Arboretum.

**6. Larz Anderson Bonsai Collection**

The Larz Anderson Bonsai Collection, while not actively developed, is of high priority within the Arboretum's Living Collection because of its historic and aesthetic value.

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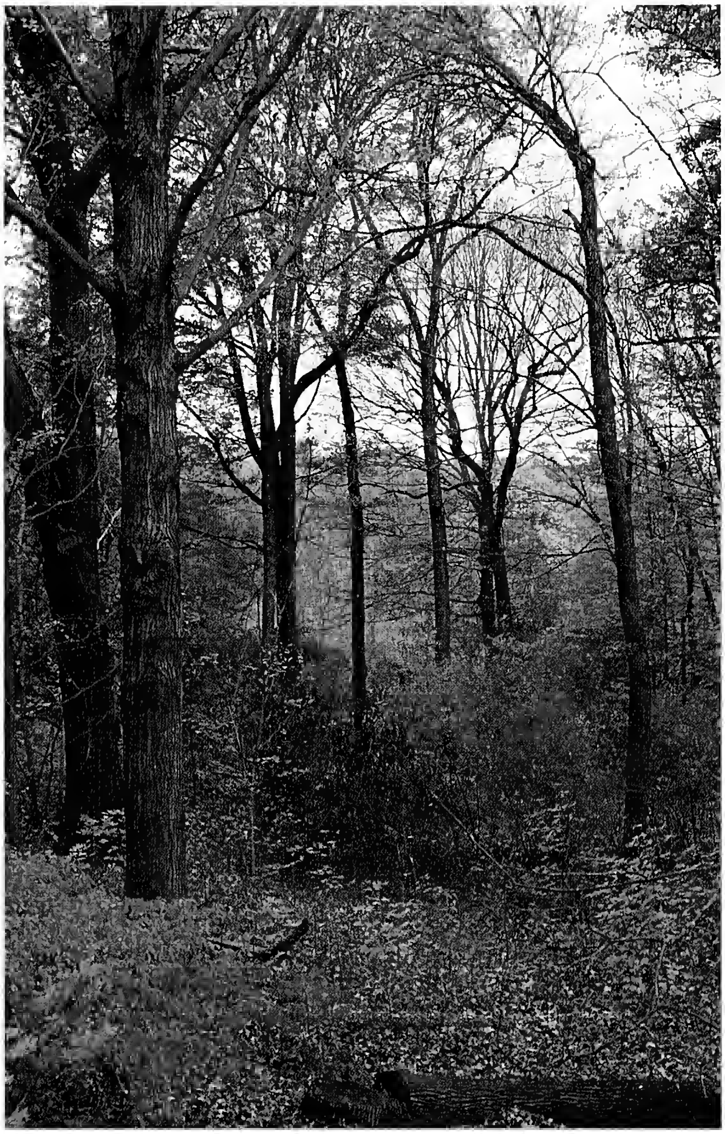
**In addition to housing permanent collections that require high maintenance, The Leventritt Shrub and Vine Garden also displays outstanding ornamentals with exemplary traits. Shown here is accession 178-93-A, *Forsythia* 'Courdijau'.**

## C. MISCELLANEOUS COLLECTIONS

In addition to those within the above collection categories, The Living Collections comprise a number of plants grown to achieve display effects, for interpretation, for evaluation, or that may fall outside of traditional scope and not even be accessioned. However, because they play important roles in the Arboretum's research, horticultural and educational work, they are included within the Living Collections. These may be obligatory or discretionary, and development and maintenance decisions are made on a case-by-case basis by the Living Collections Committee.




**While they may not contain formally accessioned plants, several natural areas in the Arboretum (including the North Woods, above) are managed as part of the living collections because of their research potential as well as intrinsic beauty.**

1. **Display Collections**
   Plants of cultivated origin, particularly cultivars selected for unique traits, serve important research and education roles; however their primary value is for display. Examples include ornamentals with exceptional ornamental qualities, landscape plants well suited to the New England climate (including those with stress-, insect-, and disease-resistance), as well as those under evaluation. These collections are regarded as discretionary and are developed and maintained as needed, with the acknowledgement that accessions may be deaccessioned when their value no longer meets the appropriate standard.
2. **Natural Areas**
   The Arboretum landscape contains several natural areas representative of the New England Flora. Generally, these are maintained through natural regeneration of the present vegetation; however development may occur under certain circumstances (e.g., restoration following major disturbance).
3. **Spontaneous Flora**
   Spontaneous generation of native, as well as exotic, plants occurs throughout the Arboretum's cultivated landscape. As a matter of course, some of these plants are removed because of their noxious characteristics, some are left in place, while others are accessioned (in particular spontaneous interspecific hybrids or landscape specimens). The forthcoming *Policy on the Spontaneous Flora* addresses this category more thoroughly.
4. **Dana Greenhouse and Nursery Collections**
   A number of plants are cultivated at the Dana Greenhouse and Nursery for experimental, observational, and other programmatic functions outside the scope of production for the accessioned Living Collections. Development and maintenance lies with the primary investigator or other assigned staff member, with the understanding that these may be formally accessioned at a later time.

## APPENDIX: DEFINITION OF TERMS USED IN THE LIVING COLLECTIONS POLICY

An **accession** is the basic unit of a collection and identified by a unique accession number. By definition it represents a single taxon, from a single source, acquired at one time, and through one means of propagation. An accession may comprise a single plant, or multiple plants, each identified by a letter qualifier following the accession number, or in the case of mass plantings, MASS.

**Accessioning** is the process of adding specimens to the Arboretum's Living Collection and occurs at the time of entry regardless of its stage (e.g., plant, cutting, scion, seed). All accession records are permanent and are not expunged should deaccessioning occur.

**Acquisition** of new accessions may be through field collection, exchange, gift or purchase. All acquisitions must meet specific collections development goals in accordance with the Scope of the Living Collections detailed in this Living Collections Policy.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**The label for accession 638-88-C, *Fraxinus tomentosa*.**

A **collection** is operationally defined as a group of accessions organized by a particular category for curatorial, educational, research, display or other use. A collection need not be physically grouped together, and a single accession may be part of multiple collections. From the perspective of commitment, collections may be discretionary or obligatory.

**Curation** is the process of managing the Living Collections to guarantee its conservation, guide its development, ensure its documentation, and facilitate its enhancement.

**Deaccessioning** is the process of removing a living specimen from the collection, but does not include the removal of any records related to that accession. Deaccessioning decisions are made by the Curator of Living Collections, in consultation with the Living Collections Committee.

**Development** is the process by which the Living Collections undergo change through the acquisition of new accessions and the deaccessioning of accessions no longer needed in accordance with the Scope of the Living Collections detailed in this Living Collections Policy.

**Discretionary** collections can be regarded as temporary or permanent. They meet specific research, display, education or other programmatic needs, but do not necessarily represent collections central to the mission and purpose of the Arboretum.

**Enhancement** is the process of adding value to the Living Collections through documentation, research, and other means.

The **Living Collections** comprise all plants formally accessioned, and in a broad sense also contain unaccessioned plants in natural areas, spontaneous flora, and research material.

**Maintenance,** from the standpoint of curating the Living Collections, is the practice of vegetatively repropagating an obligatory accession in order to preserve and perpetuate its genetic lineage. Multiple accessions of the same lineage are genetically identical.

**Obligatory** collections are considered permanent and represent collections central to the mission and purpose of the Arboretum.

A **taxon** (plural, taxa) is a unit of any rank within the taxonomic hierarchy (e.g., family, genus, species, variety, cultivar).

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SYLVIA WINTER

MICHAEL DOSMANN

**Last year a decision was made to deaccession a prominent winterberry holly, *Ilex verticillata* 22879-F, from its location along Meadow Road across from the Visitor Center. Although it was a noteworthy specimen that consistently produced copious fruits, its large size (nearly 25 feet in diameter) prevented access to one of the original *Metasequoia glyptostroboides* (524-48-AA). An examination of the records showed that the holly was of unknown origin—not even a nursery source—and that seven other vigorous plants of the accession remained in the collection.**

# Ecosystems in Flux: The Lessons of Hemlock Hill

*Richard Schulhof*

Ten years after the first detection of hemlock woolly adelgid *(Adelges tsugae)* at the Arnold Arboretum, the hard lessons of biological invasion are written across the face of Hemlock Hill. Large gaps mark the loss of hemlocks, while many survivors, diminished by infestation, stand as relics in growing swaths of successional vegetation.

Introduced invasive organisms pose an increasing threat to native biodiversity. As is conspicuously evident on Hemlock Hill, newly arrived pests and pathogens can quickly decimate susceptible native species, creating issues that range from concerns for public access and safety to the long-term management of ecological disturbance. Invasive plant species often follow in the wake of such outbreaks, further disrupting native ecosystems.

Responding to invasive species in ways that safeguard people, plants, and the larger environment demands that we more wisely manage the uncertainties of a rapidly changing world. The story of hemlock woolly adelgid (HWA) at the Arnold Arboretum recounts the lessons learned in addressing the rarely predictable, often irreversible consequences of biological invasion.

## New Invasives: A Steady Parade

The scope of the problem is substantial. A 2002 National Academy of Sciences study determined that the USDA inspects roughly 2% of cargo shipments yet intercepts over 53,000 arthropods, pathogens, and plants annually. Although few introduced organisms successfully establish, it is conservatively predicted that 115 non-native insect species and 5 plant pathogens will become naturalized in the United States between 2000 and 2020. Continuing loss of native biodiversity is recognized as perhaps the greatest long-term consequence of invasive species, which are second only to habitat loss as a primary cause of native species decline in the U.S. Of species on the threatened or endangered list, roughly 50% are at increased risk due to competition or predation from non-native organisms. Some unlisted species, such as the eastern hemlock *(Tsuga canadensis)*, face extirpation or severe reduction over large parts of their range. Each region of the country has its own list of problematic introduced insects and pathogens, with growing public awareness that emerald ash borer *(Agrilus planipennis)* and Asian longhorned beetle *(Anoplophora glabripennis)*, among others, are dire threats to both cultivated landscapes and native ecosystems.

## The Home Front

It is with some irony that I survey the introduced invasive organisms that today inhabit the Arnold Arboretum. A leader in scientific collecting and importation of plants from east

RICHARD SCHULHOF

**Egg masses in dense, cottony clusters provide a highly visible indication of the progress and intensity of hemlock woolly adelgid infestation.**


**Sweet birch *(Betula lenta)*, shown here in golden fall color, is now growing across large areas of Hemlock Hill. As is typical across southern New England, this birch species is a dominant colonizer of the post-hemlock landscape.**

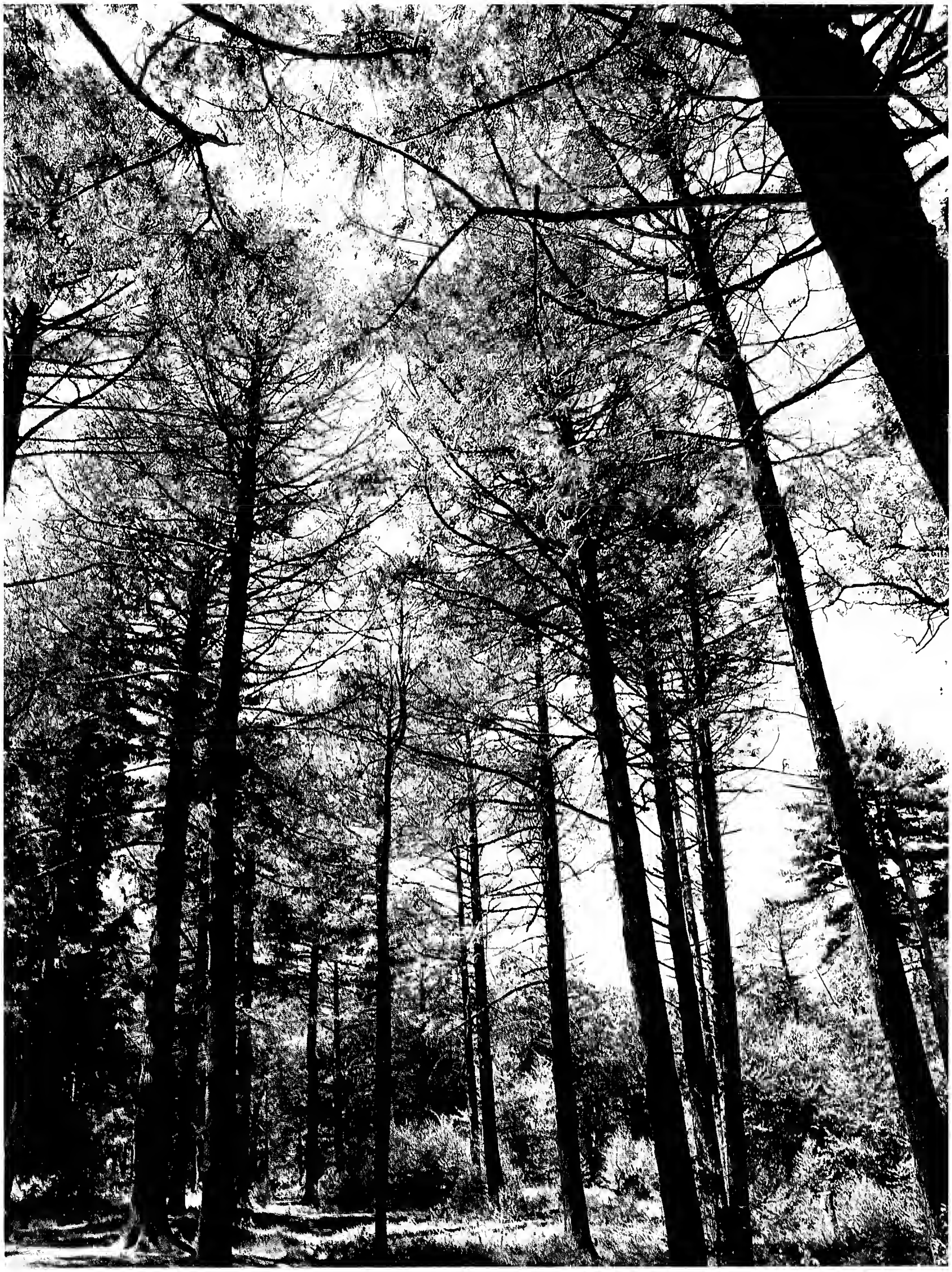
Asia in the decades before and after 1900, the Arboretum is one of a great many agents that unwittingly introduced species to the North American landscape that later naturalized and wrought destructive impacts. Regardless of our respective "rap sheets", the Arboretum and other public gardens now work diligently toward devising management strategies to deal with problematic introduced species.

At the Arboretum, developing appropriate responses to invasive species is an ongoing responsibility shared by horticulturists, managers, and administrators. Aggressive incursions of winter moth *(Operophtera brumata)*, garlic mustard *(Alliaria petiolata)*, Japanese knotweed *(Polygonum cuspidatum)*, and other invasives require that we stay abreast of new methods and information, not only to improve the efficacy of our management measures but to do so with ever diminishing environmental impacts. This past fall, the position of Manager of Plant Health was created to coordinate integrated pest management and associated environmental monitoring.

**Cautionary Tales**

As we have learned over the years, "best" practices are moving targets that shift with increasing knowledge and a changing environment. This can be particularly true in managing recently introduced insects and pathogens whose life cycles, host impacts, modes of spread, and other critical traits may still be relatively unknown. The long-term consequences of various management options are often equally unknown. How we make decisions in the face of uneertainty is of great importance. Confronted with approaching waves of introduced species, what can we learn from previous efforts to manage new invaders?

RICHARD SCHULHOF



Infested trees on Hemlock Hill in 2003 showing the defoliation and reduction of new growth typical of hemlock woolly adelgid infestation.

Most recently, the potentially harmful effects of biocontrols—non-indigenous species released to control invasive pests—have received considerable attention. The multicolored Asian lady beetle *(Harmonia axyridis)*, intended to control a range of insect pests, now appears to outcompete and replace some native lady beetle species, while becoming a nuisance in its winter aggregations in homes and buildings. In southern Florida, native *Opuntia* species are threatened by a South American moth *(Cactoblastis cactorum)* that had been introduced to control *Opuntia* naturalizing in the Caribbean. Cases of unforeseen consequence, the non-target effects of some biocontrols may be remembered as cures worse than the disease.

From an earlier period, management response to Dutch elm disease *(Ophiostoma ulmi)*, a public and politically charged effort, targeted its primary vector, the elm bark beetle *(Scolytus multistriatus)*. The American elm's *(Ulmus americana)* importance as an icon in the cultural landscapes of the Northeast made saving the species a priority for state and municipal agencies, and the resulting massive applications of toxic pesticides contributed to an environmental disaster all too well known today. Past actors on a period stage, decision-makers were undoubtedly influenced by historical biases and limited by critical gaps in knowledge, yet their legacies suggest that response to uncertainty—particularly the consequences of our own actions—merits particular focus today.

**Managing Hemlock Woolly Adelgid**

Our ten years of managing hemlock woolly adelgid is a story of decision-making in a rapidly changing informational environment. We began with many uncertainties and traveled a path of pivots and about-faces led by growing knowledge of our own site, analysis of outcomes elsewhere, and key findings from the research community.

In 1997 HWA was first detected on the Arboretum's Hemlock Hill, a 22-acre historic natural site whose early public use included frequent visits in the 1840s from Margaret Fuller and other members of the Transcendentalist circle. Prior to infestation, Hemlock Hill was home to over 1,900 eastern hemlocks, some dating to the early 1800s. With its several stands of fully mature hemlock-dominated forest, the Hill had long been appreciated as a place of seemingly wild nature in the midst of the city.

The Arboretum was hardly among the first sites to deal with HWA. First detected in Richmond, Virginia in the early 1950s, HWA spread rapidly, decimating hemlock populations in the Mid-Atlantic and coastal Connecticut before reaching Boston. Across much of the range of infestation, the ultimate consequence of HWA was near to complete hemlock mortality within four to twelve years. There were few exceptions. With the prospect of losing one of Boston's most significant natural sites and an integral part of our own history, Arboretum managers addressed challenges of a scope not seen since the 1938 hurricane.

The process began with questions. What would be the rate of decline for our hemlocks? How many trees could we protect and at what costs to the larger ecosystem? Could a biocontrol under development save our trees? Although these and other questions would remain unanswered for years, management goals drawn from our organizational mission provided a strong compass for initial decision-making. Protecting visitor and staff safety, protecting the larger environment, and preserving a still undetermined number of hemlocks were our key priorities. But where to start?

**Through the Learning Curve**

We determined that obtaining reliable, site-specific information about the spread of the infestation and rates of hemlock decline would be essential to planning an effective management response. Monitoring the health of our hemlocks required mapping the locations and assigning an accession number for each tree. This significant investment was abundantly repaid in data that detailed the progression and severity of the infestation as well as the efficacy of our control efforts; information that continues to inform our decisions. Using assessments of crown health, we evaluated all hemlocks, finding that from 1998 to 2002, the number of trees in poor health increased from 30% to 70%. By 2003, Hemlock Hill was a sickly gray-green color. Data from other sites indicated that we could expect large numbers of hazardous and dead trees within two to three years.

That winter we visited forests in Connecticut that had been closed to the public because of the danger presented by hundreds of disintegrating dead hemlocks. Further, we learned that the highly hazardous brittle snags had precluded both salvage operations and efforts to contain rapidly growing populations of invasive plants. Foreseeing similarly grim prospects for Hemlock Hill, we anticipated removing over 1,000 rapidly declining trees within the next two years.

Fortunately, that large-scale removal never occurred. The winter of 2004, the coldest in many years, brought several nights with temperatures of -5°F or colder, delivering an unexpected reprieve. Although not well documented at the time, HWA is highly vulnerable to extreme cold. Based on surveys at other sites, we estimate that well over 90% of the existing HWA population perished that winter. The following summer, which also brought much needed rain, saw a revitalization of our hemlocks that was a wonder to behold. For once, extreme cold had been a gift, resetting the clock of infestation and allowing more time to find new strategies.

Additional changes in approach came with new information from the research community. Publications that elucidated site factors affecting rates of hemlock decline, the relative efficacy of different HWA control methods, and the field performance of highly anticipated biocontrols were part of a burgeoning informational environment that enabled knowledge-based decisions. The Arnold Arboretum was fortunate in that HWA arrived in our vicinity just as many research efforts came to fruition, providing us with essential information that was unavailable to managers of previous infestations.

Perhaps our hardest decision thus far concerns the number of hemlocks we attempt to save. The absence of host resistance and limited cultural controls leave us with few management options. Clearly any chemical treatment, even relatively benign horticultural oil, brings concern for the larger environment. At the same time, we are an essential resource for a large urban population that for over 150 years has enjoyed the singular educational and aesthetic experiences of a majestic hemlock-dominated forest.

Finding balance among stewardship, education, and public service goals, we protect hemlocks that are of sufficient vigor to recover and that grow in conditions that are favorable for treatment and do not present risk of water contamination. HWA is controlled with applications of horticultural oil and, more recently, soil injections of imidacloprid , a treatment now provided to over 40,000 trees at Great Smoky Mountains National Park. We now use this method and pay close attention to ongoing research that monitors for non-target effects and persistence in the environment. Ultimately, it is hoped that these treatments will buy time for the Arboretum's hemlocks until biocontrols or other non-chemical options can offer reliable protection.

An ongoing challenge, symptomatic of ecosystem disturbances on a global scale, is the control of non-indigenous plants that often invade when native habitats are affected by introduced organisms. As hemlock mortality continues, canopy gaps become points of colonization for glossy buckthorn *(Frangula alnus)*, Japanese knotweed, and other invasives. Our long-term goal is to promote native hardwood forest where hemlock once grew, and while we actively eliminate invasive vegetation, robust native species, particularly sweet birch *(Betula lenta)*, are rapidly dominating large areas.

**Adaptive Management**

Our HWA management strategy continues to evolve, reflecting the iterative learning process needed to develop effective site-specific responses to invasive species. Gathering data that monitor changing conditions as well as the effectiveness of management actions is essential, as is a willingness to completely revise strategies based on new results.

Our experience speaks to the value of Adaptive Management, a process developed for the management of complex natural systems characterized by uncertainty. Borrowing from scientific method, it relies on carefully assembled hypotheses, field testing of proposed practices,

## RESEARCH OPPORTUNITIES

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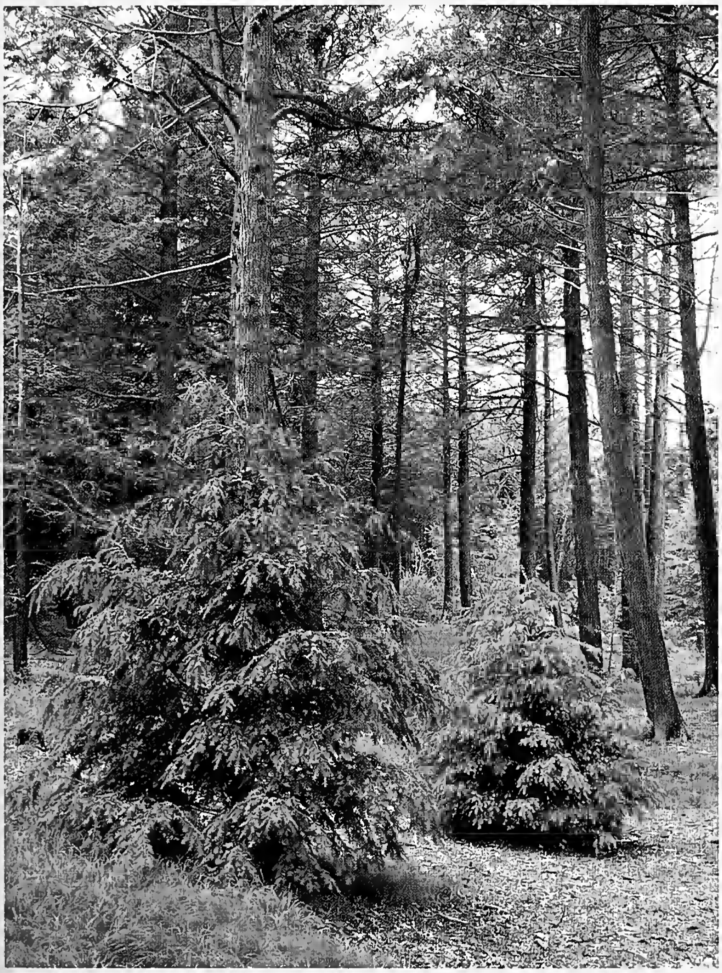

Chinese hemlock *(Tsuga chinensis)*, planted in openings on Hemlock Hill, proved highly resistant to hemlock wooly adelgid.

**An unanticipated silver lining was found in emerging research opportunities on Hemlock Hill. The severe consequences of HWA infestation pose compelling questions about the ecological changes associated with decimation of a foundation native species. Beginning a four-year investigation in 2004, the Arboretum collaborated with the Harvard Forest to establish six 15-meter by 15-meter research plots in order to measure the changes occurring when hemlock is abruptly removed from the forest system. We removed hemlocks from four of the plots, with the remaining two left unlogged for use as controls. Measurements established baseline data for soil temperature, available nitrogen, organic soil mass, and understory vegetation. Analysis compared nitrogen cycling, decomposition rates, and regeneration across the six plots. Scheduled to conclude in summer 2008, the study is part of a longer-term Harvard Forest effort to assess ecosystem impacts of HWA in southern New England.**

**A second project examined Chinese hemlock *(Tsuga chinensis)*, a species first grown in North America at the Arnold Arboretum. The research established that Chinese hemlock is cold hardy through at least Zone 6 and is fully resistant to HWA, confirming its suitability as a promising landscape replacement for *Tsuga canadensis*.**

and the monitoring of results to inform next steps and ongoing improvement. It is a model for managing disturbed natural systems that lack both predictability and stability, and for which management outcomes may be determined by variables that are unrecognized or unknowable at the outset—in short, much of the world as we now know it. At the Arboretum, we did not set out to adaptively manage; the approach was born of necessity. But with the appointment of a manager of plant health, we now seek to more fully implement its tenets.

### Public Awareness

The dramatic losses on Hemlock Hill, roughly 30% of the original hemlock population, offer an important local example of a global phenomenon. To build public awareness, the Arboretum now offers school field studies and special tours that explore the fragility of native ecosystems, disturbance caused by invasives, and the complex challenges that result for environmental stewards. As former evergreen forest converts to deciduous woodland, programs will interpret changes in nutrient cycling and species inter-

RICHARD SCHULHOF

**School children examine sweet birch seedlings as part of a new Arnold Arboretum field study investigating the ecological impacts of hemlock woolly adelgid.**

actions. Presentations to the community and feature stories appearing in newspapers and on radio and the web have further disseminated the Hemlock Hill story in Boston and southern New England.

Introduced insects and pathogens are here to stay. Looking to the future, warming temperatures will likely enable HWA and other temperature-limited invasives to expand ranges of infestation and more quickly reach lethal densities on host species. The USDA, among other domestic and international agencies, must strengthen efforts to prevent unintended introductions as well as accelerate research programs to better inform management efforts. Institutions such as the Arnold Arboretum, committed to environmental stewardship and with unique expertise, will increasingly contribute to invasive species management. Perhaps more importantly, we can foster awareness, offering our public landscapes as places of witness and learning during a time of remarkable environmental change.

**Acknowledgments**

The author thanks the Arnold Arboretum Hemlock Hill management team for its dedicated efforts: Julie Coop, John DelRosso, Peter Del Tredici, Bob Ervin, Susan Kelley, Alice Kitajima, James Papargiris, and Kyle Port.

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Richard Schulhof is deputy director of the Arnold Arboretum.

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# Silver Wins Gold

*Nancy Rose*

The tallest tree at the Arnold Arboretum isn't a majestic white pine or a venerable beech, it's a silver maple (*Acer saccharinum,* accession 12560-C). This stately 127-year-old specimen was recently measured at 126 feet (38.5 meters) tall. Its DBH (diameter at breast height) is currently 67 inches (170 centimeters); it takes three people, fingertip-to-fingertip, to encircle the trunk. This tree started its life at the Arboretum in the form of seeds (accessioned under the then-accepted name *Acer dasycarpum*) received from the nursery of Benjamin M. Watson in Plymouth, Massachusetts on June 1, 1881. Two other silver maples from accession 12560 also lived at the Arboretum for over 100 years, but specimen A was removed in 1982 and specimen B was removed late in 1985 after suffering major damage from the winds of Hurricane Gloria.

*Acer saccharinum* 12560-C displays the typical form of a mature silver maple: a massive trunk that soon divides into multiple upright limbs; thin, pendulous young branches curving up at the tip; and a rounded, spreading crown. The mature bark is characteristically gray-brown, ridged, and scaly. On this tree (and many other old silver maples) the curving bark scales appear to spiral up the massive trunk. The textured bark and impressive girth of *Acer saccharinum* 12560-C are irresistible to many visitors passing by on Meadow Road; no doubt this is one of the most frequently touched trees in the Arboretum.

*Acer saccharinum* is native to moist woods and river bottoms in much of the eastern half of the United States and a fringe of southeastern Canada. It can grow in drier soils, but may not be as successful or long-lived. Charles S. Sargent noted in *Silva of North America,* "On dry and elevated ground..." silver maple "...is not handsome...the habit is loose and unattractive...." No doubt the vigor, longevity, and stature of *Acer saccharinum* 12560-C is due in part to its ideal growing site in the moist, rich soil of the Arboretum's Meadow area.

Silver maple is often considered highly susceptible to storm damage, but *Acer saccharinum* 12560-C has survived many storms—including the devastating hurricane of 1938—with little damage. Along with other large, old trees at the Arboretum, this specimen is inspected regularly by staff arborists. In 2006, *Acer saccharinum* 12560-C was tested using radar imaging and wood density borings in addition to visual inspection. The tree proved to be amazingly sound for the most part, but the presence of some decay led to a bit of support work; two cables now connect several of the main vertical limbs, which should help reduce the chance of major limb breakage in high winds. As with most mature trees at the Arboretum, pruning on *Acer saccharinum* 12560-C is limited to removal of dead wood. To reduce soil compaction (from its many up-close admirers), mulch is spread in a wide swath around the tree and the soil is periodically loosened with a compressed-air tool.

Silver maple's popularity as a shade tree has waxed and waned over the decades. Its status as a native plant and its ability to grow quickly in a wide range of soil conditions gave rise to widespread planting in some eras. However, it has just as often been shunned for its irregular trunk habit, susceptibility to storm damage, extensive root system, and prolific seed production. Silver maple is not a good choice for small urban lots or narrow planting strips along streets, but in larger sites such as parks its leafy, shade-casting canopy is an asset. *Acer saccharinum* 12560-C certainly shows that silver maple can be a beautiful and impressive tree in the right setting.

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Nancy Rose is editor of *Arnoldia.*

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The ARNOLD ARBORETUM of HARVARD UNIVERSITY

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*Front/back covers:* The root of the matter: Exposed but functional roots of centuries-old English yews (*Taxus baccata*) flow over a ledge along the Rock Walk at Wakehurst Place, West Sussex, England. Professor Gary Johnson writes about the far less happy fate of many urban trees in his article on dysfunctional roots. Photo by Peter Del Tredici.

*Inside front cover: Tutti frutti:* Autumn brings ripening fruit of all sorts, including the nannyberry (*Viburnum lentago*) drupes shown here changing color from yellow to pink to midnight blue. Photo by Nancy Rose.

*Inside back cover:* Plant collecting can be quite an adventure, as Arboretum plant propagator John H. Alexander III describes in his plant profile of this impressively corky-branched sweetgum (*Liquidambar styraciflua*, accession 1248-79-B). Photo by Nancy Rose.

# Dysfunctional Root Systems and Brief Landscape Lives: Stem Girdling Roots and the Browning of Our Landscapes

*Gary Johnson*

**Consider this comparison of potential life spans for trees (Burns and Honkola 1990; USDA 1998)**

| | |
|---|---|
| ***Quercus macrocarpa*** **(bur oak), in upland site** | **250+ years** |
| ***Acer saccharinum*** **(silver maple), in riparian site** | **125+ years** |
| ***Acer negundo*** **(boxelder), in lowland site** | **100+ years** |
| ***Pinus banksiana*** **(Jack pine), in field site** | **80+ years** |
| ***Betula papyrifera*** **(paper birch), in northern lowland forest** | **65+ years** |
| **Tree planted in urban core street site** | **less than 10 years** |

That's a sobering thought—a tree with a normal life span of 65 to 250 years may live less than 10 years when planted in any American city's downtown landscape. Admittedly, that figure represents tree placement in the worst of our urban landscape sites: sidewalk cut-outs. These inhospitable planting sites are also known as tree coffins, tree burial mounds, or urban tree disposal units to frustrated urban foresters. When the mortality rate of downtown trees is compared to tree losses from Dutch elm disease, oak wilt, sudden oak death, and gypsy moth, it doesn't take too long to realize that there's an epidemic of urban tree loss going on and it's largely under the radar (Figure 1).

Another oft-quoted number is that the average urban residential tree lives for 30 to 35 years (Moll 1989). That life span is three times as long as a sidewalk tree, yet only half as long as a paper birch in its natural environment. Growing conditions in residential landscapes may not be quite as bad as sidewalk sites, but there are many natural and unnatural pressures on the trees that lead to briefer landscape lives. Residential landscape soils can be as stressful as downtown sites: poorly drained, outrageously alkaline, subjected to blends of every pesticide known to modern society, and compacted to such a degree that lawns may seem like nothing more than green concrete.

With few exceptions (perhaps tornadoes and a few diseases), there are no "angels of death" that descend and quickly kill trees in landscapes. More commonly, a multitude of predisposing stresses that occur in our highly altered urban landscapes combine to weaken trees over the years. Often, inciting events such as floods or hailstorms and/or contributing agents such as target cankers or wood boring insects complete the job for the majority of tree losses. Meanwhile, plant health care professionals attempt to determine the true causes of decline and death, and often the diagnoses are incomplete or incorrect because of the multiple offenders involved with the problem.

### Predisposing Factors and Tree Decline

When trees are chronically stressed (long-term drought, repeated defoliation, etc.), their normal reserves of chemical energy—primarily as complex carbohydrates—are slowly depleted. Each year as stressed trees come out of dormancy, they emerge in a weakened state due to this energy depletion and find it increas-


PHOTO BY GARY JOHNSON

**Figure 1. Trees in urban sidewalk sites are subjected to very unhealthy environments and live less than 10 years on average.**

ingly difficult to releaf, grow, and deal with the harsh realities of urban landscapes on a normal basis. It takes a tremendous amount of chemical energy to push out new leaves and shoots, recover from accidental wounds on the stems, or produce flowers and fruit.

As the tree's energy reserves continue to decline—and thereby affect the tree's ability to capture and store new energy through photosynthesis—the entire system is affected and the decline spiral to premature death begins. So decline in a sense refers to the tree's ability to deal with life's normal stresses. A tree in decline may die suddenly because of an event such as a cold winter with no snow cover, a short-term summer drought, or a defoliation from insects or hail. The other trees in the landscape tolerate the damage and survive, but the predisposed trees—those in decline—are unable to recover from the damage.

## Dysfunctional Root Systems as Predisposing Agents

Despite the fact that roots are seldom seen, dysfunctional root systems are too often the predisposing agents connected to tree health decline, and ultimately the reason why many urban landscape trees experience such brief lives. If the root system—approximately 50% of a tree's biomass—is not operating normally, the entire system will be abnormal. Abnormal is not always harmful, as seen in bonsai plants and trees growing on slopes. In bonsai plants, a restricted root system causes compacted growth in the rest of the plant system, but the system itself may be healthy and completely functional under most circumstances. In the case of a tree growing on a slope, the tree is anchored with a skewed and asymmetrical root system, but its overall health is not compromised even though the root system could certainly be considered abnormal.

PHOTO BY DAVE HANSON

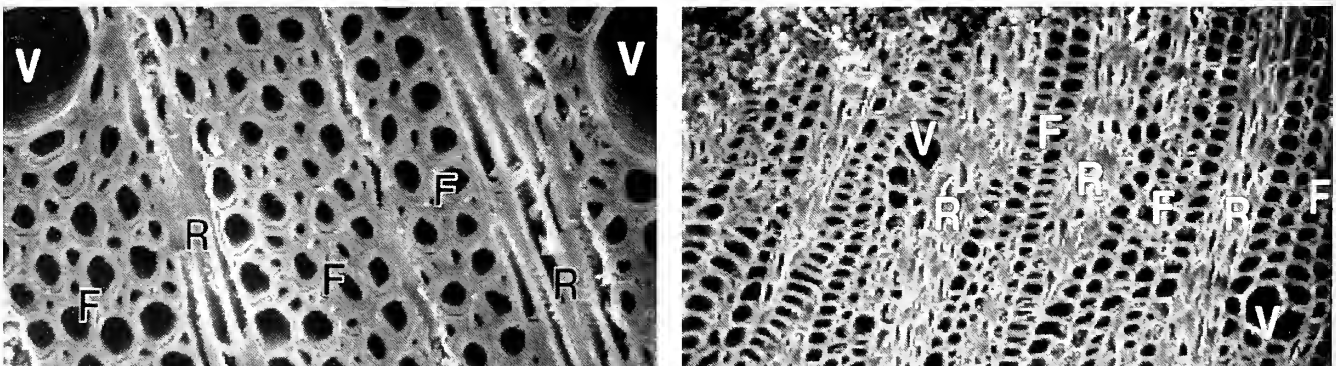
**Figure 2. With part of a stem girdling root removed, the compression to the tree's trunk is evident.**

But abnormal root systems that do affect the overall health or stability of the tree are considered dysfunctional. For example, when a container-grown tree with a severely pot-bound root system is planted, its rhizosphere does not occupy a large enough area to capture sufficient water and nutrients needed to support a normal sized tree without supplemental help. Dysfunctional root systems are also common on newly transplanted bare-root and balled-and-burlapped plants; these plants often lose 75% or more of their root systems during the harvest operation, resulting in transplant shock which may go on for several years until the root system regrows. And then there are stem girdling roots (SGRs), which create a root system so dysfunctional that it can end up killing the entire tree.

## Stem Girdling Roots as Predisposing Agents

Stem girdling roots are those roots that grow either partially or completely against the tree's stem and compress (girdle) the stem tissues (Figure 2). Xylem and phloem tissues in the stem become much narrower at the point of compression, impeding normal water movement and sap flow (Figure 3). This restriction affects energy reserves by directly and indirectly affecting photosynthesis. Trees become stressed and more vulnerable to secondary problems. For this reason, SGRs are considered to be primary predisposing agents in landscape tree decline and death.

Some of the first symptoms of SGR-impacted tree health include leaf scorch or leaf wilting on a tree when no other plants in the area are showing the same symptoms. There may be adequate moisture in the soil, but the tree's ability to move water throughout the system is thwarted by the areas of compression, i.e. the greatly reduced diameter of vessel elements. Soon, this water stress evolves into early leaf coloration and leaf drop in the summer, late leaf-out in the spring, and chlorosis or other




G. W. HUDLER, CORNELL UNIVERSITY

**Figure 3. Transverse views of normal Norway maple stem wood showing a healthy growth pattern (left), and malformed stem wood compressed by a stem girdling root (right). Water and nutrient transport in trees is negatively affected when tissue is malformed by compression. V = vessel element, R = ray, F = fiber tracheid. Both views are at the same scale.**

nutrient deficiency symptoms. If the stem compression becomes more severe, affecting 50% or more of the stem circumference, so do the symptoms. Trees will tend to suffer more damage during the winter seasons, in particular true frost cracks, cambial death, and dieback. In the latter stages of decline due to SGRs, trees usually suffer from severe stunting (very small leaves, annual twig growth of 1 to 2 inches or less) and significant defensive dieback. With so little vascular capacity left, affected trees may succumb completely from even a short-term summer drought (Figure 4).

Though often a slow-acting cause of death, SGRs can also cause tree death that is a bit more sudden and dramatic. The compressed areas of tree stems are structurally weak points and far too often are the points of failure during windstorms (Figure 5). For example, in severe windstorms that occurred in Minnesota in 1998, 73% of the lindens (*Tilia* spp.) that were lost in urban landscapes failed at compression points from SGRs, and most broke several inches below ground. This is a different type of predisposition but equally damaging to a tree's ability to grow, survive, and add to the quality of life.

PHOTOS BY GARY JOHNSON

**Figure 4. The middle littleleaf linden was in the last stages of decline from stem girdling roots at the time of this photograph. One year later it was dead.**

**Figure 5. Stem compression from SGRs located 4 or more inches below ground was the most common cause of urban tree failure in windstorms in Minnesota from 1995 to 2005.**

## More (Soil) is Not Always Better

Early SGR studies conducted by the University of Minnesota were in response to unexplained tree decline in urban areas. From 1994 through 1996, 220 declining and dying trees were diagnosed. In 81% of the cases, stem girdling roots were the only causal agents isolated. This figure closely paralleled data collected from a national survey of tree care professionals (Johnson and Hauer 2000). More specifically, these trees had been planted in the previous 12 to 20 years and had significant stem compression (greater than 50% of the stem circumference) from SGRs. In all cases, these SGRs were well below ground (from 4 to 14 inches)—out of sight, out of mind (Figure 6).

In landscape surveys conducted by the University of Minnesota Department of Forest Resources (1997 to 2004), five species of trees were investigated in three different communities. All trees were growing in public spaces: boulevards, schools, government centers, parks. Species surveyed included hackberry (*Celtis occidentalis*), littleleaf linden (*Tilia cordata*), sugar maple (*Acer saccharum*), 'Shademaster' honey locust (*Gleditsia triacanthos* 'Shademaster'), and green ash (*Fraxinus pennsylvanica*). Trees were randomly selected, evaluated for health and condition, and then examined for depth of soil over the main order roots and the presence of stem encircling roots (potentially conflicting roots within 6 inches of the stem) or stem girdling roots. The results were a bit depressing. Only 4% of the lindens, 8% of the ash, 10% of the maples, 15% of the honey locust, and 40% of the hackberries had their stems completely above ground. The rest of the sampled trees had from 1 to 12 inches of soil over the first main order roots and against the stems.

Non-destructive root collar examinations were performed on a total of 1,380 trees. The intent of these examinations was to determine the frequency of SERs (stem encircling roots—those potentially conflicting roots within six inches of the stem) and SGRs associated with different depths of soil (up to 12 inches) over the first main order roots. The excavations demonstrated that the deeper tree stems were buried in the soil or mulch, the more likely it was for them to have multiple layers of stem encircling and stem girdling roots. The increased presence of these problem roots showed up in trees beginning with as little as one inch of excess soil against the stem. In a nutshell, the more soil or pre-soil (organic mulches that will break down) that is piled over the root systems and against the stems, the more likely it is that trees will decline or fail due to multiple conflicts with SGRs (Figure 7).

PHOTOS BY GARY JOHNSON

**Figure 6. This SGR, located approximately 4 inches below ground, runs tangential to the tree trunk and is compressing 30% of the stem circumference.**

**Figure 7. As shown on this littleleaf linden, more layers of SGRs develop as the stem is buried deeper. Greater than 40% of the stem circumference of this tree was compressed by several layers of SGRs.**

## How SGRs Form

Observations from the 1,380 root collar examinations conducted during the species surveys and a separate nine-year planting depth study have led to the conclusion that stem girdling roots form in one of two ways: first, new roots regenerating from deeply buried main order roots, and second, from stem adventitious roots. When main order roots are buried too deeply, new woody roots that originate from them or any part of the buried root system tend to grow closer to the surface. It is speculated that this action is in response to a more desirable soil oxygen and moisture balance. As the roots reach the soil surface, an unpredictable percentage of them grow tangential to the tree stem or in some cases encircle the stem. For the next number of years (12 to 20, from our observations), the roots and stems expand in diameter, resulting in the ultimate confrontation between roots and stems.

Stem adventitious roots are also sources of SGRs. When a buried stem begins forming adventitious roots, many or most of those roots grow away from the stem in a radial fashion. As with new roots growing from main order roots, an unpredictable percentage of these adventitious roots do not grow radially but instead grow tangential to the stem or encircling the stem. The interface area between soil and stem appears to be a highly desirable area for stem root growth, perhaps because it provides an ideal balance of soil oxygen and moisture and is also the path of least resistance for root proliferation. The exact reasons for these root growth responses are still speculative, but it is clear that when tree stems are buried by a media that supports root growth, SGRs are highly likely to occur.

It's worth noting that stem girdling roots are a problem primarily with younger trees. As trees mature, their growth slows down dramatically, including the growth of trunk diameter and encircling roots. Because of this reduced growth—and the fact that there is often a relatively thick outer bark—stems of mature trees that then become buried by soil or organic matter are much less likely to develop stem girdling root problems. SGRs can still develop, but if they do they are less likely to result in the decline and death of the tree.

### How to Cause Stem Girdling Roots

If you want to cause the formation of SGRs, bury the tree stem with a medium that supports root growth. Here are some common ways SGRs occur:

- Excess soil is piled over the first main order roots during the growing and harvesting of balled-and-burlapped trees.
- Excess growing medium buries stems when container-grown trees are up-potted.
- Decayable organic mulch is piled high around tree stems in nurseries and landscape sites.
- Soil is piled against tree stems during construction regrading in landscapes.
- Trees are planted in a new landscape *before* final grading is completed.

There are so many different ways that stems can be buried—accidentally or with good intentions—that it is difficult to pinpoint the main source of the problem. One seemingly common cause is the act of burying trees rather than planting trees. Unfortunately, too many people still have the notion that trees are like fenceposts and need to be buried deep for stability. Not so.

In 2002, we conducted a planting depth study in collaboration with a large wholesale nursery. Bare-root birch (*Betula* spp.), ash (*Fraxinus* spp.), and crabapple (*Malus*) were potted up in number-ten containers at four different depths: 0, 2, 4, or 6 inches of soil over the first main order roots. On a weekly basis, each of the 240 trees was inspected for lean or windthrow from the containers. At the end of the four month study, all trees were well-rooted in the containers and the results of the study showed that all trees, regardless of depth, leaned at the same frequency and to the same degree. Planting tree stems deeper had absolutely no positive effect on tree stability. If newly planted trees are unstable, they may need temporary support from a guying or staking system, not entombment.

### Nine Years of Burial

In 2000, a long-term planting depth study was installed at the University of Minnesota's Urban Forestry and Horticulture Institute's research fields. Three hundred and sixty trees equally represented by two species (sugar maple [*Acer saccharum*] and littleleaf linden [*Tilia cordata*]) were planted at three depths: 0, 5, or 10 inches of soil over the first main order roots. All trees were planted in a complete, randomized block design in a .75 acre plot as unbranched, 2 to 3 feet tall liners. At three year intervals, one-third of the trees were harvested and had their root systems excavated with a supersonic air tool. Each year, mortality rates, growth rates (stem caliper), number of suckers produced, and percentage of dieback was recorded. In 2009, the final third of the original experiment will be harvested, but some interesting trends and

PHOTO BY GARY JOHNSON

PHOTO BY NANCY ROSE

**Figure 8. Bury the stem of littleleaf linden just 5 inches deep and a profusion of suckers will develop. These suckers eventually become SGSs (stem girdling suckers) as they grow in caliper and compress the tree's stem.**

significant data have already been revealed from the first two harvests, including:

- Planting sugar maples 5 to 10 inches too deep is an effective way to kill them. The mortality rates for the 0, 5, and 10 inch depths as of 2006 were 30, 40, and 65%, respectively.
- There was a significant positive relationship between placing 5 to 10 inches of soil against the stems and the frequency of SGRs on *Tilia cordata* in both the 2003 and 2006 harvests. *Acer saccharum* showed a trend in the same direction.
- *Tilia cordata* with stems buried in 5 inches of soil will produce masses of stem suckers, making the tree look more like a shrub. Sucker formation on *Tilia cordata* doesn't just ruin the tree's appearance, it can also cause premature failure. Stem girdling suckers (SGSs) are suckers that form prolifically and, when they enlarge in diameter, can girdle the stem vertically and horizontally (Figure 8).

## How Often do Trees Die from SGRs?

This question is likely unanswerable. When trees suddenly fail and die during a windstorm, diagnosing the problem below ground is not often considered. Weather alone is often blamed for the deaths, and the trees are hastily removed and replaced.

Research we conducted from 1995 through 2005 on tree failure in windstorms exposed a broader picture of the effects SGRs have on landscape trees. During this period over 1,500 "tree autopsies" were conducted on trees that had failed during wind-loading events in Minnesota. These trees were not those from the centers of severe wind-loading events such as straight-line winds or tornados. Rather, they were victims of thunderstorms or those at the edges of severe wind events.

From that data, the destruction and economic losses from premature tree failures due to SGRs were determined, and it was startling. The most common tree size category for boulevard tree failures was the 6 to 10 inch DBH (diameter at breast height, 4.5 feet above ground) range. Of those trees, 50% snapped off at compression points from SGRs at a depth of 4 or more inches below ground. The Achilles' heel was a compression root that couldn't even be seen because the stem was buried so deeply. The data also indicated that littleleaf lindens (*Tilia cordata*) were grossly affected by SGRs. Littleleaf linden ranked as the third most common species for total failure (the tree went down completely) during those years, and 73% of those trees snapped off at below-ground SGRs, almost the exact percentage of littleleaf linden that failed during the previously mentioned 1998 storms. After 11 years of data collection, the presence of SGRs and, more specifically, stem compression from SGRs that amounted to 50% or more of the stem circumference, emerged as the number one reason why urban trees failed in windstorms.

### What to Do, What to Do?

Prevention is the easiest and most effective way to eliminate the SGR problem in landscapes. Whether you are an urban forester, commercial landscaper, or home gardener, follow these steps to prevent or manage stem girdling roots:

- Don't plant container or balled-and-burlapped trees that are already buried too deeply. Assume there is too much soil over the first main order roots and remove that excess soil before planting a newly purchased tree (Figure 9).
- Plant trees, don't bury them. If stems aren't buried, it's not likely that SGRs will become a problem. They can still occur on correctly planted trees, but much less frequently than on buried trees.

PHOTO BY GARY JOHNSON

**Figure 9. Most containerized trees will have 2 to 6 inches of excess soil over the first main order roots and against the stem. Use a pruning saw to remove this excess soil before planting. Of 500 trees subjected to this treatment at the University of Minnesota's research nursery, there has been a 0.7% mortality rate in 2.5 years.**


**Figure 10. The fastest and most non-destructive method for conducting a root collar exam is with a supersonic air tool that blows the soil away without harming the roots. This root collar exam was accomplished in approximately fifteen minutes.**

- Don't pile mulch against stems. Organic mulch is basically pre-soil. Piling on mulch will result in a buried stem and a wonderful environment for SGRs to develop.
- When suspicious, investigate. Root collar exams are not all that difficult to perform (Figure 10). If you have a trowel and a wet-dry vacuum, you can perform a non-destructive root collar exam. If you find offending roots during the exam, remove them. Also, remove all that extra soil. If you do nothing, it will only get worse.
- If greater than 50% of the stem's circumference is severely compressed, it is probably best and safest to remove the tree and start over.

Treatments for affected trees are uncertain. If SERs (stem encircling roots) can be removed before compression begins, that's an excellent and effective treatment. If the SERs have become SGRs and if, during the course of removing SGRs, the stem is wounded, the long-term potential for recovery is uncertain. The study of stem girdling roots is a relatively young science and long-term data on treatment options and efficacy are not there. If 50% or more of the tree's trunk is severely compressed by the SGRs, and if the symptoms included dieback and severe stunt, the tree is probably beyond salvation. If that same tree is ten feet from a house or utility line, then the risk of leaving the tree is unacceptable. Buy a new tree. Remove the excess soil over the root system. Plant it with the trunk fully exposed. Mulch the roots, not the trunk. These steps will put your new tree well on the way to a long, healthy life.

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# Wake Up and Smell the Ginkgos

*Peter Del Tredici*



**An allée of ginkgos, about 100 years old, on the campus of Tokyo University.**

**Ginkgo has unmistakable fan-shaped leaves.**

*Ginkgo biloba* is one tree that most Americans—even those with little knowledge of botany—can recognize. There are two reasons for this: first, its fan-shaped leaves are highly distinctive and impossible to confuse with any other tree; and second, it is widely cultivated as a street tree in many urban areas throughout much of the United States. Because of its environmental adaptability, its resistance to pests and diseases, and its general tolerance of inhospitable growing conditions, ginkgo is experiencing a spike in popularity as evidenced by the long rows of them that are showing up in commercial and municipal landscape projects across the country. In this regard, Americans are following the pattern set in Japan where ginkgo accounts for 11.5% of all the street trees growing in that country—more than any other single species (Handa et al. 1997).

As well as gaining in popularity, ginkgo has also been experiencing a surge in attention from the scientific community, particularly from the Chinese, for whom the tree has become a national symbol of their botanical heritage. The pur-

**One of the old ginkgos at Bai Yuan village in Wuchuan County, Guizhou Province. Note the epiphytic ferns growing on its trunk.**

pose of this article is to acquaint the reader with some of this new information about the plant's unique evolutionary history as well as its ecological role as a plant teetering on the brink of extinction in the wild.

## Ginkgo's Homeland

Questions about the extent of *Ginkgo biloba*'s native range in China—or if native populations even exist at all—have been the subject of debate among botanists for well over a hundred years (Del Tredici et al. 1992, Li et al. 1999). The conflict has only recently been resolved with the help of DNA analyses (Fan et al. 2004, Shen et al. 2005, Wei et al. 2008) which have demonstrated that isolated ginkgo populations located in southwest China, especially around the southern slopes of Jinfo (or Golden Buddha) Mountain in Chongqing Province (28°53' N; 107°27' E), possess a significantly higher degree of genetic diversity than populations in other parts of the country, indicating native status. The area has a mesic, warm-temperate climate with a mean annual temperature of 16.6°C (62°F), and a mean annual precipitation of 1,185 millimeters (47 inches), with ginkgos growing mainly between 800 and 1,300 meters (2,625 and 4,265 feet) elevation (Li et al. 1999).

In addition to the genetic evidence, there is ecological and cultural evidence which suggests that these populations are wild. Ecological work in Chongqing Province, as well as in adjacent parts of Guizhou Province (Xiang et al. 2006), has identified dozens of small populations of ginkgos which can be considered either to be wild trees growing in the midst of native forest or the remnants of wild populations that have lost their forest context. These ginkgo populations occupy land that usually measures a few hectares at most, and they are surrounded by small villages whose residents practice subsistence agriculture. In areas where livestock has been excluded, spontaneous ginkgo seedlings and saplings are common in the forest understory.

In the cultural realm, much of northern Guizhou Province has been settled over the past three hundred years or so by people of Miao descent who, unlike the Chinese of Han descent, have no tradition of consuming ginkgo nuts and therefore have no history of cultivating the tree. While this situation began to change around 1980, cultivation by humans cannot explain the many large ginkgos scattered throughout the area that are *not* growing near temples. (Ginkgos found near temples are usually human cultivated.) From the ecological/botanical perspective, wild populations of ginkgo tend to show a number of characteristics which distinguish them from populations of cultivated trees. These differences are summarized in Table 1 (page 14).

In addition to the populations around Jinfo Shan, a second area of high genetic diversity for ginkgo occurs in eastern China, in Zhejiang Province, primarily on the slopes of Tian Mu Shan, a sacred mountain with many Buddhist shrines and temples, located about 100 kilo-

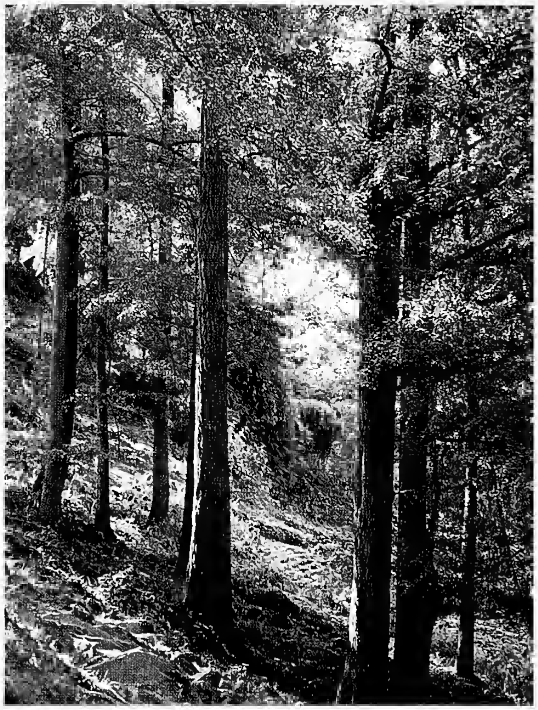
**The agricultural terraces in the vicinity of Shan Jiang village in Wuchuan County, Guizhou Province. Over the past several hundred years, these have replaced the mixed conifer–broadleaf evergreen–deciduous forest that originally grew there.**

meters (62 miles) west of the city of Hangzhou. This area, which was the site of one of the first nature reserves in modern China, has long been considered by botanists to be one of ginkgo's wild locations, but only recently—through the work of Wei Gong and her colleagues (2008) at Zhejiang University—has the distinct genetic ancestry of this population been established.

In contrast to its very limited distribution as a wild plant in China, ginkgo is widely cultivated throughout the temperate world, across a broad range of moisture, temperature, and topographic gradients. In China, the tree can be cultivated between 25° and 42° N latitude where minimum winter temperatures can reach -32°C (-26°F) and maximum summer temperatures 42°C (108°F) (He et al. 1997). Detailed phenological studies in Japan over a fifty year period by Matsumoto and his colleagues (2003) have determined that spring bud break in ginkgo occurs 40 days earlier in the extreme south of the country (30° N latitude) than it does in the far north (43° N latitude) and that autumnal leaf drop happens about 40 days later, making for an effective vegetative growing season range of 170 to 260 days across 13° of latitude. It's no wonder that ginkgo is touted as a paragon of environmental adaptability.

## Ginkgo Sexuality

*Ginkgo biloba* is a dioecious species, with separate male and female trees occurring at roughly a 1:1 ratio. Ginkgo shows a long juvenile period, typically not reaching sexual maturity until approximately 20 years of age. Male (microsporangeate) and female (ovulate) sex organs are produced on short shoots in the axils of bud scales and leaves. The male catkins emerge before the leaves and fall off immediately after shedding their pollen to the wind. Pollination



**(Left) A portion of the stand of wild ginkgos at Bai Yuan village in Wuchuan County, Guizhou Province. Note the tall, straight form of the trees indicting that they grew from seed. (Below) Cultivated ginkgos in this orchard show the typical shorter, wide-spreading form.**

## Table 1. The botanical and ecological characteristics of remnant natural ginkgo populations versus cultivated ginkgo populations in China

| Remnant natural ginkgo populations | Cultivated ginkgo populations |
|---|---|
| Sex ratio should be more or less balanced with males at a 1:1 or greater ratio than females. | Skewed sex ratio—overwhelmingly female. |
| Trees are growing mixed in with numerous other species that are native to the surrounding forest. | Few other species growing with ginkgo; if other trees are present, they are typically cultivated for some specific purpose. |
| The growth form of most of the trees is single stemmed with relatively few lower branches (indicative of having grown up from seed). | Low-branched growth form of female trees (indicative of vegetative propagation by cuttings or grafts). |

typically occurs anywhere from mid-March in areas with mild winters to late May in areas with severe winters.

The ovules on female trees are 2 to 3 millimeters (about .1 inch) long at the time of pollination, and are produced mostly in pairs at the ends of long stalks. When the ovule is receptive, it secretes a small droplet of mucilaginous fluid from its apical tip which functions to capture airborne pollen. Retraction of this droplet at the end of the day brings the pollen into the pollen chamber. Once inside the ovule, the pollen grain germinates to release the male gametophyte which attaches itself to the inside wall of the ovule. Here it undergoes a four- to five-month-long period of growth and development which is supported by the tissues of the expanding ovule (Friedman and Gifford 1997).

Ginkgo ovule with pollination drop at tip.

Sometime in September or October, depending on the latitude, the development of the male gametophyte culminates with the production of a pair of multiflagellated spermatozoids. In one of nature's most dramatic moments—first described by the Japanese botanist Hirase in 1896—the two microscopic sperm cells must swim, propelled by about one thousand tiny flagella, a full millimeter across a fluid-filled channel to reach the waiting egg cell, where only one can claim the prize. Contrary to what has often been written, fertilization takes place while the ovules are still on the tree and embryo development begins posthaste. The embryo length may range from less than 1 millimeter to 5 millimeters (.04 to .2 inch) at the time of seed drop, which can occur anywhere between September and November, depending on local weather conditions. Once the seeds fall to the ground, the embryo continues to develop until the arrival of cold temperatures (below 10°C [50°F]), at which point elongation stops. With the onset of warm weather in the spring, the embryo resumes its growth, which culminates in germination in late spring or early summer.

## Ginkgo Nuts

It is now generally accepted that ginkgo was first cultivated by the Chinese not for religious purposes but rather for its edible seeds, which at maturity are relatively large and nutritious. The seed, as it falls from the tree, consists of an embryo embedded in the tissue of the female gametophyte surrounded by a thick seed coat. The intact seed coat consists of a soft, fleshy outer layer (the sarcotesta), a hard, stony middle layer (the sclerotesta), and a thin, membranous inner layer (the endotesta).

The seed, devoid of the famously smelly sarcotesta, is generally referred to as the "nut" with dimensions that range from 19 to 30 millimeters by 11 to 14 mm (approximately 1 by .5 inch). Over the past several hundred years, Chinese horticulturists have selected scores of cultivars which produce large and/or distinctively shaped nuts. Large plantations of these select ginkgo cultivars are common throughout eastern and central China.

The putrid odor often associated with ginkgo seeds typically develops only after they have lain on the ground for several days and have begun to rot. The smell is due to the presence of two volatile compounds in the sarcotesta—butanoic and hexanoic acids (Parliament 1995). The sarcotesta also contains numerous fatty acids and phenolics, one of which, ginkgoic acid, is known to cause allergic contact dermatitis in some people (Kochibe 1997).

## A Common-Garden Experiment

The timing of pollination, fertilization, seed abscission, and germination in ginkgo are strongly affected by the latitude of cultivation as well as by local climate conditions. In the

Mature ginkgo seeds on a tree at Forest Hills in Boston, Massachusetts.

fall of 2002, I undertook a series of common-garden experiments to explore the relationship between the timing of pollination and the timing of germination in ginkgo by cultivating in a common location seeds produced by trees from two different latitudes. One lot consisted of about 500 cleaned seeds from trees that were being cultivated for nut production, which I purchased on September 22, 2002 at Tuo Le Village, Panxian, in southern Guizhou Province, China, (25°36' N). For comparative purposes, I collected ginkgo seeds on October 31, 2002 from beneath a number of trees growing at the Forest Hills Cemetery in Boston, Massachusetts (42°17' N).

When sown in the Arnold Arboretum's heated greenhouse (20°C [68°F]), the Guizhou seed began germinating on November 12—approximately 58 days after abscission—while the Boston seed did not begin germinating until January 6—some 67 days after abscission. Assuming approximate pollination dates of March 24 for the Guizhou seed and May 17 for the Boston seed, the total time elapsed from pollination to germination under continuously warm greenhouse conditions was 233 days and 234 days respectively, a remarkably confluent result given their different latitudinal origins.

A second striking result of the experiment was that only 15% of the uncleaned, outdoor-sown Boston seed germinated versus 72% germination for a replicate lot of one hundred seeds washed clean of their smelly sarcotesta. The fact that cleaned ginkgo seeds germinated at statistically significantly higher percentages than those with their sarcotesta intact suggests that animals which consume the seeds—provided they do not crush the thin-shelled nut—might play a role in promoting successful seedling germination (Rothwell and Holt 1997, Del Tredici 2000). The specific mechanism whereby the sarcotesta reduces the germination capacity of ginkgo seed is currently unknown, but the exclusion of light is probably not an explanation given that William Friedman (1986) has shown that female gametophytes with all their seed coats intact are capable of photosynthesis.

### Ecological Implications

The results of my experiment indicate that aspects of ginkgo's sexual reproduction cycle are strongly influenced by temperature (Del Tredici 2007). For seeds left outdoors immediately following seed drop, the timing of their pollination influences the timing of their germination the following spring which, in turn, influences their chances of surviving the following winter. In warm-temperate climates—such as Guizhou Province—ginkgo seeds are shed in late summer or early fall, and the embryo is able to make considerable growth during the mild weather that follows. In cold-temperate climates—such as Massachusetts—seeds are shed much later in the season and the cooler temperatures of mid to late fall delay embryo development until warm weather arrives the following spring. This differential timing of embryo maturation means that seeds produced by trees growing in warm-temperate climates will be ready to germinate during the favorable conditions of

**Table 2. A comparison of the phenology of the sexual reproduction cycle of *Ginkgo biloba* growing in Guizhou Province, China versus Massachusetts, USA.**

| Location | Pollination | Seed Abscission | Outdoor Germination |
|---|---|---|---|
| Guizhou, China (25° North latitude) | mid-March to early April | mid-September | mid-March |
| Massachusetts, USA (42° North latitude) | mid-May | late October to early November | mid- to late June |

mid to late spring (March through early June), while those in cold climates will not germinate until later in the summer (late June through early August), when conditions for establishment are less favorable and the seedlings have less time to accumulate carbohydrates before going into winter dormancy.

In this regard, it is worth noting that in Tuo Le Village in Guizhou Province, ginkgo seeds sown outdoors would typically germinate in March, while the same seed sown outdoors in Boston did not germinate until May 29, approximately two months later. From an ecological perspective, the complex phenology of ginkgo's sexual reproduction cycle may well have constrained the species' ability to migrate, independently of humans, into cold-temperate regions with short growing seasons, and probably accounts for its limited warm-temperate distribution as a wild or semi-wild tree in the mountains of central and eastern China (Li et al. 1999, Xiang et al. 2006, Wei et al. 2008). Table 2 presents a comparison of the phenology of *Ginkgo biloba*'s sexual reproduction cycle in Guizhou Province, China versus Massachusetts, USA.


NANCY ROSE

A fossilized leaf of *Ginkgo yimaensis*.

**Evolutionary Implications**

The fossil species *Ginkgo adiantoides* existed in the northern hemisphere from the Upper Cretaceous through the Middle Miocene (roughly 70 to 12 million years ago) and is considered by paleobotanists to be morphologically indistinguishable from the modern *G. biloba* (Tralau 1968). Most of the ginkgo fossils from this time period in Europe and North America come from sites above 40° N latitude that were originally disturbed stream margins and levee environments, and typically occurred in association with a consistent set of riparian plants, including *Cercidiphyllum*, *Metasequoia*, *Platanus*, and *Glyptostrobus* (Royer et al. 2003).

Fossils of a new *Ginkgo* species (*G. yimaensis*) from Liaoning Province, China, recently described by Chinese paleobotanists Zhou and Zheng (2003), have pushed the lineage of *G. biloba*-type ovules back to the Lower Cretaceous, about 120 million years ago. This suggests the possibility that the seeds of *G. yimaensis* could have possessed a temperature-sensitive, developmental-delay mechanism similar to that of *G. biloba*. Such a trait would have allowed this species to reproduce successfully in regions of the northern hemisphere that were undergoing dramatic cooling after a long period of warm conditions. Indeed, Zheng and Zhou (2004) have proposed that "the drastic climatic changes during the Upper Jurassic and Lower Cretaceous, around 140 to 150 million years ago, were responsible for the transformation of the ovulate organs of the *G. yimaensis* type into the modern *G. biloba* type," including the development of short shoots, the reduction and protection of ovulate organs, and the production of larger seeds. *Ginkgo biloba*'s temperature-sensitive, embryo-development-delay mechanism could well have been another climate-induced Cretaceous innovation—an evolutionarily primitive but ecologically functional form of seed dormancy.

### Ginkgo Seed Dispersal

Researchers studying various ginkgo populations in Asia have reported a number of animals feeding on, and presumably dispersing, the malodorous, nutrient-rich seeds. In China, dispersal agents include two members of the order Carnivora: the leopard cat (*Felis bengalensis*, family Felidae) in Hubei Province and the masked palm civet (*Paguma larvata*, family Viveridae) in Zhejiang Province (Del Tredici et al. 1992). In Japan, where ginkgo was introduced from China some 1,200 years ago, another member of the order Carnivora, the raccoon dog (*Nyctereutes procyonoides*, family Canidae), has been documented feeding on ginkgo seeds, and its droppings have been found to contain intact seeds which germinated the following spring (Rothwell and Holt 1997).

The existence of three reports of omnivorous members of the Carnivora consuming whole ginkgo seeds suggests that the rancid smelling sarcotesta may be attracting primarily nocturnal scavengers by mimicking the smell of rotting flesh—in essence acting as a carrion-mimic (Del Tredici et al. 1992). The fact that ginkgo seed germination percentage is enhanced by removal of the sarcotesta lends further credence to this theory.

### Ancient Dispersal Agents

In 2002, Zhou and Zhang reported the discovery in China of a long-tailed bird (*Jeholornis* sp.) from the Early Cretaceous with a large number of ginkgo-like seeds in its crop. This provides direct evidence that early birds potentially *could* have been involved in seed dispersal activities, although the seeds' intact nature suggests they were destined for digestion in the gizzard. In general, *Ginkgo biloba* seeds do not fit the typical profile of a fruit dispersed by modern birds (van der Pijl 1982).

Prior to the discovery of *Jeholornis*, most of the speculation about Cretaceous ginkgo dispersal agents centered on dinosaurs, based primarily on their temporal overlap. If dinosaurs were involved with the dispersal of ginkgo seeds, it probably would have been carrion feeding scavengers, with teeth adapted to tearing and swallowing flesh, rather than herbivores with grinding dentition that would have crushed the thin-shelled seeds. At any rate, any connection between dinosaurs and ginkgo seed dispersal is, at best, conjecture based on circumstantial evidence.

**A spontaneous ginkgo sapling growing out of a karst rock formation at Niu Tang village in Wuchuan County, Guizhou Province.**

### Ginkgo's Future

By rights, *Ginkgo biloba* should have gone extinct long ago along with all of its close relatives. The fact that it did not provides botanists with a unique window on the past—sort of like having a living dinosaur available to study. As remarkable as ginkgo's evolutionary survival is, the fact that it grows vigorously in the modern urban environment is no less dramatic. Having survived the climatic vicissitudes of the past 120 million years, ginkgo is clearly well prepared—or, more precisely, preadapted—to handle the climatic uncertainties that seem to be looming in the not too distant future. Indeed, should the human race succeed in wiping itself out over the course of the next few centuries, we can take some comfort in the knowledge that the ginkgo tree will survive.


This ginkgo, growing as a street tree in New Brunswick, New Jersey, shows the species' outstanding yellow fall color.


**True survivors, these severely pruned ginkgos on a Tokyo street are growing in spite of cramped planting spaces and air pollution.**

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# The Fruits of Autumn

*Nancy Rose*

Autumn is prime time for observing a great array of maturing fruits on woody plants. Fleshy types like pomes, drupes, and berries are often brightly colored and highly noticeable at this time of the year. Fall-fruiting trees and shrubs—viburnums (*Viburnum* spp.), crabapples (*Malus* spp.), mountain ash (*Sorbus* spp.), beautyberries (*Callicarpa* spp.), and hollies (*Ilex* spp.), to name a few—provide a showy display, especially as deciduous leaves begin to fall. In addition to adding color to the landscape, fall-fruiting plants also serve as an important food source for birds.

Other fruiting structures seen in autumn are less showy but still interesting. Pods, samaras, and inflated capsules are some of the diverse forms to be seen. As anyone who has ever tried to learn woody plants knows, fruits often provide the key for correct identification.

Here are some examples of fruits to look for this fall:

ALL PHOTOS BY THE AUTHOR EXCEPT AS INDICATED

**Grape honeysuckle, (*Lonicera reticulata*)**

ROBERT MAYER

**Common persimmon (*Diospyros virginiana*)**

The word "berry" is often used to describe just about any rounded, juicy-looking fruit, but botanically speaking a ***berry*** is a fleshy, indehiscent (not splitting open at maturity) fruit that develops from a single pistil and contains one or multiple seeds. A number of woody plants bear berries including vines like *Vitis* (grape), *Actinidia* (kiwi), and *Parthenocissus* (Virginia creeper, Boston ivy). Both vine and shrub species of *Lonicera* (honeysuckle) have berries, often attractive bright red ones. Common persimmon (*Diospyros virginiana*) is one of few large trees that produces true berries; look for the golden orange, globe-shaped fruits persisting on branches through late autumn.

MICHAEL DOSMANN

**Clockwise from upper left:**
**Donald Wyman crabapple (*Malus* 'Donald Wyman')**
**Korean mountain ash (*Sorbus alnifolia*)**
**Chinese sand pear (*Pyrus pyrifolia*)**
**Black chokeberry (*Aronia melanocarpa*)**

A ***pome*** is a fleshy, indehiscent fruit that develops from a compound ovary set within a fleshy floral cup or tube. Multiple seeds are found in the core of the fruit. Pomes are the fruits of a number of well-known genera in the rose family (Rosaceae), including *Malus* (apple, crabapple), *Sorbus* (mountain ash), *Pyrus* (pear), *Crataegus* (hawthorn), *Aronia* (chokeberry), *Cotoneaster*, and *Pyracantha* (firethorn).

**Clockwise from upper left:**
**Sapphireberry (*Symplocos paniculata*)**
**American cranberrybush (*Viburnum trilobum*)**
**Purple beautyberry (*Callicarpa dichotoma*)**
**Winter Red winterberry (*Ilex verticillata* 'Winter Red')**

Another common berrylike fruit found on woody plants is the ***drupe.*** A drupe is a fleshy, indehiscent fruit containing a single seed which is surrounded by a stony endocarp. Many of the showiest fall-fruiting shrubs and small trees bear drupes, including viburnums (*Viburnum* spp.), beautyberries (*Callicarpa* spp.), dogwoods (*Cornus* spp.), and hollies (*Ilex* spp.). Many delicious drupes are found in the genus *Prunus* including cherries, plums, and peaches.

A ***hip*** is a pomelike structure formed by a fleshy hypanthium (a cup-shaped structure formed from fused floral parts at the flower's base) which surrounds multiple achenes (small, dry fruits containing single seeds). The term hip is used specifically for roses (*Rosa* spp.). The large, scarlet hips of *Rosa rugosa* (left) give it one of its common names: beach tomato.

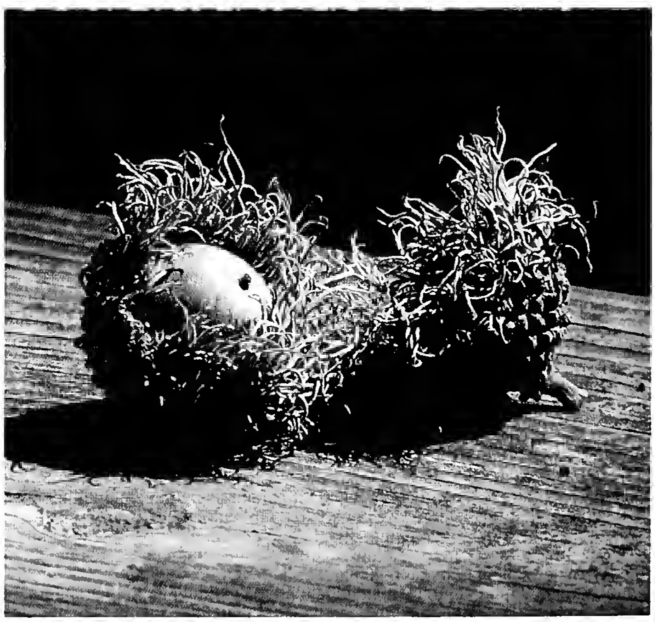
***Aggregate*** fruits are composed of numerous small fruits that develop from multiple pistils in a single flower. Raspberry fruits, for example, are aggregates of drupelets. Magnolias produce conelike aggregates of follicles; at maturity, each follicle opens to reveal a seed covered by a brightly colored aril (fleshy seed coat) and attached by a stretchy thread. The fruit of a hybrid sweetbay magnolia (*Magnolia virginiana*) is seen here (right).

***Multiple*** fruits develop when the fruits derived from numerous individual flowers in an inflorescence fuse together to form what appears to be a single fruit. Pineapple (*Ananas* spp.) and mulberry (*Morus* spp.) are examples of multiple fruits. The unique, baseball-sized green fruits of osage orange (*Maclura pomifera*), shown at left, are also multiple fruits.

Built to be carried by the wind, ***samaras*** are winged achenes. The papery wing part of the structure takes variable forms; for example, in elms (*Ulmus* spp.) the wing encircles the achene, in ash (*Fraxinus* spp.) the wing extends like a paddle from a single achene, and maples (*Acer* spp.) bear paired (two-winged) samaras that usually split apart when they mature and fall. The size and wing angle of maple samaras provide a good identification key among species.

**Three-flowered maple (*Acer triflorum*) bears triplets of two-winged samaras. Another samara variation—a single achene dotted in the middle of the wing—is seen in this red-fruited form of the notoriously seedy tree-of-heaven (*Ailanthus altissima* f. *erythrocarpa*).**

Exclusive to oaks (*Quercus* spp.), ***acorns*** are hard-shelled seeds (nuts) nested in cup-shaped involucres. Acorn size and degree of involucre extension on the nut provide a good clue when trying to identify oak species. Noted for their extensively fringed involucres, the acorns of bur oak (*Quercus macrocarpa*) are seen in this image.

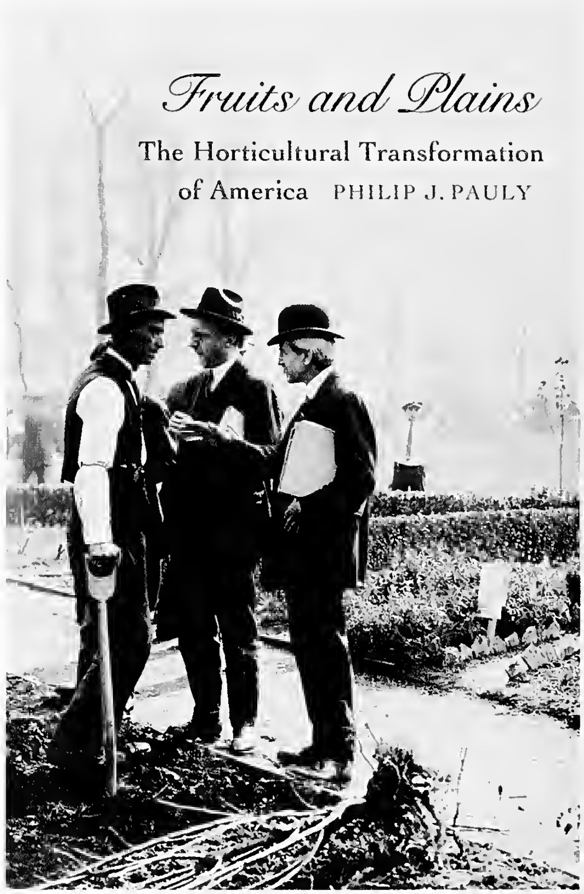


Many plants bear seed-holding ***capsules*** but the forms of these dry, dehiscent (splitting open at maturity) fruits vary widely. The inflated, paper-lantern-like capsules found on golden rain tree (*Koelreuteria paniculata,* left) turn from green to tan—sometimes with a blush of pink—and often persist well into the winter. Also shown (right) are the small, rounded capsules of summersweet (*Clethra alnifolia*), filled with numerous tiny seeds.

***Pods*** are dry, dehiscent or indehiscent fruits that contain seeds. The legume family (Fabaceae) is well-known for producing pods as its fruiting structure. Woody plants in this family include honey locust (*Gleditsia* spp.; pods of *G. triacanthos* pictured), Kentucky coffee tree (*Gymnocladus dioicus*), wisteria (*Wisteria* spp.), and silk-tree (*Albizia julibrissin*).

# Book Review: *Fruits and Plains: The Horticultural Transformation of America*

*Thomas J. Schlereth*




*Fruits and Plains: The Horticultural Transformation of America*
Philip J. Pauly. Harvard University Press, Cambridge, Massachusetts, 2007. 336 pages.
ISBN-13: 978-0-674-02663-6

Many readers, at first glance, may find this book's main title a bit puzzling. What do pomology and plains have in common? The author intends this minor mystery but he does provide several clues in his introduction and the nine chapters that follow. I must admit I had not completely grasped his full meaning until reaching his closing chapter where a complete explanation is found. Out of respect for the author's book-craft, I too will leave this resolution for the end.

Long before arriving at the book's conclusion, I knew that what I was reading was a provocative and persuasive re-interpretation of several interrelated research fields; namely American plant pathology, biogeography, and cultural history. Moreover, it was a brilliant and novel re-interpretation of nineteenth-century American history using American cultivated plants as a primary resource.

Beginning with the introduction ("Taking the History of Horticulture Seriously"), Philip J. Pauly launches his methodology of interconnecting American horticultural history with American cultural history. This fruitful hybrid yields many useful insights, one of which is how our perpetual indulgence in claiming to be exceptional in our nationhood can also be found, repeatedly, in our horticultural history.

As one might expect of a cultural historian, Pauly frequently reminds us of a more universal issue evident in all of our interactions with the natural word: that is, whether we are home gardeners or plant scientists, landscape architects or arboretum directors, USDA bureaucrats or environmental historians, we all *culture* nature. When we *horti*-culture nature, its plants become, to various degrees, natural artifacts subject to various forms of human artifice.

Hence there are two general perspectives that characterize Pauly's achievement. First, one can see it as a revisionist interpretation in American Character historiography, a subfield in interdisciplinary American Studies scholarship since the 1950s. Second, the book is also a carefully documented survey of how Americans, despite their professed objectivity (scientific and otherwise), historically brought various types of cultural baggage (political and economic; regional and religious; professional and personal) to their several centuries of interactions with other living organisms and particularly with plants and plant pests.

To document this dual approach—explaining both American history and the history of American horticulture—Pauly analyzes the motives and actions of a cadre of Americans who cultured nature in diverse ways and often for divergent purposes. Many will be familiar to *Arnoldia* readers: for instance, Thomas Jefferson, Frederick Law Olmsted (Senior and Junior), Charles Hovey, Charles S. Sargent, Horace J. McFarland, Jens Jensen, and Liberty Hyde Bailey. Also studied are less well-known but influential plant culturists such as David Hosack, Beverly T. Galloway, William Saunders, Ephraim Bull, Charles T. Simpson, Daniel Simberloft, Charles L. Marlatt, and Katherine Bates.

With these *dramatis personae,* Pauly explores several additional subthemes. In chapter one, for example, he stages Thomas Jefferson as an early exemplar of American horticultural chauvinism, particularly in his *Notes on the State of Virginia* (1785, 1787) written, in part, to answer Guillame Raynal's *Historie de deux Indes* (1770), a European best seller that claimed the New World's flora, fauna, climate, as well as its native peoples and even its recent emigrant Europeans were all in a state of continual anthropological and biological degeneracy.

In chapter one, he also provides early definitions for terms readers will find throughout the book: first, a vocabulary of " N-words": nature, natural, naturalism, nationalism, and nativism; second, a litany of "C-words" that no cultural historian can do without: culture, cultural, and culturalism, plus related "culture" nomenclature that Pauly uses frequently.

Chapter two initiates another important book topic—the tensions and controversies (diplomatic, military, economic, political, and scientific) that have been factors in the history of plant introductions and plant pests all arriving in increasing numbers to a supposedly virgin land. The first culprit is the Hessian fly (*Mayetiola destructor*) which Pauly discusses as "America's first invasive" as well as "the nation's first postcolonial public scientific issue."

This initial late eighteenth-century debate over invasives and introductions resurfaces in several places throughout the book in its survey of nineteenth- and early twentieth-century arguments over exotic vs. native species as well as the horticultural practices (organic vs. chemical) in solving plant pathologies. Chapters five and six, cleverly named by Pauly as "Immigrant Aid: Naturalizing Plants in the Nineteenth Century" and "Mixed Borders: A Political History of Plant Quarantine," document the local, regional, and national aspects of these prolonged conflicts, many of which are still contested issues in present-day horticulture.

**Massachusetts Gypsy Moth Commission employees scraping gypsy moth egg masses off of a notable elm in Malden, Massuchusetts in the early 1890s. From *The Gypsy Moth* (1896), Edward H. Forbush and Charles H. Fernald.**

**5544 Wellesley College from Hunnewell's Gardens.**
Copyright 1901 by C. H. Graves.

In chapter six's subtitle, another Pauly interpretive emphasis appears. He recognizes that plants have politics in the sense that people culture plants with political (and other) motives. For some readers, however, his extremely detailed accounts of the political infighting among plant importers and breeders, university science faculty and nursery growers, government officials and departments as well as plant collection administrators may prove too tedious a tale to stay with until the chapter's conclusion.

Turning back to chapters three and four, respectively titled "The Development of American Culture, with Special Reference to Fruit" and "Fixing the Accidents of American Natural History: Tree Culture and the Problem of the Prairie," we find major clues to the book's main title as well as nineteenth-century America's fascination with pomology. It also introduces us to Midwestern horticultural biogeography, one of the book's three such foci—the other two being the country's northeastern corridor and the anomaly of the "horticultural construction" of Florida. The latter history turns out also to have interesting ties to northeastern plant culturists, as diverse as diplomat Henry Perrine, proprietary town builder and citrus magnate Henry Stanford, railroad and luxury hotel entrepreneur Henry Flagler, plus the USDA's David Fairchild (after whom the Fairchild Tropical Botanic Garden in Coral Gables is named), and America's most famous nineteenth-century woman abolitionist and author, Harriet Beecher Stowe. (Interestingly, author Pauly grew up in Ohio, one gateway to—as well as an important part of—the Midwest's horticultural hearth.)

Pauly's chapter nine (titled "Culturing Nature in the Twentieth Century") is unfortunately only a 28-page introduction to what might have been a larger *Fruits and Plains* or a second volume as its sequel. Here we find important developments such as the founding, at long last, of a National Arboretum in 1927, and the influential Midwestern prairie restoration by James Curtis and Aldo Leopold at the University of Wisconsin Arboretum in 1936. Also treated are the importance of the American Society for Horticultural Science and the enormous multiplication of garden clubs nationwide, plus a brief survey of "How Pests Became Invasive Species." Given its brevity, the chapter is a tantalizing but selective overview of an extremely complicated and conflicted century in American horticultural history.

In beginning his final chapter, Pauly references the poetry, travels, and academic career of Katherine (Kitty) Bates, an undergraduate and later a lifelong English professor at Wellesley College. Pauly muses that Bates, both as student and teacher on the Wellesley campus, could gaze across Lake Waban and see the highly cultured conifer topiary garden and arboretum at the estate of H. H. Hunnewell, one of New England's most well-known horticulturists and a generous benefactor of the Arnold Arboretum. In 1893, Professor Bates took a combined pleasure/professional trip to teach a summer-school course at Colorado College. En route she visited Chicago's World's Columbian Exposition designed in part by Frederick Law Olmsted, Sr., travelled through Kansas prairies and wheat fields, and climbed Pikes Peak for a majestic view of the seemingly never-ending Great Plains. Atop that mountaintop, she reflected on all that she had seen on her westerning odyssey. On the peak, the beginning words of a poem also came to her. It was published in 1895 by *The Congregationalist* as its Fourth of July number. New Yorker Samuel A. Ward set the poem to music and we have sung it ever since, a geographical and horticultural counter point to Francis Scott Key's militant navel ode whose melody Key borrowed from a British drinking song.

Professor Pauly deploys Professor Bates's verses (obviously "the fruited plain") to announce his final chapter titled "America, The Beautiful." More an epilogue than a chapter, it serves as his own anthem to his subject's meaning in both American horticultural history and American cultural history. He concludes by noting that the Bates metaphor provided him with "a kind of professional and personal perspective" by which to summarize and to reflect on his book's methodology (the transformation of horticulture by American culture, culturing, and culturists) and its ambitious scope and synoptic brilliance (to offer an answer, in my judgement, to the question: "What's American about American nature?").

In his moving, intimate acknowledgements—placed significantly but uncharacteristically at the end of his conclusion—he alludes to his personal battle with lymphoma cancer. Phillip J. Pauly died of the disease in April, 2008, at age 57, and American historical scholarship lost one of its most insightful culturists.

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Thomas J. Schlereth is Professor of American Studies and History at the University of Notre Dame.

# An Excerpt From *Fruits and Plains: The Horticultural Transformation of America*

*Philip J. Pauly*

### *Prairie Spirit*

Northeasterners' struggles to garden landscape were recapitulated, in a shorter time span and with greater seriousness, in Illinois and Wisconsin. Interest in replicating familiar Anglo-Hudson scenery competed with desires to evoke the regionally distinctive prairie. Landscape historians have focused on the pre-World War I innovations of the Danish German immigrant Chicago park designer Jens Jensen and the American horticulturist Wilhelm Miller. I suggest, however, that Jensen's and Miller's "prairie style of landscape gardening" drew so much from German and Olmstedian naturalism, and placed so much emphasis on shrubs and trees, that it contained little that was distinctive. The truly important development occurred, not on Chicago parklands or North Shore estates in the 1910s, but in southern Wisconsin in the 1930s, where Aldo Leopold planted a vast wildflower garden. [p. 187]

### *Original Wisconsin*

Aldo Leopold, Norman Fassett, and Theodore Sperry were the developers of a real prairie style of landscape gardening. Between 1935 and 1940, they transformed about twenty-seven acres of old pasture in Dane County, Wisconsin, a few miles southwest of Madison, into a naturalistic garden of grasses and wildflowers that they called a prairie. This act of historical naming enabled them to resolve the problem faced by landscape gardeners from Downing to Miller. They planted a landscape that was distinguishable from, and an improvement upon, the common vegetation around it, but which was plausibly naturalistic.

The University of Wisconsin Arboretum began as a provincial Olmstedian park project. In 1911 the private Madison Park and Pleasure Drive Association hired the young Massachusetts landscape architect John Nolen to prepare a comprehensive plan for the improvement of their city. Among Nolen's recommendations was the idea that the city and the university should emulate Boston and Harvard's partnership of the 1870s by establishing an arboretum-park on the shore of Lake Mendota, west of the city and the university campus. That suggestion went nowhere. The arboretum idea was revived in the late 1920s, however, by local boosters seeking to transform a failed suburban development on the small and marshy Lake Wingra, a few miles southwest of the city. They argued that the state and the university should fund a park, arboretum, and wildlife refuge as part of the ongoing initiative to establish a conservation professorship for Madison-based forester and game manager Aldo Leopold. The university approved this plan in 1932, appointed landscape architect William Longenecker to the position of executive

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MOLLY FIFIELD MURRAY, UNIVERSITY OF WISCONSIN

**The Curtis Prairie at the University of Wisconsin Arboretum as it appears today.**

director, and asked Leopold to take on the arboretum's research directorship as one of his professorial duties.

Disagreements arose immediately over issues of plant choice. Longenecker envisioned a landscape park containing systematically and ecologically ordered displays of all the perennials, shrubs, and forest trees that might prove hardy in Wisconsin. Visitors to the arboretum would be inspired to beautify their own properties, and would learn what different ornamentals and woodland trees looked like and which were worthwhile. Leopold wanted to send the visiting public a different message. He was uninterested in what he considered merely "a 'collection' of imported trees." Instead he wanted to show how much the state's vegetational quality had declined since the 1830s, and to provide a vision for improvement in the future. Advised by botany professor Norman Fassett, he proposed that the arboretum should be "a reconstruction of original Wisconsin." It would be "a bench mark, a datum point, in the long and laborious job of building a permanent and mutually beneficial relationship between civilized men and a civilized landscape." This disagreement was resolved by dividing the arboretum into areas controlled by either Longenecker or Leopold.

For Leopold and Fassett, original Wisconsin was an essentially steady state, consisting of forest, wetland, and prairie, that had existed prior to Anglo-American settlement. (They passed over the major presence of Indians in Dane County during the Woodland Period, evident in the number of mounds—over one thousand, more than anywhere else in the United States.) Creating replicas of these plant communities on a few hundred acres would require a number of different kinds of effort. Sections with trees could redevelop on their own if there were fire suppression and culling of undesirable species. The right mix of wetland vegetation depended largely on

COURTESY UNIVERSITY OF WISCONSIN-MADISON ARCHIVES

**This photograph from the 1930s shows University of Wisconsin horticultural director William Longenecker directing Civilian Conservation Corps workers planting prairie sod.**

steam dredges that could change the monotonous marsh into a more varied landscape of islands and lagoons. Shoreline areas with different slopes and soil compositions could then be planted with cattails and pondweeds that would attract wildfowl.

The real gardening challenge, however, was to create a "Wisconsin prairie" (the present-day Curtis Prairie). The basic prerequisite was labor. In 1934 the arboretum received a windfall when the state established a work relief camp for transients on its grounds. Then, when complaints arose about the behavior of these migrants and hoboes, the university persuaded the National Park Service to take over the camp and use it for the Civilian Conservation Corps (CCC) (see Figure 7.9). The CCC recruited a more tractable pool of young local men, and its involvement enabled the university to hire the young National Park Service plant ecologist Theodore Sperry as foreman. "Camp Madison" averaged about two hundred residents during the second half of the 1930s, at a cost to the federal government of more than two million dollars.

UNIVERSITY OF WISCONSIN-MADISON ARBORETUM ARCHIVES

**A Civilian Conservation Corps worker displays a massive *Silphium* taproot.**

The first step in the creation of a Wisconsin prairie park was to clear existing old-field growth. Tree control was a straightforward matter of destroying saplings, but was complicated by Fassett and Sperry's interest in leaving one large tree standing to evoke early settler accounts of "oak openings"; each year laborers had to pull up a crop of squirrel- and bird-distributed oak seedlings. The major problem was quack grass. Sperry and his workers sought to eliminate this Old World pasture mainstay and agricultural weed by plowing deeply, harrowing to dry out the rhizomes, and then replanting with clover to smother remaining growth. Irritating plants such as nettles and thistles were also a concern, without regard to their geographic origin. Finally, Leopold sought to suppress high-density populations ("thickets") of plants that were too common, such as goldenrods and asters.

Once the ground was cleared, the major issues involved plant choice. In principle, Fassett and Sperry's palette could include any of the species


**Compass plant (*Silphium laciniatum*) was one of the forbs selected by plant ecologist Theodore Sperry for the Wisconsin prairie park.**

associated with prairies in or near Wisconsin during the previous century. A present-day list of such plants totals between 340 and 550. But prairie gardeners in the 1930s were neither capable of nor interested in cultivating such a diverse flora. Sperry's planting list from 1935 to 1939 consisted of about fifty species. In both his exclusions and featured species, his goal was to plant an assemblage that would not be confused with common or despised pasture.

The largest category of excluded species consisted of the dozens of plants that were small, had inconspicuous flowers, or were visually generic. There was minimal interest in devoting labor and space to vegetation that added little to the field's visual composition. More straightforwardly, Sperry did not replant the nettles and thistles that had been removed when the land was cleared, nor did he introduce additional species with similar properties. While some of the more memorable native species that people encountered on Wisconsin prairies were greenbrier (*Smilax lasioneura*), prickly pear (*Opuntia macrorhiza*), and poison ivy (*Toxicodendron radicans*), they were not part of the arboretum plantings. The most interesting group of exclusions was of species poisonous to livestock. Prairie larkspur (*Delphinium carolinianum* subsp. *virescens*), sundial lupine (*Lupinus perennis*), and death camas (*Zigadenus elegans*) were all visually impressive Wisconsin natives. But the prosperous rural citizens whose sensibilities Leopold wanted to touch would not have appreciated a field filled with seed-bearing specimens of the weeds they had worked for a century to eradicate.

Sperry wisely emphasized familiar species that would, under proper cultivation, provide a spectacular mass display. His most frequently planted species was turkeyfoot grass (*Andropogon gerardii*, now commonly called big bluestem). The most-planted forbs were stiff sunflower (*Helianthus rigidus*) and three species of *Silphium* (including compass plant and rosinweed). Others included blazing star (*Liatris*), prairie goldenrod (*Solidago rigida*), prairie rose (*Rosa carolina*), prairie bush clover (*Lespedeza capitata*), prairie coneflower (*Lepachys pinnata*), and prairie painted cup (*Castilleja sessiliflora*). They were either large (big bluestem, compass plant, and stiff sunflower could all grow ten feet high in a good summer), had conspicuous flowers (blazing star, rose, coneflower), or unusual characteristics (indicated in names such as compass plant and painted cup). While Wisconsinites might know these plants, they would have seen them only in small populations or in fields browsed by livestock. At the arboretum, by contrast, they were able to display their capabilities and to reinforce each other visually as elements of a multiacre garden. People who visited this landscape, especially in the peak summer vacation months of July and August, would experience a wonderful wildflower garden in the style of a prairie. It was both easy and pleasant to imagine that this was original Wisconsin. [pp. 190 to 194]

# Collecting Sweetgum in the Wilds of Missouri

*John H. Alexander III*

On a sunny day in December, 1979, in the countryside near Zalma, Missouri, a tractor dutifully worked the upper end of a 40-acre field. In search of native tree seeds, Arboretum horticulturist Gary Koller and I were about half way across the lower end of the field when the tractor turned toward us. The farmer, clearly silhouetted against the skyline, picked up a rifle.

It suddenly became clear that we were trespassing. Gary turned to me and said "Do you have a business card?" I don't recall the expletives or the suggestions I proffered, but I handed him a card. He ran toward the tractor, waving the card like a tiny white flag. Dumbfounded, I stood and watched, then followed.

As it turned out, the farmer's brother had been shot (not fatally) by errant hunters while working in these fields a week or two earlier. The farmer was friendly, apologized for the rifle, and welcomed us to collect seeds in an uncultivated area by the river. It was there in the floodplain of the Castor River that Gary and I collected the seed from which the sweetgum (*Liquidambar styraciflua*, accession 1248-79-B) pictured at right was grown.

At 28 years old, this sweetgum is 36 feet (11 meters) tall with a DBH (diameter at breast height) of 16 inches (40 centimeters). Typical mature height for sweetgum is around 60 to 80 feet (18 to 24 meters). Sweetgum has a pyramidal habit when young; older trees often have a rounded canopy. Its star-shaped leaves can develop striking fall color in shades of yellow, red, orange, and purple. The spiky, 1 to 1 ½ inch (25 to 38 millimeters) diameter fruits may be dried and used in decorations, but in large numbers can be an inconvenience when they fall on lawns and walkways. Sweetgum's branch texture is variable from tree to tree; branches may be fairly smooth or have corky wings. The latter trait is impressively displayed on specimen 1248-79-B; its eye-catching abundance of large, corky, winged protrusions gives the tree great textural interest, especially in the winter.

**Native Ground**

The Arnold Arboretum is well-known for its international plant explorations, especially in China. Woody plants from around the world fill the Arboretum's collections. But collecting from wild populations of native North American plants is also important to the Arboretum's mission. Gary and I were in Missouri to attend a plant propagators' conference in St. Louis, but we had also scheduled a couple of extra days for collecting in the area.

Our goal in southeast Missouri was to find species that were native to southern regions of the United States but were growing wild in a climate that was similar to our own in Boston. Sweetgum's principal native range extends from New Jersey to southern Illinois, south to eastern Texas and northern Florida. It is usually listed as hardy to USDA Zone 5, but specimens grown from seed sources in the southern part of its range may suffer significant damage in northern winters. We must have succeeded in collecting from an appropriate location—all three specimens of accession 1248-79 are in good condition. Currently, these are the only sweetgum trees in the Arboretum that are from a known wild source.

In addition to sweetgum, we collected a number of other species in Missouri and neighboring Illinois, including Ohio buckeye (*Aesculus glabra*), pawpaw (*Asimina triloba*), sycamore (*Platanus occidentalis*), possumhaw (*Ilex decidua*), buttonbush (*Cephalanthus occidentalis*), American hornbeam (*Carpinus caroliniana*), and river birch (*Betula nigra*). These species are all fairly common, but what's important is that our collections provide a genetic representation of each of these species as it exists in the wild. When one of these plants, like sweetgum specimen 1248-79-B, turns out to have ornamental characteristics that appeal to us as gardeners, that's icing on the cake.

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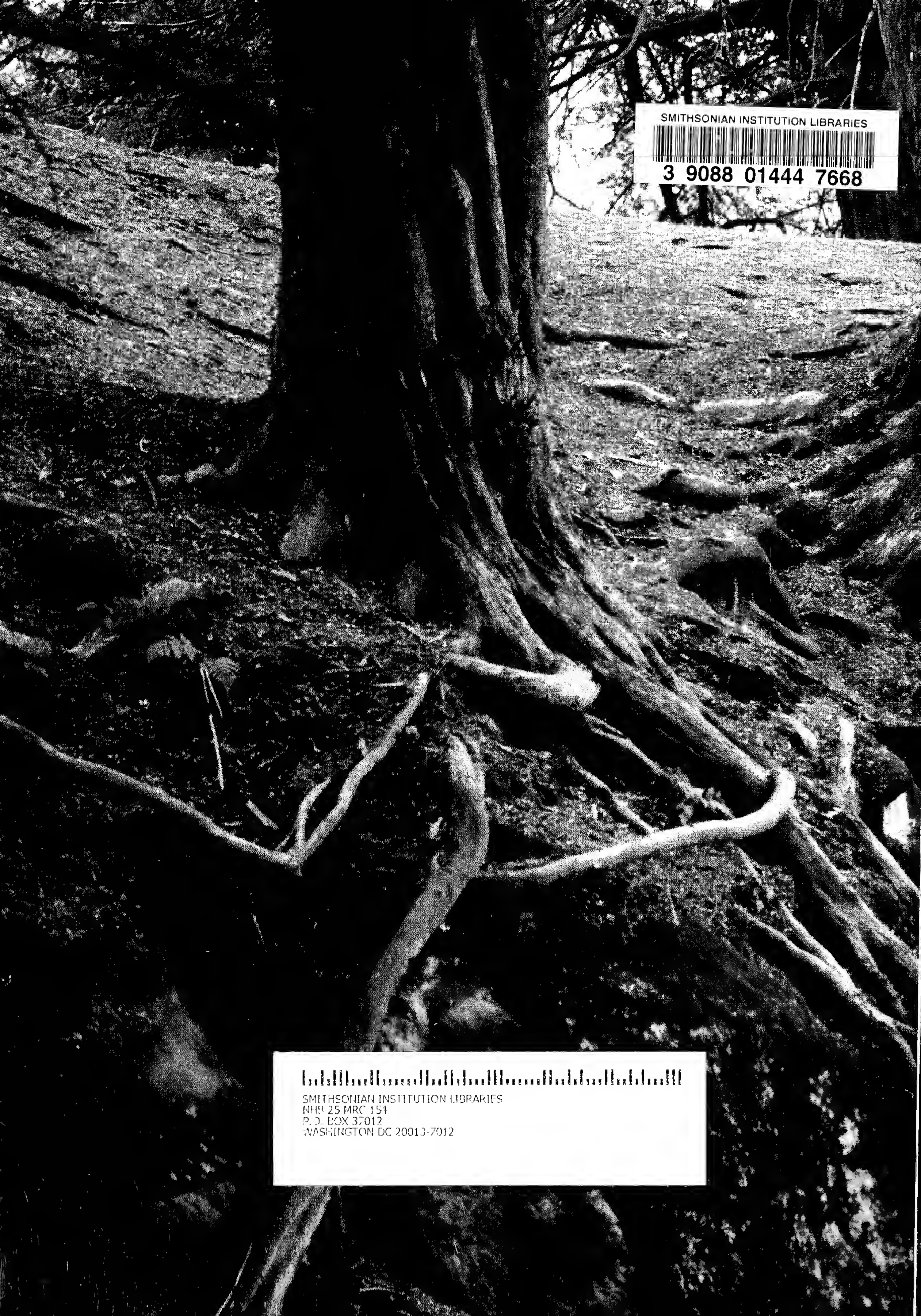
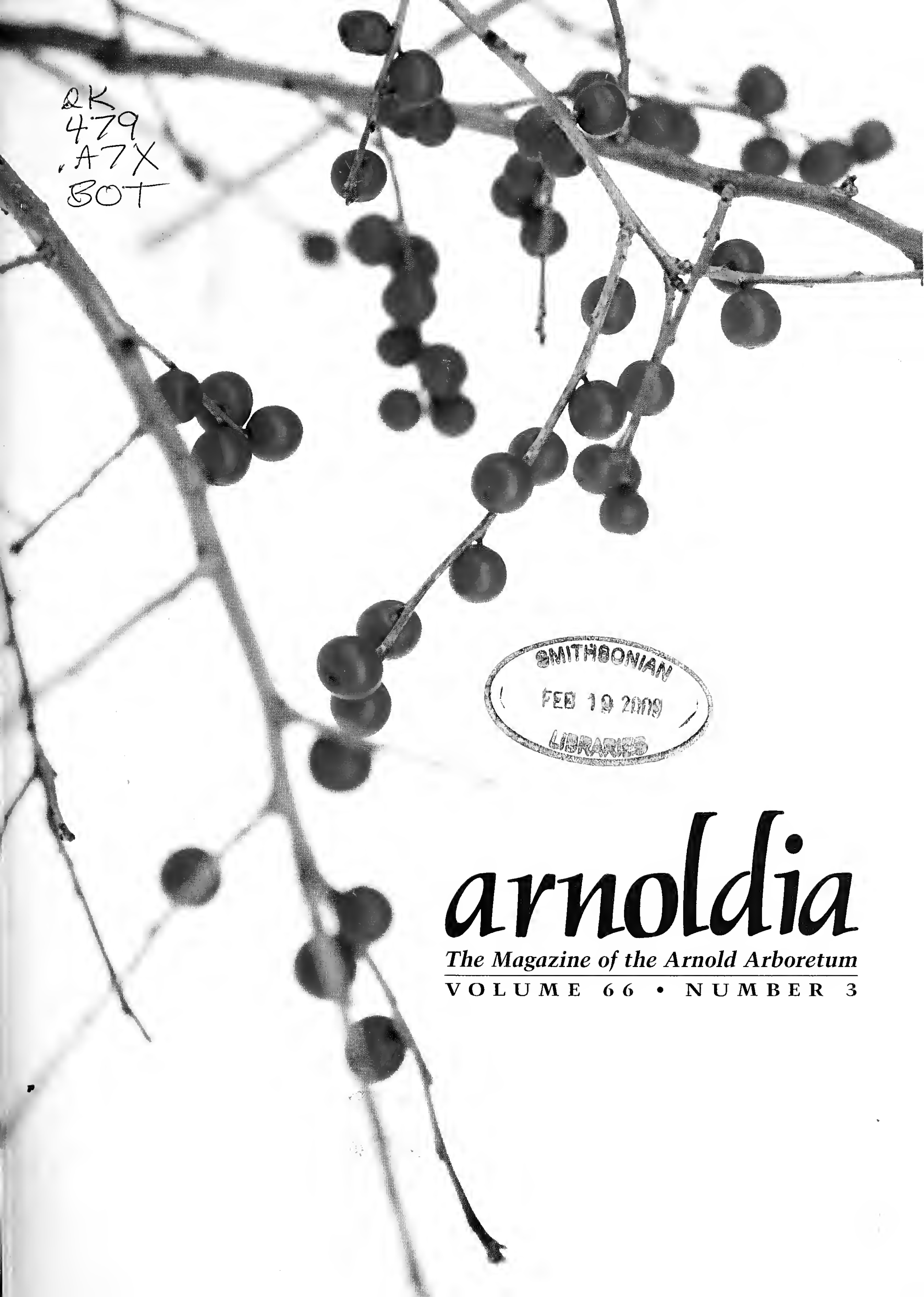
John H. Alexander III is Plant Propagator at the Arnold Arboretum.







# arnoldia

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*Front cover:* The plump scarlet fruits of Red Sprite winterberry (*Ilex verticillata* 'Red Sprite') brighten a snowy landscape. Photo by Nancy Rose.

*Inside front cover:* Groundnut (*Apios americana*), a North American native vine with edible tubers, is part of the well-documented flora of Concord, Massachusetts. Photo by Abraham Miller-Rushing and Richard Primack.

*Inside back cover:* Kyle Port, Manager of Plant Records, profiles one of the few Arboretum accessions that hails from Africa: a Moroccan fir (*Abies pinsapo* var. *marocana*) growing in the Conifer Collection. Photos by Nancy Rose.

*Back cover:* Colorful Chinese lanterns dangle from a linden (*Tilia* sp.) at Tivoli, Copenhagen's 165-year-old public pleasure garden. Photo courtesy of Tivoli.

# The Impact of Climate Change on the Flora of Thoreau's Concord

*Abraham J. Miller-Rushing and Richard B. Primack*

Climate change is driving major shifts in ecosystems all over the world, including here in the United States. Tree swallows and many other bird species are breeding earlier, forest edges are extending up the sides of mountains, and the distributions of pest insect species such as the hemlock woolly adelgid are shifting northward. Notably, most of the evidence for biological responses to climate change, including these examples, is based on studies of one or a few species. The number of examples is large, but it is difficult to know how representative they are. How is climate change affecting entire natural communities of plants and animals? Are all of the species within a community changing, or are just a few? Are most species in a location changing in the same way, or are there substantial differences among species? Are there ways to predict how species within communities might change and what the consequences of these changes will be? Despite the obvious importance of these questions, we do not really know the answers. We know many changes are happening, some of them major, but thus far our knowledge is limited to a relatively few species in a few places.

ALL PHOTOS BY THE AUTHORS UNLESS OTHERWISE INDICATED

**The statue of Henry David Thoreau at Walden Pond, with a replica of his cabin in the background.**

To help answer the question of how plant communities are responding to climate change, we turned to one of the best-documented floras in the country—the flora of Concord, Massachusetts. The flora has been inventoried five times since 1830, a huge effort for the flora of a single town. During two of these inventories, the botanists collected observations not only of plant occurrences, but also of flowering times. One of these two botanists was the well-known philosopher and naturalist Henry David Thoreau, and the other was a local shopkeeper, Alfred Hosmer. Between them, they recorded the flowering times of over 700 plant species in Concord.

**Concord is home to a wide diversity of wildflowers such as this Britton's violet (*Viola brittoniana*).**

We know of no other climate change study in the United States that has recorded observations on as many species in a single location for as long a period as Thoreau and Hosmer. These observations have major scientific value because we can use them to examine the response of an entire flora to climate change. Their value is further enhanced because changes in the timing of phenological events—those biological events like flowering, fruiting, and migrations that recur on a seasonal basis—are among the most sensitive biological responses to climate change.

Many phenological events in different places in the world are now occurring earlier than in the past. However, it is clear that species' phenologies are changing at different rates. For example, in England some species are flowering more than a month earlier than they did 50 years ago, while other species' flowering times are advancing more slowly, or are not changing at all. In some instances, plants are even flowering later than they did in the past. This variation has the potential to alter important relationships among species, such as those between plants and pollinators. If a plant is flowering much earlier now than it did in the past, but its preferred pollinator is active at the same time each year, the plant and the pollinator could be mismatched in time, to the disadvantage of both. Similarly, variation in changes in timing could affect relationships among plants competing for resources, between plants and herbivores, and between predators and their prey. In the Netherlands, pied flycatcher populations are already declining because they are breeding too late to feed on their caterpillar prey. More broadly, the populations of European migratory birds species that are not migrating earlier in response to warming temperatures are declining, possibly because of temporal mismatches between their migrations and breeding and their environments.

Thus, we are left to question, why do species respond differently to climate change? What species are most (or least) sensitive to changes in climate? Are there characteristics that make a species particularly sensitive? The observations of Thoreau and Hosmer provided an opportunity to make headway in answering these questions.

**The flowering time of sweet birch (*Betula lenta*), seen here, proved to be much more responsive to temperature than did the flowering time of gray birch (*Betula populifolia*).**

## The Remarkable History of Botanical Investigation in Concord

The surveys of Concord's flora since 1830 are remarkable not only for their number, but also for their intensity. Aside from simply noting species occurrences, in some cases the surveyors recorded species abundance and the presence of invasive species, and noted botanically important areas. Building on the extraordinary historical base of previous surveys of Concord's flora, over the past five years we have conducted our own survey of the flora. All of the previous surveys provided interesting data, but the precise observations of flowering times by Thoreau and Hosmer proved to be the most important for our study.

In the 1850s, after a decade of observing nature and four years after his experience of living on



**Thoreau's cove on Walden Pond, photograph made by Alfred Munroe in the 1890s (exact year unknown).**

***How suddenly the flowers bloom! Two or three days ago I could not, or did not, find the leaves of the crowfoot. To-day, not knowing it well, I looked in vain, till at length, in the very warmest nook in the grass above the rocks of the Cliff, I found two bright-yellow blossoms, which betrayed the inconspicuous leaves and all. The spring flowers wait not to perfect their leaves before they expand their blossoms.***

**From the journal of Henry David Thoreau**

**The influence of temperature on plant development is shown by lily of the valley (*Convallaria majalis*). Plants next to a warm building have undergone more development than plants further away.**

the edge of Walden Pond, Thoreau began recording flowering times of plants in Concord. He cared deeply about the seasonal changes, as can be seen in his many observations in *Walden.* In describing his activities at Walden, Thoreau states, "I want to go away soon and live away by the pond ... But my friends ask what I will do when I get there. Will it not be employment enough to watch the progress of the seasons?"

One might say he was obsessed with the progress of the seasons. From 1852 to 1858, he hiked around Concord and made regular observations of the first flowering times of over 500 different species of plants in an effort to create a calendar of the natural events in Concord. His intention was to write a book about the seasons in Concord. Unfortunately, he died before he was able to complete his project. His friends also wrote about his obsession with the seasons, as Ellery Channing did after a walk with Thoreau on March 6, 1859: "Our round of walks is as regular as the seasons; now to low spots to look for early spring plants, also for early birds. Nature is an eternal provision and repetition. H[enry] says there is nothing but the seasons."

His efforts to record flowering times were followed by another botanical enthusiast, Alfred Hosmer, who recorded the first flowering times of over 700 species of plants in 1878 and from 1888 to 1902. We do not know exactly why Hosmer made these observations, but we are quite thankful that he did. His records can all be found in precisely organized notebooks, presently housed in the Special Collections Section of the Concord Free Public Library.

The idea of tracking phenological events was not new at the time of Thoreau and Hosmer's work. The practice is said to be as old as agriculture, if not older. Well-known Americans such as Thomas Jefferson kept records of flowering and bird migrations. But the incredible effort and continuity of the observations that Thoreau and Hosmer made was exceptional. They made observations across an entire town (without the aid of a car) several days each week for many consecutive years. In the processes, they created a list of flowering phenology for more species in a single location than any other of which we are aware.

### Linking Historical Observations with Climate Change Science

When we learned about these flowering time observations from the late Thoreau scholar, Brad Dean, and the active New England botanist, Ray Angelo, we recognized that we had an opportunity to test whether climate change had affected the flowering times across the entire community of flowering plants in Concord. We immediately set out ourselves to document the current flowering times of as many species as we could throughout the town. From 2003 to 2006 we visited Concord two to three days each week throughout the flowering season, from March to October, and recorded the plants we saw in flower each day. We deliberately sought out locations of difficult-to-find species, such as Britton's violet (*Viola brittoniana*) and rose pogonia (*Pogonia ophioglossoides*), with hopes of observing as many of Thoreau's and Hosmer's species as we could. Eventually, we made observations of the first flowering dates, in addition to recording the entire period of flowering, of over 500 species. Many of the species we observed, and even the places where we saw them, were identical to those that Thoreau and Hosmer had seen.

With these data in hand, we set out to test whether first flowering dates had changed in Concord, and whether species differed in their response to a warming climate. To simplify things, we started by analyzing changes in the first flowering dates for 43 of the most common spring-flowering species that Thoreau, Hosmer, and we had all observed in nearly every year we looked. These species were abundant and widely distributed, and probably reflected fairly the changes in flowering times that had occurred more broadly in the Concord flora. On average, these 43 species were indeed flowering about a week earlier in recent years than they had in Thoreau's day, with Hosmer's observations right in the middle. Some of these species' flowering times changed dramatically. For example, highbush blueberry (*Vaccinium corymbosum*), a shrub of wetlands, and yellow wood sorrel (*Oxalis stricta*), a native herb of fields and roadsides, are now flowering 21 and 32 days earlier, respectively, than they did 150 years ago.

This trend toward earlier flowering corresponded with warming temperatures in the Concord area. Temperature records from the Blue Hill Meteorological Observatory in Milton, Massachusetts showed 2.4°C (4.3°F) warming from 1852 to 2006. Most of this warming occurred because of urbanization and development in the greater Boston area, while some of it occurred because of global climate change. (For comparison, the average global temperature warmed by about 0.7°C (1.3°F) over the past 100 years.) The relatively large warming in Concord, boosted by urbanization, makes this flora a good example for how floras in the rest of the country, away from cities, may respond to future warming. Global temperatures are predicted to warm by about 3°C (5.4°F) in the next 100 years. Of course, the responses of plants in a developed area may be different from rural areas for a variety of reasons, pollution and the rate of warming among the most important. However, pollution is thought to have a negligible effect on flowering times relative to temperature. And although the rate of warming could alter how quickly flowering responses to temperature might evolve, evolution is likely to be slow in a flora, such as Concord's, dominated by long-lived perennials and should have little impact on flowering responses to temperature on the time scales with which we were working.

We found a strong relationship between temperature and flowering times in Concord; temperatures in January, April, and May explained most of the variation in flowering dates. (More on why those months later.) On average, plants flowered about three days earlier for each 1°C warming. When we examined a much larger list of 296 species, we found the same response of flowering dates to temperatures.

Because plant flowering dates respond to temperatures at particular times, we examined the relative importance of temperatures in each month. Temperatures in January, April, and May were by far the most important for most species; warmer temperatures in all three months were linked to earlier flowering dates. April and May were important because they were the temperatures immediately preceding flowering for most species. Why January temperatures were so important was more of a mystery.

Winter temperatures are typically understood to influence flowering times in temperate plants through a process known as vernalization. Plants have biochemical methods to keep track of how cold it is and for how long. Once it has been cold enough for long enough, plants are said to be competent—that is, their dormancy is nearly complete and they are ready to start developing leaves and flowers as soon as it warms up. If it never gets cold enough for long enough, the plants may still flower when temperatures warm in the spring, but it will take longer to flower; the colder it gets, the closer the plants come to being fully competent, the faster they flower in the spring. The need to track the cold is a defense against abnormally warm temperatures in mid-winter. Plants in New England are adapted to avoid flowering in January or February, even when the weather is

**Rose pogonia (*Pogonia ophioglossoides*) is an elusive native orchid found in fens and other damp sites. Cardinal flower (*Lobelia cardinalis*) grows in moist soils and produces spikes of bright red flowers in mid to late summer.**

warm. Under this scenario, plants should flower earlier in the spring after cold winters, because they should become more fully competent. However, we found that plants flowered later after particularly cold Januaries. Vernalization was apparently not responsible for the response we saw. Instead, we suspect that it gets so cold in Concord in January that in the coldest years plants suffer physical damage to the vascular tissue that delays flowering. We found support for this hypothesis in a subsequent project of ours in which we looked for this sort of damage in birches at the Arnold Arboretum.

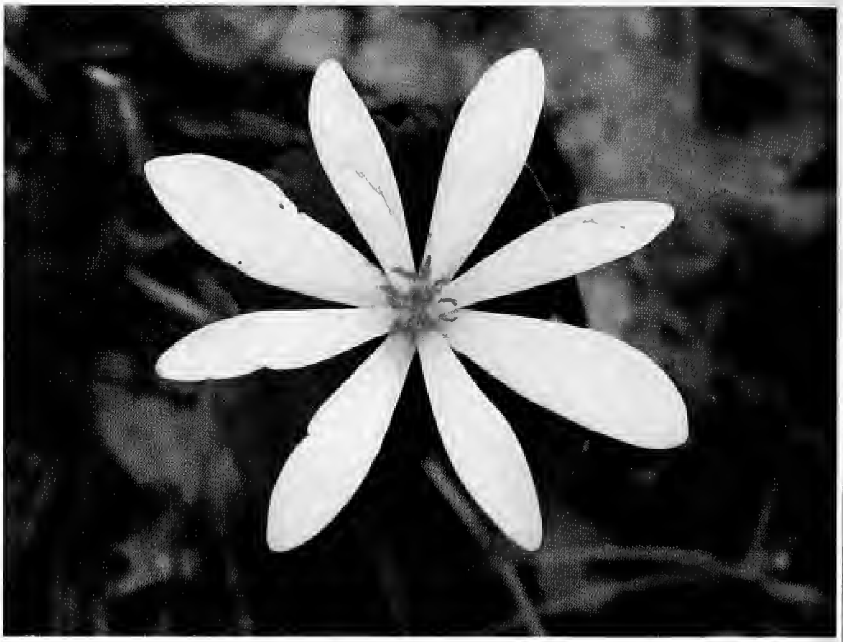
## Variation Among Species

With data on all these species, we looked for patterns of variation. Which species were the most sensitive to temperatures? Did particular traits seem to be associated with strong responses to temperature?

The flowering responses of plants from different habitats (e.g., aquatic, forest, grassland, roadside, and wetland) did not differ, nor did the responses of natives and non-natives differ from each other. However, season of flowering seemed to matter a great deal. The flowering times of early-season plants were on average strongly correlated with temperature, whereas the flowering times of late-season plants had a much weaker link with temperature. If this pattern continues, the flowering season may lengthen as temperatures warm. Spring species may flower ever earlier and the flowering times of summer species may not change much at all. As a result, the degree of overlap in species' flowering times may be reduced.

Growth form seemed also to matter, although in a more indirect way. Among perennial herbs, the flowering dates of late-season plants varied a lot from year to year compared to the flowering dates of early-season plants. However, the variation in flowering time was not related to temperature. We are still unsure of what is driving the year-to-year variation in the flowering dates of late-season perennial herbs; it might have do with soil moisture, degree of shading, or land use. Meanwhile, woody plants showed the pattern we expected—lots of climate-driven variation in flowering dates for early-season plants and relative stability in the flowering of late-season plants.

Lastly, we noted that the flowering responses of several closely related species varied substantially. For example, sweet birch (*Betula lenta*) and gray birch (*Betula populifolia*), which occur in many of the same habitats in Concord and elsewhere, showed very different responses to temperature. Sweet birch flowered about three days earlier for each 1°C increase in January, March, and April temperatures, whereas gray birch flowering dates were unrelated to temperature. In an even more dramatic example, rough-stemmed goldenrod (*Solidago rugosa*) flowered 11 days earlier for each 1°C increase in temperature, whereas the flowering dates of lance-leaved goldenrod (*Solidago graminifolia*) and most other goldenrods were unrelated to temperature. These varied responses to climate change could lead to increased hybridization among closely related species, if flowering times that previously occurred at distinct times began to overlap. It could also cause more competition for pollinators; if plants that share pollinators and have historically flowered at different times begin flowering at the same time, they may start competing for the pollinators' services. Competition for nutrients and water needed at critical times in plant development could also increase.



**Bloodroot (*Sanguinaria canadensis*) is one of the early spring ephemerals recorded in Concord's flora.**

## The Big Picture

Our study found that the plant community in Concord is responding to climate change in dramatic ways. Spring is coming earlier on average, but there is a lot of variation among species. Highbush blueberries are flowering three weeks earlier than they were in Thoreau's day, yet the flowering times of other species are not changing at all.

Ecologically, these results reflect the complexity of plant response to climate change. The flowering times of early-season plants are shifting more quickly than those of late-season plants. Perennial herbs and woody plants respond differently. Habitat and nativeness do not seem to affect flowering responses to climate change. With such a wealth of data from this single location, we found surprising patterns, leading to questions that still must be answered. For example, why do the flowering times of closely related species respond so differently to warming temperatures? How will species interactions change as a result? Given the remaining uncertainty, it is difficult to assess how exactly flowering times will shift in the future and what the changes will mean for plants and animals. Thoreau was also aware of the effects of climate on plants and animals and their interactions more than 150 years ago when he wrote, "Vegetation starts when the earth's axis is sufficiently inclined; i.e. it follows the sun. Insects and the smaller animals (as well as many larger) follow vegetation ... The greater or less abundance of food determines migrations. If the buds are deceived and suffer from frost, then are the birds."

The results of our study show how perceptive he was and suggest likely impacts of a warming climate. Interactions among species—e.g., predators and prey, competing plants, plants and herbivores—will certainly change. Most plant species can be pollinated by many animal species or by the wind, and most pollinators can feed on various flowers. For them, the relationships will shift, but they will probably continue to persist. However, shifts in the timing of specialist interactions, like those between hummingbirds and plants with long flower tubes, will probably lead to more dire consequences for the species involved. If a plant with a specialist pollinator flowers before its pollinator is active, its chances of reproducing may decline significantly. Additionally, as the flowering times of early-season plants continue to advance and pull away from the flowering times of late-season plants, there may be times of low floral resources for pollinators like bumblebees. Undoubtedly, some species will do well and thrive under the changed circumstances, while others will do poorly and may even go extinct.

**What's Next?**

Research efforts are underway to solve these unanswered questions, but more data are needed. Known sets of phenological observations like those of Thoreau and Hosmer are quite rare. Yet scores of people have recorded observations—flowering dates in gardens, birds' spring arrivals at feeders—that now sit in boxes in attics and basements. The newly formed USA National Phenology Network (www.usanpn.org) is beginning to collect these valuable "shoebox" data sets to make them freely available to the research community and the public. There is great potential for these phenological observations to shed light on ecological responses to climate change.

In addition, evidence of changes in phenological events can improve public awareness of the effects that climate change is already having on biological systems. People can see changes in phenology in their back yards, neighborhoods, parks, and forests. We believe that building on the observations of a well-known figure such as Thoreau can further increase the potential for public outreach.

Thoreau was keenly aware of the importance of educating people about environmental issues. He helped Concord's citizens to appreciate wild nature, and he encouraged them to protect it. He wrote, "I think that each town should have a park, or rather a primitive forest of five hundred or a thousand acres, either in one body or several, where a stick should never be cut for fuel, nor for the navy, nor to make wagons, but stand and decay for higher uses—a common possession forever, for instruction and recreation." Residents of Concord and the government have followed this advice; about 40% of Concord's land is preserved in parks and protected areas, such as Walden Pond State Reservation, Great Meadows National Wildlife Refuge, and the Estabrook Woods. With the help of these protected areas, we have been able to continue the same observations of flowering times made by Thoreau at many of the same localities in Concord. We now hope that Thoreau's observations and our own work will promote broad discussion of the effects of climate change on biological systems.

**Resources:**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USA National Phenology Network. www.usanpn.org


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Abraham Miller-Rushing and Richard Primack completed this research together while working at Boston University. Dr. Miller-Rushing is now the coordinator of the Wildlife Phenology Program, a collaboration between the USA National Phenology Network and The Wildlife Society. Dr. Primack is a professor at Boston University.

# A Matter of Taste: Pleasure Gardens and Civic Life

*Phyllis Andersen*

**"To be natural is such a very difficult pose to keep up."**
**—Oscar Wilde, *An Ideal Husband***

"Popular taste is not a criterion that those who serve our public can respect." So said Mariana Van Rensselaer, the distinguished New York art critic and first biographer of architect H.H. Richardson. That remark, made in 1888, fueled the controversy that erupted over her criticism of flowerbeds in Boston's Public Garden. Describing them as crude hues in false situations, she took particular offense at 'Crystal Palace Gem' geraniums: "The cherry colored blossoms with yellow-green leaves are the most hideous products of recent horticulture." William Doogue, the Irish-born horticulturist in charge of the Garden's plantings, took exception to her criticism and also rebuked her social position, personal gardening habits, and Harvard-connected friends. Doogue defended his work as accommodating the general taste of the public, who loved his plantings. He protested to the local newspapers and the Mayor, and anyone else who would hear him out.

Was all of this brouhaha caused by some ill-placed geraniums, or was it indicative of a deeper division in how we imagine our public parks? This division is illustrated by the well-known story of the 1858 design competition for New York's Central Park, won by Frederick Law Olmsted and architect Calvert Vaux with a plan titled "Greensward." Their proposal offered a picturesque landscape evocative of the English countryside, combining rustic structures with meadows punctuated by groves, rock outcroppings, and sinuous water bodies. "Sylvan" and "verdant" were words used by the designers to describe their design as "a constant suggestion to the imagination of an unlimited range of rural conditions." The contrast with the majority of proposals from competitors—

COURTESY OF JIMMY TURNER

**A source of color and controversy, 'Crystal Palace Gem' geranium.**

engineers, landscape gardeners, and talented amateurs—represented a remarkable shift toward the narrative of the picturesque. Other more traditional plans presented highly embellished gardens with formal promenades, fountains, arches, statues of Greek deities and New York politicians, bandstands, and extensive formal layouts of flowering plants.

By the mid nineteenth century, the educated public understood that the picturesque landscape was the aesthetic ideal for public parks, allowing the mind to wander along with the body. Among others whose opinions counted, economist and social critic Thorstein Veblen pointed to an upper-class predilection for public parks that were rustic and natural. Enlightened park advocates rejected the pleasure garden model with its emphasis on flowery display, theatricality, sociability, and amusement, beleiving its artificiality and "claptrap and gewgaw" lacked moral uplift and tasteful restraint.

Like sin and grace, the picturesque park and the pleasure garden are mutually defining. Olmsted used medical metaphors to promote his notion of the park ideal: parks should be an antidote to urban ills, healing places for damaged minds. Calvert Vaux's famous comment on Americans' intuitive love of the country was at the core of learned park discussions. Vaux spoke of an "innate homage to the natural in contradistinction to the artificial, a preference for the works of God to the works of man." Supporters of the pleasure garden model rejected the imposition of rural scenery on the city and embraced the seductive lure of sensual sound, color, and light—a sustained Fourth of July celebration, an extended summer fête.

### The Origin of the Public Pleasure Garden

The public pleasure garden originated in London in the eighteenth century with extensive public gardens established at Ranelagh, Marylebone, and Islington. But Vauxhall Gardens on London's South Bank most completely and intensely captured the public's imagination. A favorite watering hole for Samuel Johnson, it was frequently used as a fictional backdrop by novelists. It offered grand promenades, open-air temples imitating ancient buildings, an array of dining and drinking pavilions, small theatres, bandstands, tea gardens, and private bowers for romantic interludes. Linking the attractions were elaborate flower displays of local and foreign blooms selected for color, fragrance, and mood-evoking exotic origins. There were fireworks and beguiling night-lighting in an era when both were rare. In its heyday, Vauxhall Gardens attracted aristocracy, royalty, and anyone who wished to mingle and immerse in an environment designed to please.

New York entrepreneurs transported the Vauxhall Gardens concept, name, and menu of

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**Central Park's Sheep Meadow reflects the pastoral, naturalistic theme inherent in Olmsted and Vaux's winning design for the park.**

**Music, dining, and assorted other revelries made London's Vauxhall Gardens the place to see and be seen. *Vauxhall Gardens*, 1785, engraved by Robert Pollard II after Thomas Rowlandson. credit: The Metropolitan Museum of Art, The Elisha Whittelsey Collection, The Elisha Whittelsey Fund, 1959 (59.333.975). Image © The Metropolitan Museum of Art**

attractions to New York in 1805, to the area around Broadway and East 8th Street, which is now known as Astor Place. At the same time, even the less than sybaritic Hoboken, New Jersey created Elysian Fields, a popular waterfront park that offered ferry service from Manhattan, and where, some say, the first organized game of baseball took place. The last of the New York pleasure gardens, Palace Gardens, opened in 1858 (the same year as the Central Park competition). It offered the usual array of dining pavilions, water features, and elaborate night-lighting.

## Legacy of the Pleasure Garden

Today, the tradition of the pleasure garden continues to influence the way we think about urban parks. Certainly the questions posed 150 years ago continue to resonate: Who owns the parks? The planners? The middle class? The working class having no other options? And just as important: What is the purpose of a park?

The success of the public pleasure gardens was due to diligent management by entrepreneurs who owned them and developed new attractions: balloon launches, water gondolas, music commissioned for special occasions. The eventual demise of the public pleasure garden was due in part to competition from new urban amenities: restaurants, concert halls, theatres, tearooms, and cafes dispersed throughout the city. It was due as well to the growth of petty crime that, then as now, often attaches to public venues that draw huge crowds. And some pleasure gardens, having contributed to the growth and desirability of the city, became victims of their own success and were lost to real-estate development pressures. The prototypical evocation of a pleasure garden that survived is Copenhagen's Tivoli, which opened in 1843. Patterned on London's Vauxhall and named for the beautiful resort town near Rome, it still offers families a complete pleasure garden experience with attractions interspersed among flower displays appropriate to the season.

The horticultural display of pleasure gardens, with its emphasis on seasonal flowering, evolved into civic horticulture—embellishment of city-spaces that are not within the purview of the professional landscape architect and most often maintained by gardeners trained through apprenticeship and guided by trade magazines. These plantings typically feature massing of large numbers of flowers of strong color contrasts arranged in geometric or pictorial patterns. Some traditions, such as the theatrical display of plants in graduated tiers, evolved from the eighteenth-century English estate garden into the public pleasure garden, as still seen in Boston's Public Garden today. Civic horticulture draws on a rich planting tradition that evokes admiration of both the beauty of the plantings and the ingenuity of the gardener. The immense popularity of the Rose Garden in the Fens section of Boston's Emerald Necklace, of the planted borders in downtown Boston's Post Office Square, and the grand flowerbeds at Copley Square are fine examples of horticulture that enlivens the city, akin to Pop Concerts on the Esplanade.

Although theme parks and amusement parks are obvious descendents of the pleasure garden, recent trends in urban public parks suggest that the pleasure garden is enjoying a renaissance

PHOTOS COURTESY OF TIVOLI

**Modeled on public pleasure gardens such as Vauxhall, Tivoli opened in Copenhagen, Denmark, in 1843. Tivoli's exotic Moorish-styled Nimb building is shown in 1910 (left), one year after being built, and as it appears today (right).**


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**Beds of brightly colored annual flowers feature prominently in views of Boston's Public Garden from an early-1900s postcard (top) and a 2006 photograph (bottom).**

of sorts. We are in the midst of defining a new urban park discourse, one that rejects the picturesque and encourages new kinds of urban engagement—drawing in the city, making use of technology, and embracing theatricality. Chicago's Millennium Park, an assemblage of cultural attractions and elaborate planting displays, lists "theatre consultant and lighting designer" as part of the design team. The team of Kathryn Gustafson and Crosby, Schlessinger and Smallwood have developed a highly ornamental planting plan for the North End Park of Boston's Rose Kennedy Greenway. The Dutch horticulturist Piet Oudolf is acting as a consultant for a number of new urban parks in the United States, bringing his skill at highly textured perennial planting in changing seasonal patterns to a new audience. Yet, we still drag issues of public taste behind us, although now couched in concerns for environmental suitability, often with the same moral overtones that characterize the Central Park discussions of the mid-nineteenth century.

We lay a huge responsibility on our urban parks. They must be didactic, educate about ecology, unify communities, and convey history. They must exhibit good taste and local values. But if we are to sustain parks in cities, they must embrace the imagination of the public. The term "Disneyfication" is now an indictment, but one suspects that William Doogue would have welcomed Walt Disney's words: "We are not trying to entertain critics. I'll take my chances with the public."

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Phyllis Andersen is a landscape historian and the former director of the Institute for Cultural Landscape Studies of the Arnold Arboretum. She is currently working on a book on public pleasure gardens scheduled for publication in 2010.

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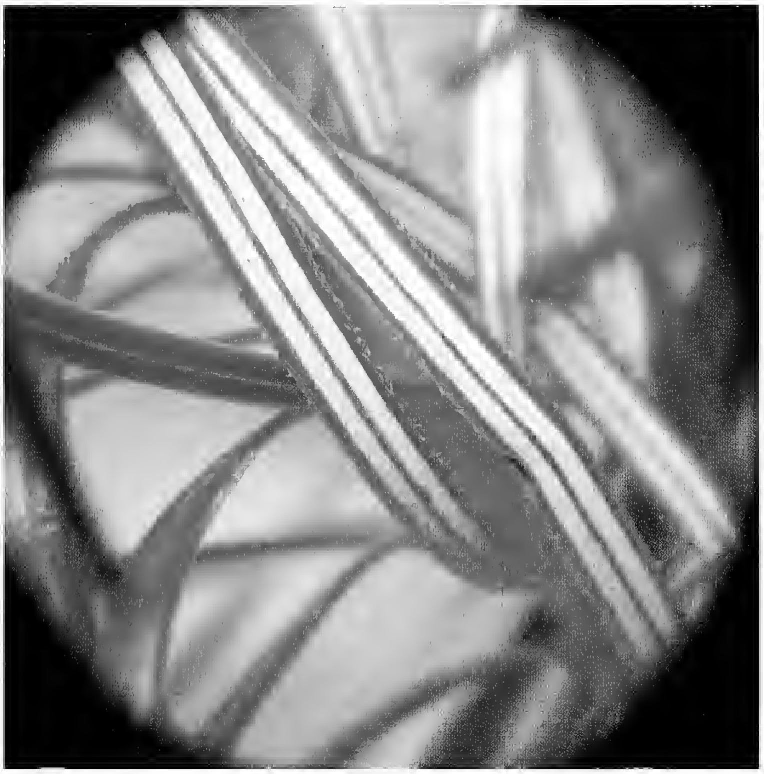
# The Cathay Silver Fir: Its Discovery and Journey Out of China

*Christopher B. Callaghan*



AUSTRALIAN BICENTENNIAL ARBORETUM

**Prominent stomatic bands on the undersides of leaves give *Cathaya argyrophylla* its silvery flash.**

All that glitters isn't gold. Sometimes it's silver, especially when it's the rare Cathay silver fir (*Cathaya argyrophylla*). It is now over 50 years since the discovery of this "living fossil", yet it remains largely unknown. Access to this conifer has been tightly controlled by China; reportedly, even the offer of a Trident jet in exchange for a single plant during the late 1970s was not sufficient to entice the Chinese to release their grip on this endemic "treasure tree," whose fir-like leaves reflect their silvery undersides when they catch the sunlight.

This offer may not sound so far-fetched when compared with the more recently discovered Wollemi pine (*Wollemia nobilis*) of Australia, which has grossed millions of dollars in worldwide sales since its public release in early 2007 following a well- orchestrated marketing and publicity campaign highlighting its ancient origins. Earlier, a pre-release auction of the first Wollemi pines realized over one million Australian dollars with an average of A$3,627 per tree, and this without any American bids because of U.S. import restrictions on trees over 18 inches (0.5m) tall. So for China, the Cathay silver fir—mass produced and properly marketed to the west—had the potential of being a similar financial success story.

Described as another "living fossil" when it made world headlines in the 1950s, the Cathay silver fir did not make it out of China prior to its official release by Chinese authorities in the 1990s. In contrast, dawn redwood (*Metasequoia glyptostroboides*), the previous world-renowned "living fossil", was introduced into western cultivation from China in late 1947, a mere six years after its discovery. This was thanks in large part to the efforts of Elmer D. Merrill, then Arnold Professor of Botany at the Arnold Arboretum and previously the Arboretum's director.

By the time of the discovery of *Cathaya argyrophylla* just eight years later, the changing political landscape in China and the cutting of ties with the west meant that this botanically interesting tree, which Chinese botanists have described as "The Giant Panda of the Plant Kingdom," was to languish in near obscurity for over thirty years. Even with the gradual lifting of the bamboo curtain post-1972, it still took many years before the Chinese allowed the tree to be taken out of the country, or distributed any seeds to overseas botanical institutions. Consequently, the Cathay silver fir is still little known even today, more than half a century after its scientific discovery.

**A New Plant is Found**

This discovery occurred in 1955 during a botanical exploration of the remote Huaping region of northern Kwangsi province (now Guangxi Zhuang Autonomous Region) in southern China. Deng Xianfu, a member of the Kwangfu-Lingchu Expedition, literally unearthed the first Cathay silver fir when he dug up a seedling of what he thought was *Keteleeria fortunei*. Following a closer inspection of the seedling, expedition leader Professor Zhong Jixin found that it didn't resemble Fortune's keteleeria. He also knew that *Keteleeria fortunei*, while occurring naturally in Kwangsi province, could not survive there at above 1400 meters (4600 feet) in the Tianping Mountains, and so considered that it might be a new species of *Keteleeria*.


Sketch maps not to scale

**Numbers on the enlarged map indicate the approximate locations of wild *Cathaya* (see facing page). Additionally, *Cathaya argyrophylla* is said to occur at Luohandong in Hunan province and in Tongzi county, Guizhou province. The approximate position of these two localities has not been determined and is therefore not indicated on the map. C.M. = Chongqing Municipality.**

Upon receiving further information that a tree had been seen in these mountains with some resemblance to both a pine (*Pinus*) and a fir (*Abies*), Professor Zhong realized that they should be looking for something special. He directed expedition members to intensify their efforts to find the parent plant(s) of the unfamiliar seedling.

Continued searching of the precipitous, mist-shrouded mountains led to the discovery of a mature tree on the southern slopes of Mt. Hongya on May 16, 1955. Herbarium specimens were collected by expedition members, with further specimens collected from the same locality by H.C. Lei, H.C. Chung, H.L. Hsu and H.F. Tan from May to July the following year. All these specimens were deposited at the herbarium of the South-China Institute of Botany, later renamed Kwangtung Institute of Botany (now held at Guangxi Institute of Biology).

Here they were seen by the Soviet botanist Sugatchey [likely a mistranslation of the name Sukachev] who advised that they resembled plant fossils previously found in the Soviet Union and Europe dating back to the Pliocene of the Tertiary Period, and hence the newly discovered tree represented a "living fossil". *Cathaya* fossils found since then include fossil pollen in Asia and North America dating back to the Cretaceous.

Chun Woon Young (Chen Huanyong) and Kuang Ko Zen (Kuang Keren) published a description of the new genus and species in 1958. They also described a second species, *Cathaya nanchuanensis*, discovered in 1955 on Jinfo Shan (Golden Buddha Mountain) in southeastern Sichuan. However, this name was reduced to a synonym of *Cathaya argyrophylla* in 1978.

## Natural Occurrences of *Cathaya* in China

| PROVINCE/ REGION | NUMBER ON MAP | LOCATION (Reserve area in ha) |
|---|---|---|
| GUANGXI ZHUANG AUTONOMOUS REGION | ❶ | Dayao Mountain Nature Reserve (aka Dayao Shan National Forest Park) Established 1982. Jinxiu County. |
| | ❷ | Huaping Nature Reserve (aka Huaping Primeval Forest), Mt Tianping. Established 1961. Sanmen, Longsheng County (type specimen of *Cathaya argyrophylla* found here in 1955 near Yezhutang, Southern slope of Mount Hongya). |
| GUIZHOU | ❸ | Cathay Silver Fir Nature Reserve (aka Dashahe Cathaya Reserve) Established 1984. Daozhen Xian, Daozhen County. |
| | ❹ | Forest Reserve of Guizhou Botanical Garden. Founded 1964. Liuchongguan, Guiyang. |
| | ❺ | Mount Fanjing Nature Reserve. Established 1978. Jiangkou County. |
| HUNAN | ❻ | Dingliao Nature Reserve. Established 1986. Zixing County/ Bamian Mountain Nature Reserve est. 1982. Guidong County. |
| | ❼ | Ziyunwanfeng Mountain Nature Reserve. Established 1982. Xinning and Chengbu Counties. |
| CHONGQING MUNICIPALITY (previously part of Sichuan Province) | ❽ | Wulong County. |
| | ❾ | Jinfo Mountains Nature Reserve. Established 1979. Nanchuan County. (*Cathaya nanchuanensis,* now regarded as an ecotype of *C. argyrophylla,* found here in 1955.) |

The generic name *Cathaya* derives from the historic place name Cathay, a dominion of the Mongol Emperor Kublai Khan at the time of Marco Polo's travels during the late thirteenth century, and now the northern section of today's China. However, the areas of the present day natural occurrence of *Cathaya* are actually outside the realm of what was known as Cathay in Marco Polo's time. Instead, they fall within another of Kublai Khan's dominions known as Mangi or Manzi, now the region of China south of the Yangtze River. So perhaps in a historical context the name *Mangia* would have been more appropriate, although without the appeal of implied antiquity in the name *Cathaya.*

### Guarding the Silver

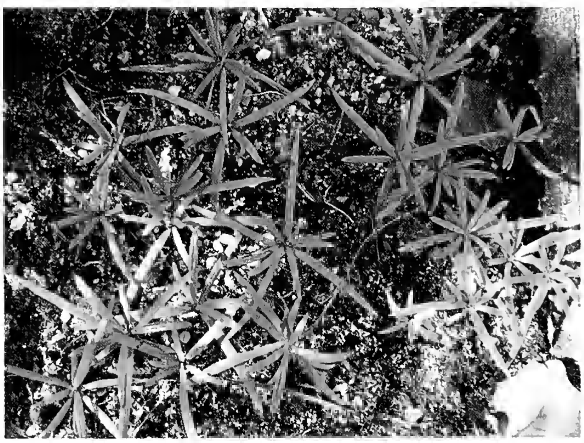
The significance of the discovery of the Cathay silver fir in 1955 was considered by the Chinese to be so important that they established Huaping Nature Reserve in 1961 to protect the first found population of the trees. This was one of the earliest nature reserves created in China. Since 1976 many more nature reserves have been established throughout China, and around 4,000 Cathay silver firs presently occur in about a dozen of these (see map).

Even when China opened to the west in the late 1970s, these nature reserves were generally off-limits to most foreigners. As late as 1997, I and my colleague S.K. Png of the Australian Bicentennial Arboretum, during a visit to Guizhou Botanical Garden in Guiyang, were steered clear of the natural stand of *Cathaya argyrophylla* growing in the forest reserve of the garden. A similar situation befell the authors of *Southwest China, Off the Beaten Track* while they were researching their book during the mid-1980s, and were discouraged from visiting Huaping Nature Preserve in Longsheng County,

AUSTRALIAN BICENTENNIAL ARBORETUM

**Seven- and ten-year-old trees at the Australian Bicentennial Arboretum are the first known *Cathaya* in cultivation outside of China to bear male and female strobili (a male strobus on the seven-year-old tree is shown here). In China, cultivated specimens are said to take as long as 17 years to bear male flowers and even longer to bear fruit.**

AUSTRALIAN BICENTENNIAL ARBORETUM



**A miniature forest of *Cathaya argyrophylla* seedlings emerges from a propagation flat.**

where *Cathaya argyrophylla* was first found. As they commented, "Longsheng County has a nature preserve, though what is there is anyone's guess since we could never get a straight answer". [Ed. note: William McNamara of Quarryhill Botanical Garden also had a challenging experience trying to see *Cathaya*—read his account on page 24]

Ultimately, China must have realized that one way to protect these rare and endangered trees in their natural habitat is to make them available for cultivation elsewhere. The earliest record I've found for *Cathaya argyrophylla* introduced outside China is a 1993 accession at the Royal Botanic Gardens, Sydney, Australia, The accession's exact fate wasn't recorded, but as of May, 2003, it was listed as "no longer in the nursery". However, since plants which had lost their identification labels in the botanic garden's nursery were sometimes sold at the annual Friends of the Garden's plant sales, it is at least possible that the oldest *Cathaya* in cultivation outside of China is growing unrecognized in a yard somewhere in Sydney.

The next earliest year for introduction of definitely surviving *Cathaya argyrophylla* is 1995 when seeds were received by the Royal Botanic Garden, Edinburgh, Scotland from Shenzhen Botanical Garden in China. These seeds were then redistributed by Edinburgh's Conifer Conservation Program to various other gardens,

**A juvenile plant of *Cathaya argyrophylla* growing at the Australian Bicentennial Arboretum.**

DENDROLOGICAL ATLAS PROJECT TEAM—ZSOLT DEBRECZY, ISTVAN RACZ

**A native stand of *Cathaya argyrophylla* grows on a steep, misty mountainside in China.**

including 50 seed sent to the Arnold Arboretum, where none germinated. The Arnold Arboretum received further seed in 1998 from Fairy Lake Botanical Garden in China, with excellent germination [Ed. note: Read more about *Cathaya* at the Arnold Arboretum on page 22].

Finally, seed was allowed out of China in commercial quantities in 1998. Worldwide, apart from botanical gardens, arboreta, and rare plant collectors, relatively few private individuals appear to have acquired this desirable conifer, although many have expressed interest in obtaining the plant if and when it becomes available.

### *Cathaya* in the landscape

Although not yet widely grown, Cathay silver fir certainly has potential as a landscape plant. It is beautiful as a young plant, and ultimately develops into a noble tree of about 20 meters (65 feet) or more tall with a columnar trunk and horizontal branching. Its long, narrow, evergreen leaves are about 4 to 6 centimeters (1.4 to 2.4 inches) long (sometimes longer), and 2.5 to 3 millimeters (.08 to .11 inches) wide. Leaf color is deep green. On the underside, two prominent silvery-white stomatal bands are separated by the midrib. This flash of silver provides the species with its specific epithet, *argyrophylla*, "with silvery leaves".

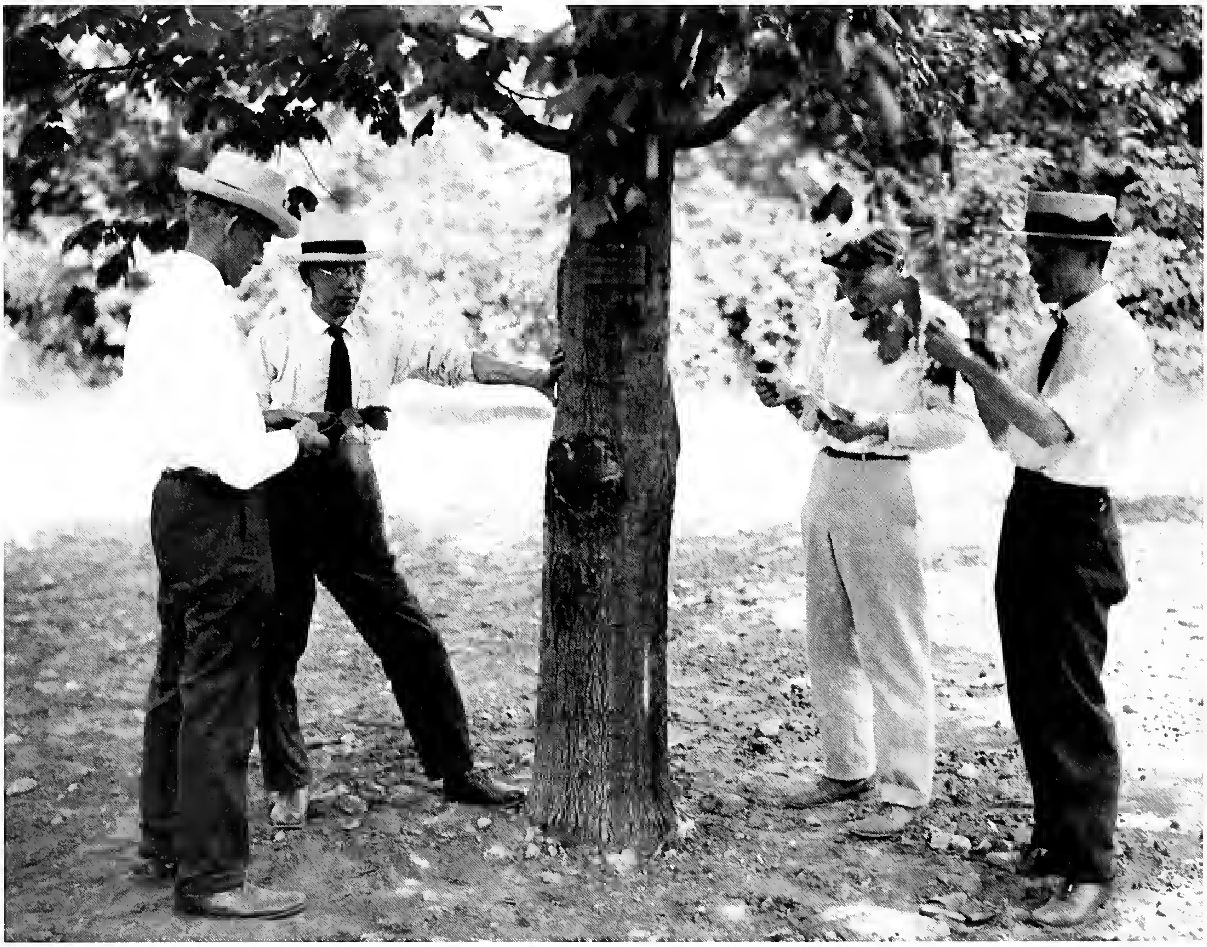
Surviving as it does in Chinese botanical gardens at Shanghai near the coast and Wuhan in central China, which experience minimum winter temperatures of -12°C ( 10°F) and -18°C (0°F) respectively, this rare and endangered tree should be hardy in USDA zones 7 or warmer. In slightly colder regions it may be suited to cultivation provided it is given a sheltered microclimate where it is protected from extremes of winter cold and freezing winds. In its native range Cathay silver fir experiences cool summers, winter snow, high humidity, and plen-

## Two Living Fossils and the Arnold Arboretum Connection

*Cathaya argyrophylla* co-author Chun Woon Young (Chen Huanyong) had undertaken dendrology courses with Professor John Jack at the Arnold Arboretum from 1915 to 1919 while completing graduate studies at Harvard's Bussey Institution. He was to comment that it would take him a lifetime of travel to learn as much about Chinese trees as he did while studying at the Arnold Arboretum for a few years.

Hsen Hsu Hu (Hu Xiansu), who was the lead author with W.C. Cheng in naming and describing the dawn redwood (*Metasequoia glyptostroboides*), also studied under John Jack from 1923 to 1925. Thus, both the monotypic "living fossil" conifers endemic to China, *Cathaya argyrophylla* and *Metasequoia glyptostroboides*, were named and described by pioneering Chinese botanists who undertook forestry courses at the Arnold Arboretum.

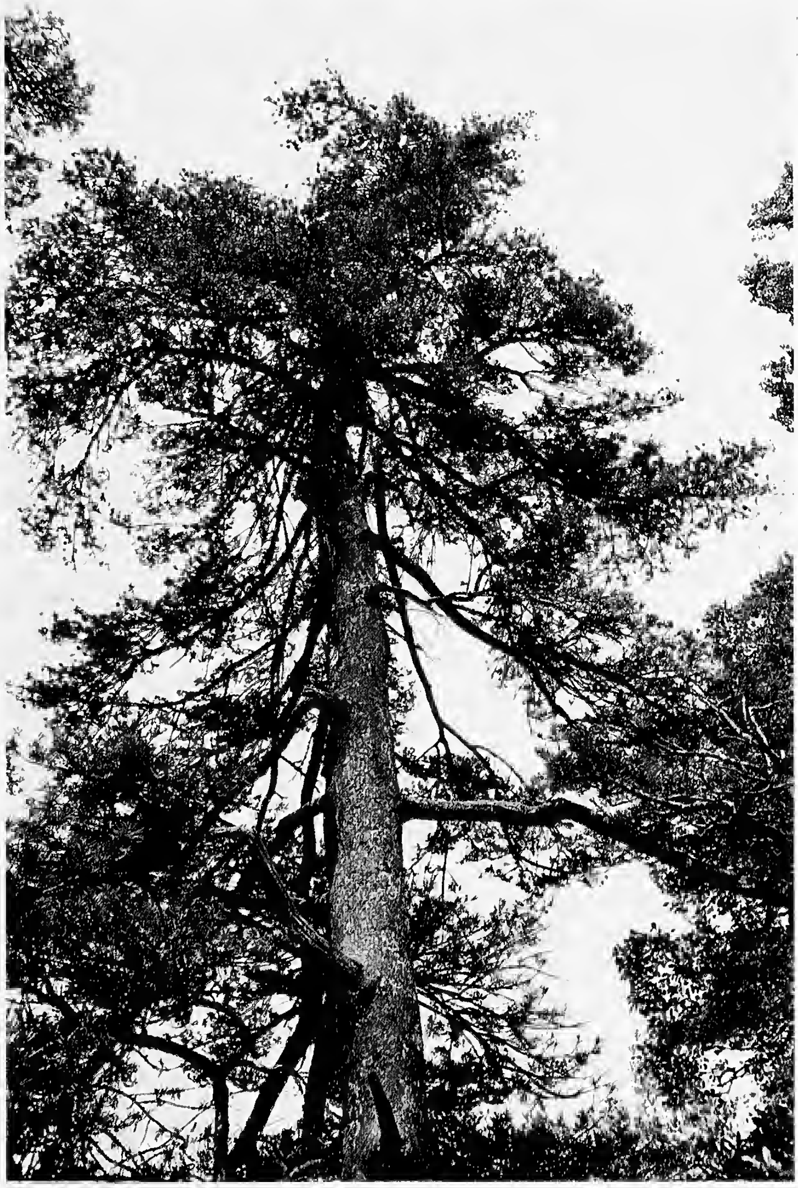
ARCHIVES OF THE ARNOLD ARBORETUM



**In this 1917 photograph, Professor John G. Jack studies a black maple with several students, including Chun Woon Young (Chen Huanyong) at right.**

tiful rainfall. When planted in the landscape it should grow best if it receives plenty of moisture, particularly in summer, and is situated in a sunny, well-drained site.

The Cathay silver fir is one of the most notable in a long line of rare, endemic, and endangered plants to come out of China, Ernest Wilson's "Mother of Gardens," and I suspect that there remain others yet to be discovered. We can only hope that they are found before human population pressure and the resultant clearing of ever-diminishing forested areas forces them to extinction, as is sadly happening throughout the world.



DENDROLOGICAL ATLAS PROJECT TEAM—ZSOLT DEBRECZY, ISTVÁN RÁCZ

**A mature Cathay silver fir displays its picturesque habit.**

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*(continues on page 25)*

## *Cathaya* Comes to the Arnold Arboretum

***Peter Del Tredici***

On October 21, 1998, like a bolt out of the blue, the Arnold Arboretum received an unsolicited packet of nearly 600 seeds of the extremely rare Chinese conifer *Cathaya argyrophylla* from the Fairy Lake Botanical Garden in the city of Shenzhen, Guangdong Province, China. We were excited about getting these seeds for two reasons: first, *Cathaya argyrophylla* is an endangered species endemic to China, with only limited distribution outside that country, and second, we had received seeds three years earlier, in 1995, but to our great disappointment they had failed to germinate.

When the *Cathaya* seeds arrived at the Arboretum they had no markings other than the name of the plant and the return address. It was all rather mysterious, and it wasn't until nearly three years later, during a chance encounter at the New York Botanical Garden, that I met Dr. Li Yong who told me that the seeds had been collected from wild trees growing in Zi Yuan County in Hunan Province, and that he had sent them to the Arnold Arboretum. Needless to say, I thanked him profusely for the wonderful gift.

The day after the seeds arrived at the Arboretum they were counted and divided up into various lots to test their germination following various periods of moist stratification in the refrigerator. Because we could find no written information about the dormancy requirements of the seeds, and because the species is native to a warm temperate–subtropical area, we made the assumption that the seeds probably required minimal chilling. Table 1 lays out the parameters and results of the seed germination experiment we set up in the Dana Greenhouses.

| Number of days of chilling | Number of seeds | Percent germination (Number of seedlings) | Number of days to first seed germination |
|---|---|---|---|
| 0 | 200 | 6 (12) | 170 |
| 57 | 100 | 21 (21) | 24 |
| 70 | 100 | 31 (31) | 29 |
| 112 | 159 | 74 (118) | 18 |

**Table 1. Germination of seeds of *Cathaya argyrophylla* which were sown or moist stratified on October 22, 1998.**

Despite our best guess, the seeds which received four months of cold stratification germinated much faster and in much higher percentages than seeds which received less than seventy days of chilling. So much for a propagator's intuition. By the time the experiment ended in July 1999, we had potted up a total of 182 seedlings, which made for an overall germination rate of 32.6%.


**This ten-year-old *Cathaya argyrophylla* was transplanted to the Arboretum grounds in spring 2008. From the botanical perspective, this species is intriguing because it occupies an intermediate position within Pinaceae, sharing certain morphological similarities with true pines (*Pinus*), Douglas firs (*Pseudotsuga*), and spruces (*Picea*).**

On April 5, 2000, the Arboretum distributed 79 seedlings to various botanical gardens throughout the United States, keeping about a dozen plants for ourselves. Several of our plants grew well; by spring of 2006, after eight growing season, the three biggest plants were 1.2, 0.8, and 0.7 meters (4, 2.6, and 2.3 feet) tall. Five of the biggest seedlings were moved from the shade house to the nursery in June of 2006, but three of them failed to survive the transplanting. Only one plant was still alive by April 2008, when it was planted out on the grounds. Our fingers are crossed that it will survive its first winter out on the grounds. As for the seedlings that we distributed back in 2000, the Mendocino Botanical Garden and the University of California Botanical Garden in Berkeley have both reported having plants that are still alive.

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Peter Del Tredici is a Senior Research Scientist at the Arnold Arboretum.

## An Excerpt From: *Three Conifers South of the Yangtze*

***William McNamara***

Our final goal was to reach the Jinfu Shan, the mountainous home of the extraordinary conifer *Cathaya argyrophylla* ... After a good night's rest in a fairly decent hotel in Nanchuan, we eagerly headed to the jeeps for the drive up into the Jinfu Shan. To our surprise, blocking the gate to the hotel were at least a dozen people arguing with Dr. Yin and Professor Zhong. Apparently several of them were determined to keep us from visiting the Cathaya. There was a representative from the local police, the local tourist bureau, the forestry department, the public security bureau, the Chinese army, the mayor's office, and who knows what else. All were yelling and throwing their arms up in the air. Finally they agreed that we could go see the trees but stated emphatically that we would not be allowed to touch or photograph them. At this point the argument was on the verge of getting seriously out of control. Dr. Yin then made a phone call to the governor, who told the troublemakers that we could indeed visit and photograph the valuable resource Yinshan, the Chinese name for *Cathaya argyrophylla*, as we were important scientists from England and America.


WILLIAM MCNAMARA

**The expedition's reward: seeing the silver-backed foliage of *Cathaya argyrophylla* in person.**

Two and a half hours later our jeeps, with an escort of six Chinese to keep us under control, were climbing up steep, mist-covered mountains. We stopped at about 1700 meters (5600 feet) elevation in an area of dense bamboo ... We then hiked in a light rain for about 20 minutes, slightly uphill, to a large limestone outcrop about 15 meters (50 feet) high and wide. Our Chinese escorts pointed to the top of the outcrop and said, "There they are." Through the mist we could barely make out several conifers growing on the top. As we stood there wondering if they would let us climb up to view them closer, we noticed that someone had already rendered that nearly impossible. Everywhere that it might have been possible to climb, the limestone outcrop had been altered to prevent that possibility. Cracks that might have been footholds had been filled in with concrete, rough areas that might have served as grips were smashed smooth, and in areas of easy accessibility, barriers of rock and concrete had been installed. Someone was undoubtedly determined to keep people away from the *Cathaya*. As we looked around, clearly frustrated and not trying very hard to disguise it, the Chinese surprised us all by picking up a small fallen tree and leaning it against the outcrop. They then found another similar log and together with the other, they created a makeshift ladder. Several minutes later, after pushing and pulling each other up onto the top of the outcrop, we were standing in a grove of *Cathaya*. Our hosts further surprised us by telling us that it was all right to climb the trees and to take an herbarium specimen.

The dozen or so trees averaged about 10 meters (33 feet) in height and superficially resembled short-needled pines... After a good half hour of climbing, examining, and photographing the trees, we slowly made our way back down the outcrop. The rain intensified as we walked back to the road. While getting into the jeeps, our escorts told me that I was the first American to see *Cathaya argyrophylla* in the wild. Though very suspect of that statement, and rather cold and wet, I was nonetheless very happy to have seen, photographed, and even climbed the *Cathaya*.

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William McNamara is Executive Director at Quarryhill Botanical Gardens in Glen Ellen, California. Full article at: http://www.quarryhillbg.org/page16.html

*(continued from page 21)*


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Christopher B. Callaghan is a plant researcher and Curator of Living Collections at the Australian Bicentennial Arboretum.

# The Li Jiawan Grand Ginkgo King

*Zhun Xiang, Yinghai Xiang, Bixia Xiang, and Peter Del Tredici*

The largest *Ginkgo biloba* tree in the world, the Li Jiawan Grand Ginkgo King, is located about a hundred kilometers west of Guiyang, the capital of Guizhou Province, China. The tiny hamlet of Li Jiawan (26°39' N and 107°25' E) is too small to appear on any maps. Administratively, Li Jiawan is part of Lebang Village, which is part of Huangsi Town in Fuquan County.

The Grand Ginkgo King is growing at an altitude of 1,300 meters (4,265 feet) in a narrow valley where it towers over the surrounding bottomland vegetation, which consists mainly of cultivated crops (Figure 1). It is a male tree, about 30 meters (98 feet) tall, with a ground level trunk diameter of 460 centimeters (181 inches) in the east–west orientation and 580 centimeters (228 inches) in the north–south direction. Its circumference at breast height is 15.6 meters (51 feet) and its canopy shades an area of roughly 1,200 square meters (13,000 square feet). The primary "trunk" is completely hollow and encloses an area of 10 to 12 square meters (108 to 130 square feet), more than enough for seating a dinner party of ten people. Indeed, during the 1970s, an old man by the name of Pan Shexiang, accompanied by his cattle, lived in this natural tree cave for two years.

The inside of the trunk—up to a height of about 5 meters (16 feet)—is charred black from lightning-ignited fires (Figure 2). The outside of the trunk shows no signs of fire, but has a ragged appearance caused by the excessive amount of callus tissue that has formed between the new branches and old trunks. In addition, large hanging chichi (downward growing shoots that look something like stalactites) have developed in response to various wounds and breaks, adding more confusion to the convoluted woody excrescences that cover the trunk. As battered as the outside of the tree appears, however, it maintains a vigorous hold on life, as attested to by the presence of numerous young shoots sprouting out all over the tree (Figures 2 and 3).

Chinese investigators have determined that the Grand Ginkgo King is a "five-generations-in-one-tree" complex. In other words, the first generation was a normal seedling which—as a result of repeated sprouting from the base over the course of several millennia—produced four succeeding generations of trunks, each of which has continued the tree's growth and development after the preceding generation was damaged or died (Figure 4). The tree, as we know it today, is the result of at least five generations of stems produced over the course of thousands of years. There are five distinct trunk sectors which are separate at ground level but are partially merged at the height of about a meter (3.3 feet) above the ground, and new branches often sprout from the tissue between trunk sectors. While each trunk section seems to be physiologically independent, the secondary fusion creates the appearance of a single tree (Figures 2 and 3).

**Age Estimation**

Extensive field work has shown that the Li Jiawan Grand Ginkgo King is the biggest (in terms of trunk diameter) ginkgo tree in the world, a fact what was recognized by the Guinness Book of World Records in 1998. The question of how old the tree might be is unclear given that its internal tissues—with all their growth rings—are totally gone. What we do know, however, is that ginkgo trees of different ages have very different appearances and growth characteristics, and that different generations of ginkgo trunks typically have different growth rates and different longevities. We have come up with a rough estimate of the Grand Ginkgo King's age based on what we know about the ages of other ancient ginkgo trees in China with a similarly complex developmental history: the first generation stem(s) can typically reach up to 1,200 years of age, the

P. DEL TREDICI

**Figure 1. The Li Jiawan Grand Ginkgo King as it appeared in September 2002.**

second generation stems live for about 1,000 years, the third 800 years, the fourth 600 years, and the fifth about 400 years. According to this highly theoretical formula, the Li Jiawan Grand Ginkgo King has a maximum estimated age of around 4,000 to 4,500 years.

### Legends and Romance

The Grand Ginkgo King has been living for thousands of years without an official record in the history books of the local government. However, there are many folk legends surrounding this tree. Writer Shixian Xu described one of these legends:

During the Tang dynasty there was a scholar named Bai who had recently gained a governor's position by winning a national competition. At some point after taking office, Bai had a fight with a treacherous court official who had done a lot of bad things to the ordinary people. Given that bad officials typically protect each other, the scholar Bai was punished for his actions and sent off to an isolated army camp. On the way there, he was severely beaten and eventually died from his wounds. His body was buried at Li Jiawan by the local people, who deeply loved this scholar who tried to help ordinary people. Soon afterwards, a huge tree grew out from the tomb. This tree was considered the avatar of scholar Bai and given the name "bai guo tree" (one of the Chinese names for *Ginkgo biloba*).

Another story about the origin of the tree dates from the Ming dynasty and holds that the Li Jiawan Grand Ginkgo tree transformed itself into a scholar and entered a national competition. The tree-scholar won the championship and was appointed to be a high official by the king. When the tree-scholar failed to show up for the position, the king sent two messengers to find him, both of whom were killed when they came back empty handed. The third messenger that the king sent was worried about his own safety since he too could find no trace of the mysterious scholar. During his disturbed sleep one night, he had a dream in which a person appeared calling himself "Bai." At this point

DRAWING BY YINGHAI XIANG.

**Figure 2. The Li Jiawan Grand Ginkgo King.**

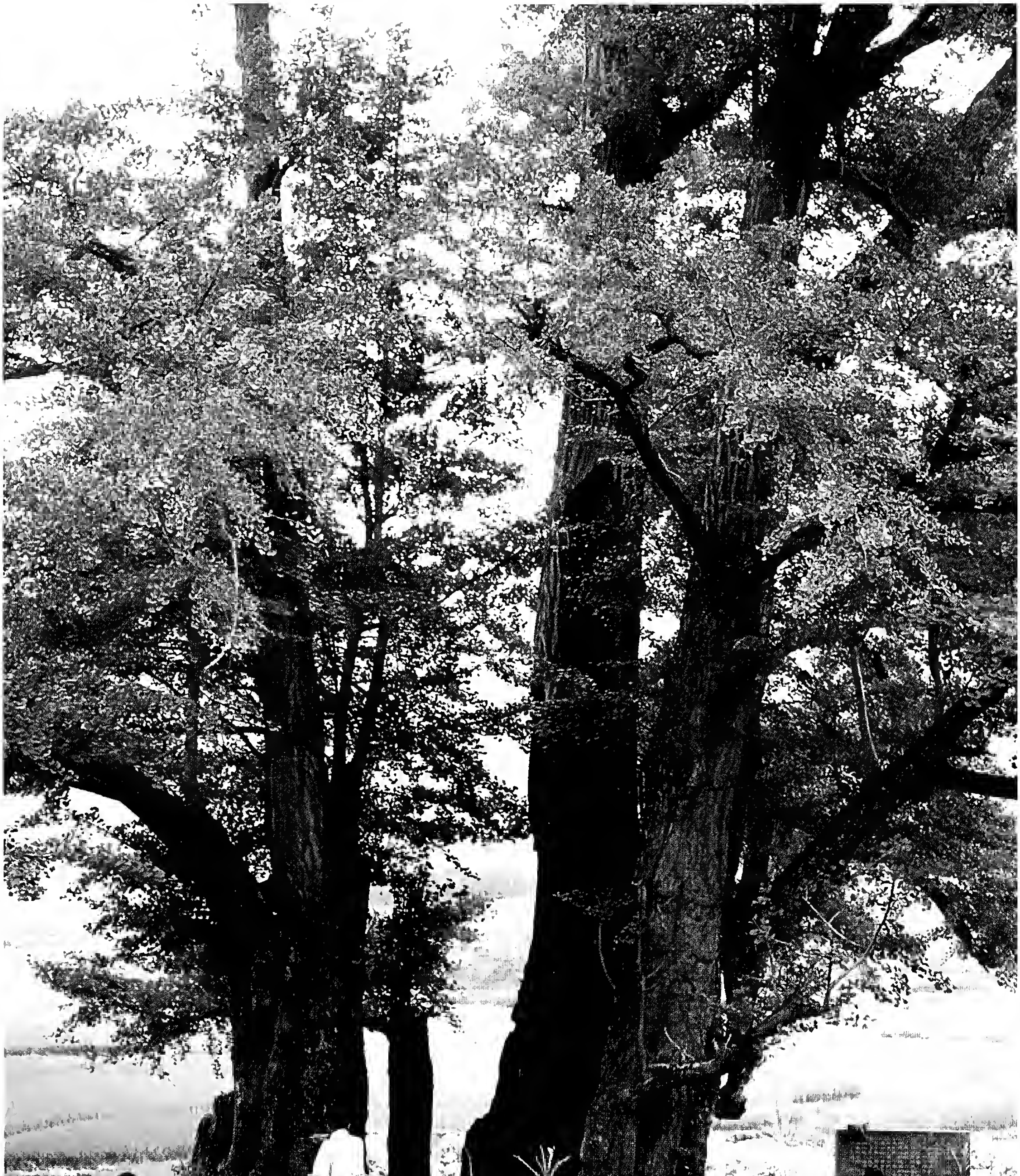

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**Figure 3. The multi-generational trunk of the Li Jiawan Grand Ginkgo King.**

DRAWING BY YINGHAI XIANG.

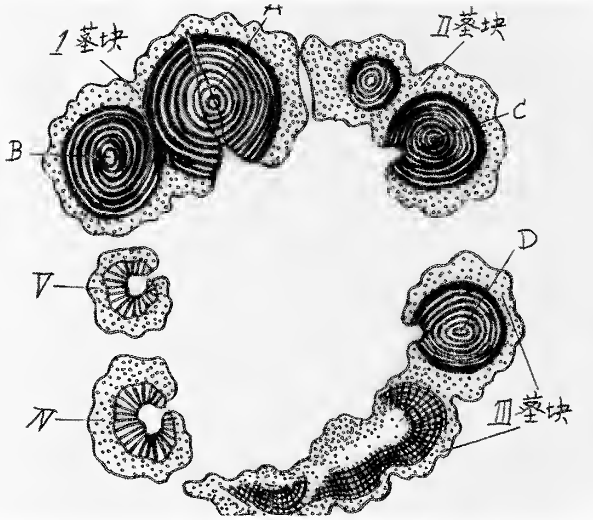


**Figure 4. A cross-section of the Li Jiawan Grand Ginkgo King at ground level: Part 1 has two trunks: A, 30 meters (98 feet) tall, 110 centimeters (43 inches) diameter; B, 20 meters (66 feet) tall, 90 centimeters (35 inches) diameter; Part 2 has produced trunk C with a height of 28 meters (92 feet) and diameter of 80 centimeters (31 inches); Part 3 has trunk D of height of 28 meters (92 feet) and diameter of 60 centimeters (24 inches). The smallest and youngest trunks, Parts 4 and 5, have produced many small, weak stems, only a few meters tall, which seem to have lost their capacity to grow into upright trunks.**

the messenger woke up and saw an official's hat hanging on the top of a nearby ginkgo tree and immediately understood that the scholar and the tree were one and the same.

This story—that the ginkgo tree had changed to a spirit—is an astonishing, age-old story, and there are lots of "big tree changed to spirit" stories in the south of China. Luckily, people usually worship such "spirit trees" and don't dare to damage them. Many of these trees grow in temple courtyards or on sacred mountains and are preserved out of respect for the spirits that inhabit them but, unfortunately, this kind of conservation is not good enough to protect trees in the modern world.

## What the Future Holds

The Li Jiawan Grand Ginkgo King was seriously damaged and its overall appearance dramatically changed by a storm in July, 1991, in which the biggest trunk on part 2 was broken off (Figure 4). The stem was pruned off below the break, but the resulting scar still looks fresh with no sign of callus growth to cover it over. It is also worth noting that for eighteen years there have been no new sprouts from part 3. Such a loss of normal regenerative function suggests that the Li Jiawan Grand Ginkgo may be losing its vigor. Based on what we have seen of other multigenerational trees, it is predictable that the Li Jiawan Grand Ginkgo will get smaller over time rather than bigger and that in 50 to 100 years or so it will be dead.

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NANCY ROSE

**Fireworks for the New Year: *Hamamelis* x *intermedia* 'Jelena'.**

# An African Fir Grows in Boston

*Kyle Port*

The Arnold Arboretum's Conifer Collection offers visitors an opportunity to explore gymnosperms collected from around the world. While Eastern Asian, European, and North American species dominate the collection, a solitary Moroccan fir, *Abies pinsapo* var. *marocana,* stands as an exceptional North African taxon.

Grown from seed collected by former Arboretum plant propagator Rob Nicholson on Mt. Tisouka near Chefchaouen, Morocco, in 1982, specimen 1435-82-A has thrived undamaged in the landscape for 15 years. It is one of two plants of accession 1435-82 that were moved from the Arboretum's Dana Greenhouse to the grounds on September 21, 1993. One plant did not survive transplantation and was noted as dead in the spring of 1994. The lone survivor, which was approximately 4.3 feet (1.3 meters) at the time of transplant, is now a stunning exemplar at 28 feet (8.5 meters) tall with a DBH (diameter at breast height) of 12.6 inches (32 centimeters).

Conical in youth, the tidy habit of this specimen has opened slightly over the years to reveal smooth gray bark. Radially arranged needles persist for 11 to 13 years, giving even older branches an armored appearance. The dark green needles are streaked with 7 to 11 silvery stomatic lines on the upper surface; the lower surface is marked with two pronounced stomatic bands on either side of the midrib. Unlike the characteristically soft-to-the-touch foliage of most *Abies,* the needles of *Abies pinsapo* var. *marocana* have sharply pointed apices, making the foliage far less friendly to fingers. The upright cylindrical cones typical of the species have not yet been observed on this specimen but can be expected soon; sexual maturity for Moroccan fir is typically reached when the trees are between 25 and 35 years old.

Described by French botanist Louis Charles Trabut in 1906 as *A. marocana,* the Moroccan fir is confined to the Rif Mountain Range of Morocco, growing at altitudes between 4,600 and 6,900 feet (1,400 to 2,100 meters). The calcareous soil of this region supports associated taxa, and notes from the Arnold Arboretum's collecting trip detail an open fir forest containing *Cedrus atlantica, Acer* (*A. opulus* ssp. *hispanicum, A. campestre, A. monspessulanum*), and *Paeonia* (*P. coriaceae* var. *maroccana*).

Rare in cultivation, the International Union for Conservation of Nature and Natural Resources considers *Abies pinsapo* var. *marocana* to be a "near threatened" species, an indicator that it could become threatened in the wild in the near future. Human activities (logging, expansion of cultivated areas, population growth) and climate change may further restrict the range of this taxon. However, preservation efforts are ongoing and the establishment of the Talassemtane National Park, which contains the only remaining Moroccan fir forest, was celebrated by conservation organizations in 2004.

**Related species:**

*Abies pinsapo* 'Glauca', blue Spanish fir, is also represented in the Arboretum's collection (accession 192-42-A, obtained from W.B. Clarke and Company, San Jose, California). Planted in the fall of 1954, this blue-hued cultivar is topped with dozens of cones this year. Separated from the Moroccan fir by the Straits of Gibraltar, the Spanish Fir (*Abies pinsapo* var. *pinsapo*) is endemic to the Sierra de Ronda in Southern Spain.

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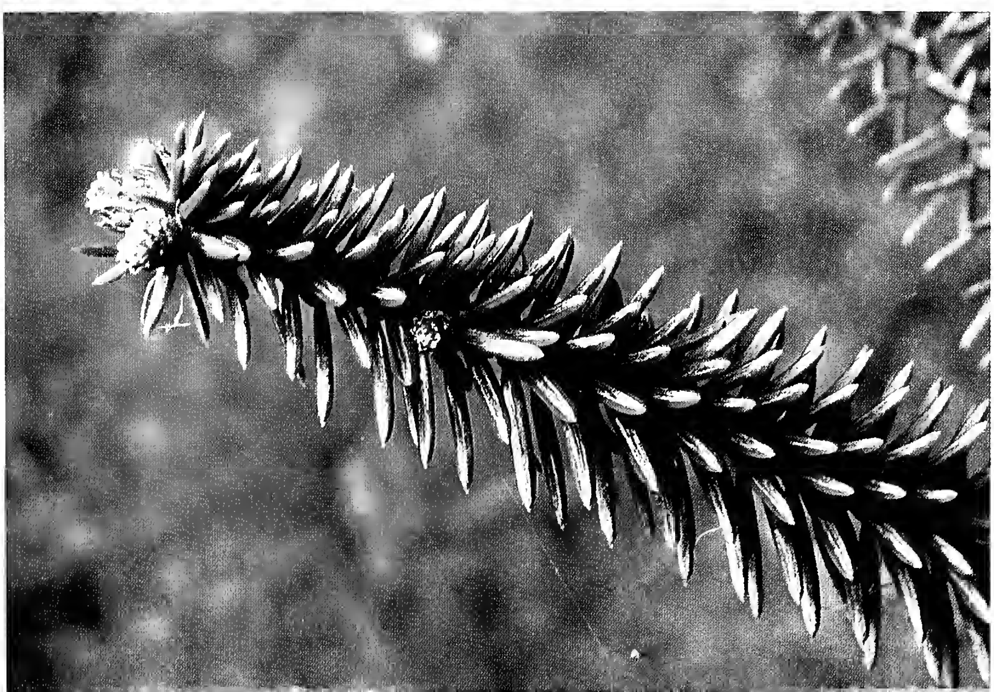
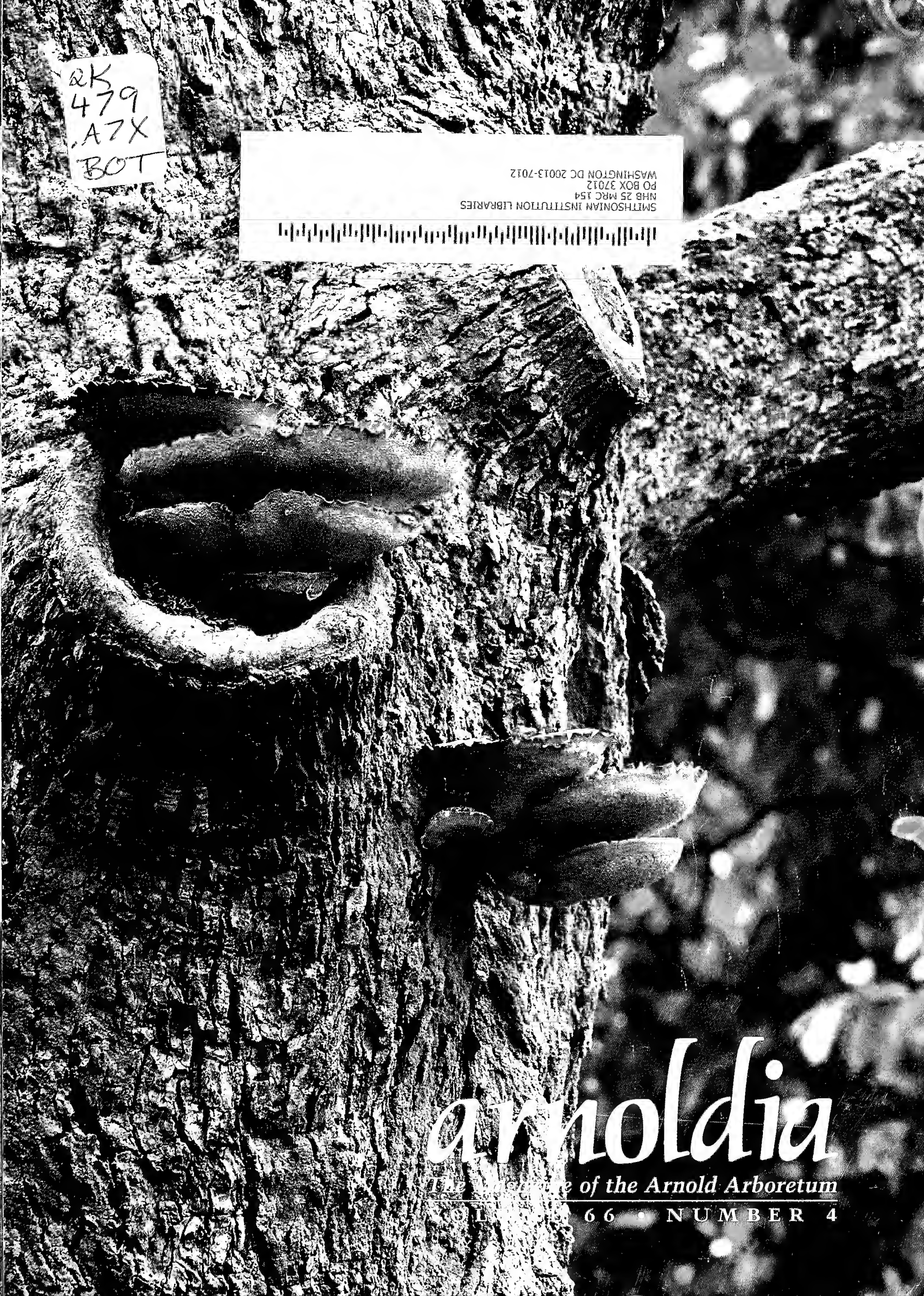
Kyle Port is Manager of Plant Records at the Arnold Arboretum.









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The ARNOLD ARBORETUM of HARVARD UNIVERSITY

**CONTENTS**



*Front cover:* Fungi feature prominently in this issue, which includes curatorial assistant Kathryn Richardson's article on Arboretum fungi. Turn to page 15 to read about this pheasant's-back polypore growing from an old cucumbertree magnolia (*Magnolia acuminata*, accession 15154-E) near the Arborway Gate. Photo by Nancy Rose.

*Inside front cover:* April 22, 2008: A fine day for a bumblebee to visit the dangling yellow flowers of *Corylopsis sinensis* var. *glandulifera*. Month-by-month details of weather at the Arboretum are featured in the 2008 weather summary. Photo by Nancy Rose.

*Inside back cover:* Deputy director Richard Schulhof profiles one of the Arboretum's hidden gems, an impressive specimen of Japanese clethra (*Clethra barbinervis*) accessioned in 1886. Photo by Richard Schulhof.

*Back cover:* When Charles Faxon drew this illustration of butternut (*Juglans cinerea*) for C. S. Sargent's *Silva of North America* (volumes published from 1891 to 1902), butternut canker disease had not arrived. Researchers Keith Woeste and Paula M. Pijut describe butternut's current state in their article.

# The Peril and Potential of Butternut

*Keith Woeste and Paula M. Pijut*

Butternut (*Juglans cinerea*), also known as white walnut because of its light-colored wood, is a short-lived, small- to medium-sized tree (40 to 60 feet [12 to 18 meters] tall; 30 to 50 feet [9 to 15 meters] crown spread) (Fig. 1). Butternut's native range includes most of the northeastern United States and southern Canada from New Brunswick to Georgia, and west to Arkansas and Minnesota (Rink 1990; Dirr 1998) (Fig. 2). Butternut often grows in widely scattered clusters, with each cluster containing a few individual trees. It was never a highly abundant species (Schultz 2003), but for reasons that will be described later, it is even less common now than before. The former prevalence of—and appreciation for—butternut in the landscape is reflected evocatively by the many Butternut Hills, Butternut Creeks, and Butternut Lakes found across the eastern United States.

**Figure 1. Researchers collect samples from a true butternut growing in Daniel Boone National Forest, Kentucky.**

Butternut is a member of the walnut family (Juglandaceae), which includes many familiar nut trees including eastern black walnut (*Juglans nigra*), Persian or English walnut (*J. regia*), pecan (*Carya illinoinensis*), and all the hickories (*Carya* spp.). How butternut relates to the other walnuts remains a puzzle. Early taxonomy placed butternut in its own section within *Juglans* (*Trachycaryon*), but more recent treatments place it with Japanese walnut (*J. ailantifolia*) and Manchurian walnut (*J. mandshurica*) in section *Cardiocaryon* (Manning 1978; Fjellstrom and Parfitt 1994), or with the New World walnuts (*Rhysocaryon*) (Aradhya et al. 2007). Butternut cannot hybridize with eastern black walnut, but it can hybridize with Persian walnut to form *J.* × *quadrangulata*, and with Japanese walnut to form *J.* × *bixbyi* (USDA-NRCS 2004). Of all the walnuts, butternut is considered to be one of the most winter-hardy, to USDA Zone 3 (average annual minimum temperature -30 to -40°F [-34 to -40°C]).

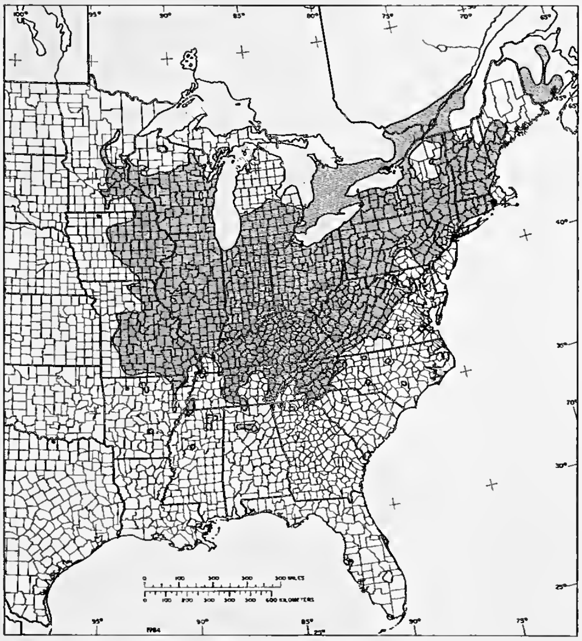
### Food, Furniture, and Forage

Butternut has a long history of usefulness. Native Americans extracted oil from the crushed nuts by boiling them in water, made syrup from the sap (Goodell 1984), and threw butternut bark (which contains toxins) into small streams to stun and capture fish. They taught early European settlers how to make medicine from butternut bark, roots, and husks (Johnson 1884; Krochmal and Krochmal 1982). The inner bark of butternut and its nut hulls can be used to produce a yellow-brown dye. This dye was used most notably on some of the Confederate Army's Civil War uniforms, giving rise to the practice of referring to southern troops and their sympathizers as "butternuts" (Peattie 1950).

Butternut is valued economically and ecologically today for its wood and edible nuts (Ostry and Pijut 2000) (Fig. 3). The sweet, oily, edible nuts are used in baked goods and are also popular for making maple-butternut candy. Butternuts were often planted near homes on farmsteads for the use of the nuts. There has been limited selection of butternuts for nut quality and production (McDaniel 1981; Goodell 1984; Miliken and Stefan 1989; Miliken et al. 1990; Ostry and Pijut 2000), but a few butternut cultivars with large nut size and superior ease of cracking (e.g., 'Chamberlin' and 'Craxezy') have been propagated, and some of these are available from commercial nurseries.

The nuts are also an important food source for wildlife. In forests, butternut trees produce seed at about 20 years of age, with good seed crops occurring every two to three years (Rink 1990). Open-grown trees, which benefit from more sun and less competition, can begin bearing as early as five years of age and bear annually under ideal conditions.

The sapwood of butternut is light tan to nearly white and the heartwood is light brown (Fig. 4). The wood is moderately hard, but workable; it saws and carves easily, finishes well, and resembles black walnut when stained. The commercial availability of butternut wood is now extremely limited, but quality butternut

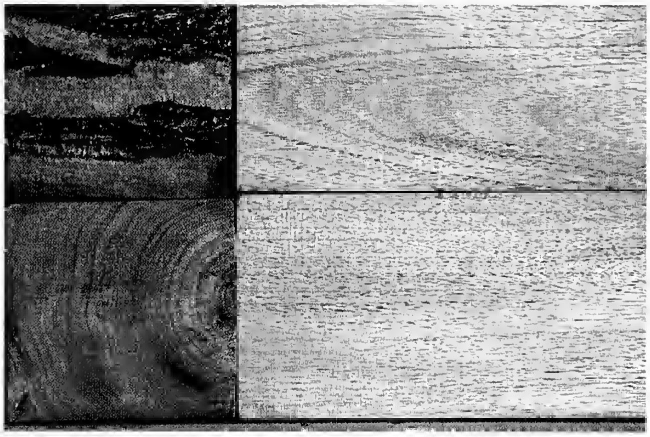


RINK, G. 1990

**Figure 2. The native range of butternut.**

BILL COOK, MICHIGAN STATE UNIVERSITY, BUGWOOD.ORG

**Figure 3. Butternut fruits have thick husks covered with sticky glandular hairs. Inside the husk is an edible nut enclosed in a thick, hard shell that is elaborated with eight prominent ridges (Brinkman 1974; Flora of North America Editorial Committee 1993+).**



NANCY ROSE

**Figure 4. Butternut wood samples: (clockwise from upper left) bark, slab-sawn, quarter-sawn, and cross-section (note darker brown heartwood). From the Ralph F. Perry wood collection at the Arnold Arboretum.**

COURTESY OF GREY TOWERS NATIONAL HISTORIC SITE

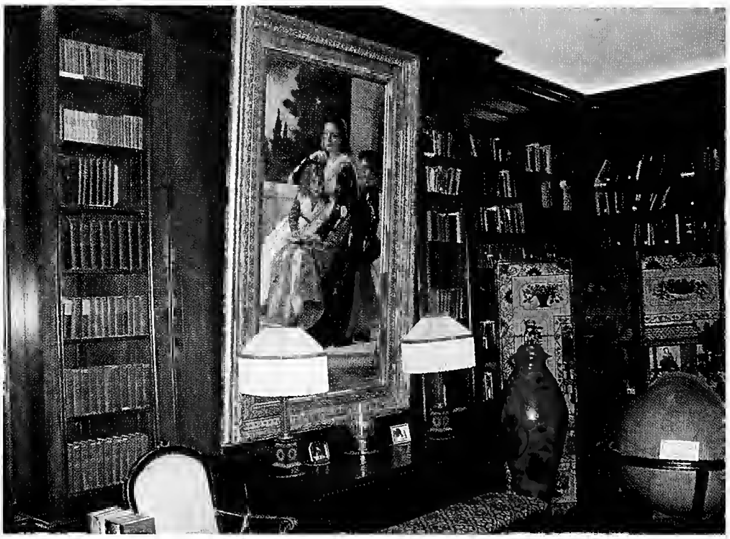


**Figure 5. The library at Grey Towers National Historic Site is paneled in butternut.**

wood commands a high market price today for many uses including furniture, veneer, cabinets, paneling, specialty products such as instrument cases, interior woodwork, and fine woodworking. The library of Grey Towers, a National Historic Site near Milford, Pennsylvania, and formerly the home of Gifford Pinchot, the first chief of the United States Forest Service, is paneled entirely with butternut (Fig. 5).

### A Deadly Disease Arrives

Sadly, a devastating canker disease has caused range-wide butternut mortality in recent decades and threatens the survival of the species. Unusual stem cankers were first observed on butternuts in southwestern Wisconsin in 1967 (Renlund 1971). A pest alert announcing butternut decline was issued in 1976 (USDA 1976), and by 1979, the fungus responsible for butternut canker disease, *Sirococcus clavigignenti-juglandacearum*, was described as a new species (Nair et al. 1979). Surveys of butternut trees in Wisconsin in the 1990s revealed that 92% were diseased and 27% were dead (Cummings-Carlson 1993; Cummings-Carlson and Guthmiller 1993). By the early 1990s butternut canker was reported in Canada (Davis et al. 1992), and butternut is now considered an endangered species in that country. In 1992, the state of Minnesota placed a moratorium on the harvest of healthy butternut on state lands, and butternut is considered a species of special concern in all United States National Forests.

Although the origin of the fungus is uncertain (evidence suggests it may have come from Asia), it is believed to have been introduced into North America as a single isolate (Furnier et al. 1999). Butternut trees of all ages and sizes, regardless of site conditions, can be infected. The spores of the fungus are spread by rain splash and aerosols to adjacent trees where new infections originate at leaf scars, lateral buds, bark wounds, and natural bark cracks. Perennial cankers eventually develop on twigs, branches, stems, and even the buttress roots (Tisserat and Kuntz 1983). Cankers can be seen most easily if the bark is removed, revealing a sunken, elliptically-shaped region of dark brown to black stained wood, often with an inky black center and a whitish margin (Ostry et al. 1996) (Fig. 6). Cankers reduce the quality and marketability of the wood, and the girdling effect of multiple coalescing cankers eventually kills a host tree.

PHOTO ON LEFT BY KEITH WOESTE. PHOTO ON RIGHT USDA FOREST SERVICE – FOREST HEALTH PROTECTION – ST. PAUL ARCHIVE, USDA FOREST SERVICE, BUGWOOD.ORG

**Figure 6. Healthy butternut (left), and tree with bark removed showing cankers (right).**

While its spread to adjacent trees is understood, just how the fungus travels long distances to find new hosts remains a mystery. Several beetle species have been found on infected trees carrying fungal spores (Katovich and Ostry 1998; Halik and Bergdahl 2002), but it is not known which species (if any) carry spores over long distances. The fungus has also been found on the fruits of butternut and black walnut, causing lesions on the husks of both species (Innes 1998), which means that the movement of seeds can also spread the disease.


KEITH WOESTE

**Figure 7. Foresters identified this healthy butternut in a central Indiana forest.**

### Conservation and Restoration of Butternut

There is no cure for butternuts once they become infected with butternut canker. In order to maintain butternut populations, conservationists must rely on a strategy of encouraging the growth of as many young, healthy trees as possible. The methods used include the management of regeneration (often by improving local habitats for seedling establishment) and reintroduction (for example, planting butternuts into suitable habitats from which they have been lost) (Ostry et al. 1994).

Butternut is a pioneer species, its seedlings require full sun to thrive (Rink 1990), and the presence of areas of exposed soil seems to benefit its establishment (Woeste, personal observation). These factors explain why young butternuts tend to be found now on road-cuts, steep terrain, fence-rows, old fields, clear-cuts, washouts, and the banks of swiftly flowing streams. The management of most hardwood forests—both public and private—favors minimal disturbance, so there are relatively few large, sunny openings for butternut seedlings to find a foothold. Browsing and antler rubbing by deer also limit the growth and survival of butternut seedlings in the few sites sunny enough to support regeneration (Woeste et al. 2009).

Butternut canker, of course, also plays an important role in reducing the natural regeneration of butternut (Ostry et al. 1994). A high percentage of the mature butternuts growing in the eastern forest are cankered, and infected trees have limited energy reserves to put towards flower and fruit production. Because butternuts almost never self-pollinate (Ross-Davis et al. 2008b), when a high percentage of the trees in an area become diseased or are killed, the number of potential mates can be reduced to the point that adverse genetic and demographic consequences become likely (Geburek and Konrad 2008).

For all the above reasons and more, poor natural regeneration has been a hallmark of the butternut canker epidemic (Ostry and Woeste 2004; Thompson et al. 2006). Until we learn how to effectively assist natural regeneration of butternuts, reintroduction will be needed to restore butternut populations to the eastern

KEITH WOESTE

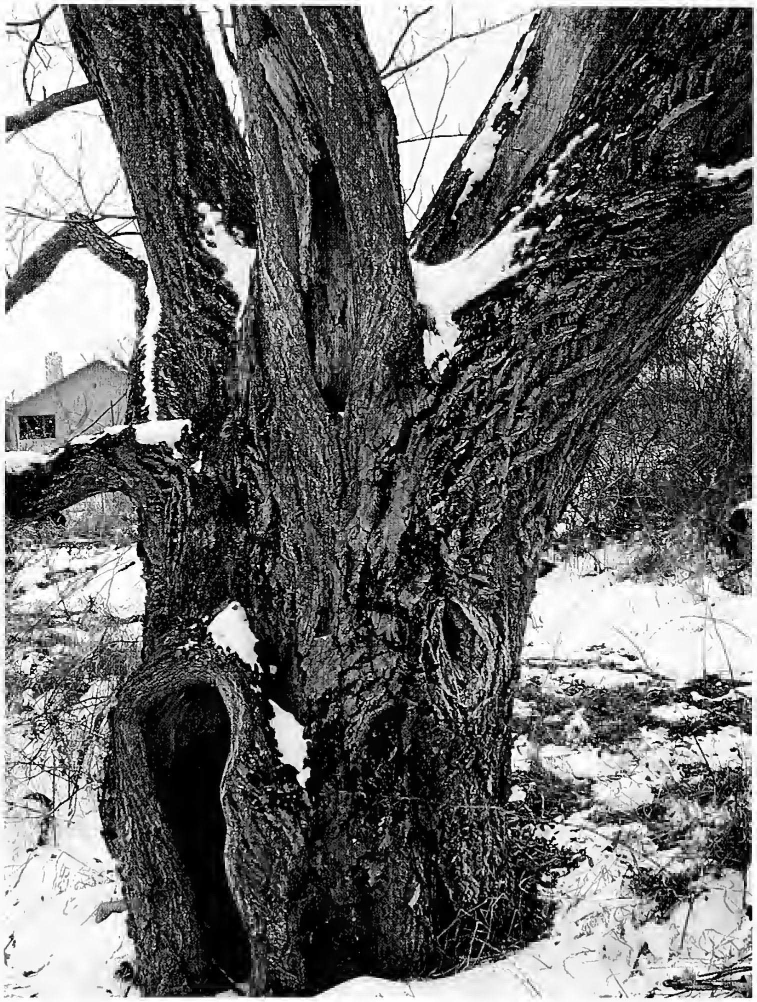


**Figure 8. The trunk of a very old buart growing in central Indiana.**

forest. Reintroduction, whether by afforestation (establishing plantations on old fields) or by supplemental planting in existing habitats, requires a ready source of seeds. Seeds from genetically diverse and locally adapted sources are preferred (Broadhurst et al. 2008). Because seed supplies from wild trees are so unreliable, numerous state and federal agencies as well as private nurseries have worked over the past 20 years or so to document the location and health of butternut trees that could be used as seed sources (Fig. 7). Others have collected and grown butternut trees to provide seeds that will be needed for reintroduction.

These collections constitute a germplasm repository for butternut, a living bridge to the future, and a method for preserving the genetic diversity of the species in the face of a devastating population crash. Butternut collections must be conserved as living specimens growing in arboreta or other repositories because butternut seeds do not remain alive in long-term storage (even controlled-environment seed banks) unlike the seeds of many other species (Bonner 2008). Butternut can be propagated vegetatively by cuttings (Pijut and Moore 2002), through tissue culture (Pijut 1997; Pijut 1999), and by grafting.

The ideal seed source for butternut reintroductions would be an orchard of genetically diverse, locally adapted, and canker-resistant butternut trees. Starting in the 1980s, a small group of scientists began identifying, grafting, and growing butternuts that appeared healthy even though they were growing in locations with many dead or diseased trees (Ostry et al. 2003). It was assumed that these candidate trees had been exposed to the canker disease fungus, but because they remained healthy—or at least sufficiently healthy to continue to grow and reproduce—it was hoped that some of them would have genes for resistance to butternut canker. By the late 1990s, about 200 of these trees had been identified by Dr. Michael Ostry of the USDA Forest Service – Northern Research Station in St. Paul, Minnesota, and other colleagues.

**Butternut or Buart?**

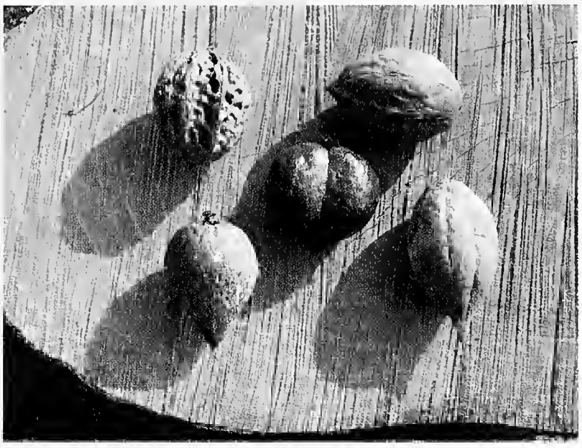
By growing a large number of butternuts together in one location, Ostry and others were able to observe differences among these trees that had not been obvious at the time of collection. Differences in traits such as nut size and branch habit led him to wonder if some of the collected butternuts were, in fact, buarts (Ostry and Moore 2008). A buart (pronounced *bew*-art), also called a buartnut, is the common name for *Juglans* × *bixbyi* (hybrids between butternut and the exotic Japanese walnut) (Fig. 8). Buarts were well known among nut growing enthusiasts in the United States and Canada, but virtually unknown by dendrologists and forest biologists

(Ashworth 1969). Buarts had probably already been growing unnoticed in yards and orchards for a generation when they were first described by Willard Bixby in 1919 (Bixby 1919).

Japanese walnuts were introduced into the United States around 1860 (Crane et al. 1937). In Japan, these walnuts were exploited as a food source by early tribal settlers (Koyama 1978), but never became an important commercial nut crop. By the late 1800s, Japanese walnuts had become popular among nut growers in the eastern United States because the kernels separate easily from the shell, and because some horticultural selections of Japanese walnut have an attractive and distinctively heart-shaped shell (Crane et al. 1937) (Fig. 9). Trees bearing heart-shaped nuts became known as heartnuts (technically *J. ailantifolia* var. *cordiformis*), and the hybrid combination of ***bu***tternut plus he***art***nut results in the common name "buart".

Cultivars of heartnut have been selected and named (Ashworth 1969; Woeste 2004), but heartnuts never became a market success in the United States, perhaps because the nuts, while exotic in appearance, tend to be bland tasting. Although Japanese walnut never became popular as a nut crop, it gained a permanent foothold in the New World by intermating with butternut. Over time, as buarts became more common and as the gene pools of butternut and Japanese walnut intermixed, it became almost impossible and certainly impractical for most people to distinguish butternuts from buarts (Fig. 10). As early as 1919, Bixby (1919) found that "[c]ertain Japan walnuts [are] so near like butternuts as to be readily mistaken for them.... [A]s far as the appearance of the nuts was concerned, the butternut could not be well separated from certain Japan walnuts."

Buarts are remarkable hybrids. They stand out as exceptionally vigorous trees, sometimes exceeding 40 inches (102 centimeters) in diameter when mature (butternuts typically reach 12 to 24 inches [30 to 61 centimeters] in diameter). Buarts often bear enormous crops of nuts, and typically appear to be resistant to butternut canker (Orchard et al. 1982), although it is not certain that these trees truly are more resistant. It is easy to see why nut enthusiasts found buarts so attractive.



KEITH WOESTE

**Figure 9. A distinctively shaped heartnut (center) surrounded by nuts of other (non-heartnut) forms of Japanese walnut. All the nuts in the photo came from Japanese walnuts grown at the National Clonal Germplasm Repository for *Juglans*, in Davis, CA.**

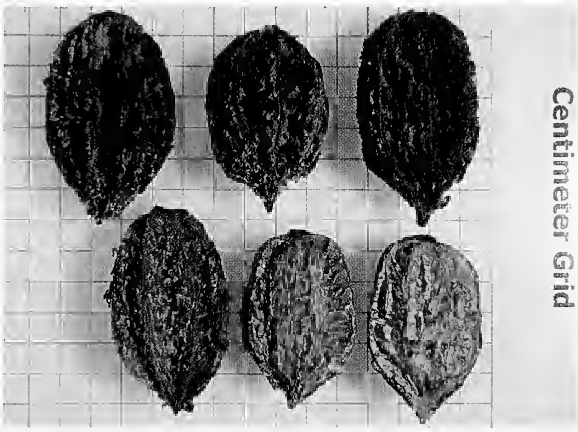



PHOTO COURTESY SALLY WEEKS

**Figure 10. Butternut (top row) and hybrid nuts (bottom row) with the husks removed look nearly identical.**

As butternut populations dwindled and disappeared because of canker, buarts began to confound butternut conservation. Buarts were mistakenly identified as butternut survivors, and buarts planted in yards, parks, and cemeteries attracted seed collectors who gathered and sold the nuts to nurseries or through local markets, made them available through local conservation groups, or simply gave them away to friends and neighbors. Concerns about butternut's status in the forest caught some unaware because there were so many large, healthy "butternuts" (really buarts) growing in farmyards all over the countryside. It is likely that landowners have planted many more buarts than butternuts over the past 20 years, since so many of the

## Figure 11. Summary of Characteristics Distinguishing Pure Butternut from Hybrid Butternuts.

| CHARACTERISTICS | BUTTERNUT | BUTTERNUT HYBRIDS |
|---|---|---|
| HABITAT | Forests, occasionally as a grafted tree or wildling | Parks, forest edges, farmyards, urban areas, planted trees, orchards |
| *1-YR-TWIGS* | | |
| CURRENT-YEAR STEM | Olive green changing to red-brown near terminal, glossy, few hairs except immediately beneath terminal buds | Bright green to copper brown or tan, often densely covered with russet or tan hairs, especially near terminal buds. Pale green near terminal bud |
| TERMINAL BUD | Beige in color; longer and narrower than hybrids, and the outer, fleshy scales more tightly compact. | Pale green to tan or yellowish in color, wider and squatter than *J. cinerea*. Outer fleshy scales more divergent than butternut and often deciduous. |
| LATERAL BUD | Vegetative buds are elongated (sometimes stalked) and somewhat angular, creamy white to beige in color | Vegetative buds are rounded, and green to greenish brown in color. |
| LENTICELS | Small, round, abundant, evenly distributed, sometimes elongating horizontally across the branch (perpendicular to the stem axis) | Large, often elongating laterally down the branch (parallel to the stem axis) on 1-yr-wood, patchy distribution. On 3 and 4-yr-wood, lenticels often form a diamond pattern as they become stretched both transversely and longitudinally |
| LEAF SCAR | Top edge almost always straight or slightly convex; scar usually compact | Top edge almost always notched; often with large, exaggerated lobes |
| PITH | Dark brown | Dark brown, medium brown or even light brown |
| *MATURE TREE* | | |
| BARK | Varies from light grey and platy to dark grey and diamond patterned in mature trees. In older trees, fissures between bark ridges may be shallow or deep but are consistently dark grey in color. | Silvery or light grey, rarely darker. Fissures between bark ridges moderate to shallow in depth and often tan to pinkish-tan in color. |
| LEAF SENESCENCE | Leaves yellow and brown by early-mid autumn, dehiscing in early to mid autumn. | Leaves often green until late autumn, dehiscing in late autumn or may freeze green on the tree. |
| CATKINS | 5–12 cm in length at peak pollen shed | 13–26 cm in length at peak pollen shed |
| NUT CLUSTERS | One or two nuts per terminal in most clusters, sometimes 3–5, rarely more. | Usually 3 to 5 per cluster, sometimes as many as 7. |

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**Figure 12. Twigs of butternut (top and bottom), Japanese walnut (upper middle,) and buart (lower middle). The shape of the lenticels is characteristic of each type.**

remaining butternut trees have low vigor because of the effects of butternut canker and because butternuts, even when healthy, usually only produce a crop every two to three years (Rink 1990).

For butternut, the existence of these hybrids presents something of a dilemma. On the one hand, buarts represent the dilution and potential loss of a distinctive native species with deep cultural connections and a complex quilt of ecological roles that evolved over many hundreds of thousands of years. On the other hand, hybridization is a common theme in plant evolution (Wissemann 2007), and for butternut, hybridization could represent a way forward, especially if it is determined that all butternuts are completely susceptible to butternut canker (something that is far from certain at this point). What role hybrids will play in butternut recovery remains to be seen.

### Detailing the Differences

Whatever the possible uses of buarts, by 2003 it became clear to researchers that they needed reliable mechanisms to distinguish buarts from butternuts (McIlwrick et al. 2000; Ostry et al. 2003; Michler et al. 2005). The first task was to describe the two parental species. Published descriptions of the vegetative and reproductive tissues of butternut, Japanese walnut, and the hybrids are often brief, and based on an unknown number of samples of unidentified provenance. By surveying published descriptions of butternut, especially those made before the introduction of Japanese walnut to the United States or before hybrids had an opportunity to become widespread, a clearer picture of the morphology of butternut and Japanese walnut emerged (Ross-Davis et al. 2008a). To verify our findings, we examined old butternut specimens at the Herbarium of the Missouri Botanical Garden. These long-preserved samples provided additional certainty that what we saw in the wild today matched what was collected over 100 years ago. We also obtained authenticated samples of Japanese walnut from the National Clonal Germplasm Repository in Davis, California, for comparison.

Armed with the best possible descriptions of butternut and Japanese walnut, we had to conclude that trees with intermediate traits were buart hybrids. After examining a large number of samples we developed a list of characters that can be used in combination to separate butternut and hybrids (Woeste et al. 2009) (Fig. 11). After a few years of observing these traits in the field we have trained our eyes and now find that most hybrids are fairly easy to spot, though for more complicated cases a careful examination is needed to make a determination. (Fig. 12)

At the same time, we began development of a series of DNA-based tools for identifying butternuts and hybrids (Ross-Davis et al. 2008a). The DNA markers are being used in both the United States and Canada to identify true butternut seed sources. To understand the genetic diversity of butternut, we developed DNA-based markers called microsatellites, and used these to evaluate samples of butternuts from five locations spanning the upper south and midwestern United States. To our relief, we learned that the genetic structure and neutral genetic diversity (diversity at the DNA level that is not associated with genes) of the current generation of large, standing butternuts was quite similar to that of black walnut, a much

KEITH WOESTE

**Figure 13. Young butternut trees are screened for canker resistance at the Hardwood Tree Improvement and Regeneration Center in West Lafayette, Indiana.**

more common related species (Ross-Davis et al. 2008b). This observation held out hope that it was not too late to begin to collect and preserve the genetic diversity of butternut.

Armed with new DNA-based markers, and support from The Nature Conservancy and the USDA Forest Service – State and Private Forestry, a small group of scientists and collaborators spent 2008 collecting butternut seeds as part of a long-term gene conservation program. A permanent home for the seedlings that will grow from these seeds is envisioned in western Iowa, sufficiently distant from sources of butternut canker it is hoped, to ensure the collection will be safe. These trees represent one of several collections that will reconstitute the future for butternut.

A final note of good news is that an evaluation of candidate canker-resistant butternuts using our DNA-based methods confirms that many of the trees are truly butternuts and not hybrids (Woeste, unpublished data). Recently, pathologists proposed protocols for inoculating and testing candidate trees to determine if these are truly resistant to butternut canker (Ostry and Moore 2008) (Fig. 13). If future pathology studies demonstrate that some candidate trees contain useful levels of resistance to butternut canker, an aggressive program of breeding will be undertaken to transfer the resistance genes into butternuts from all across the species' range. The goal will be to produce seed orchards of genetically diverse, regionally adapted, disease-resistant butternuts for reintroduction to areas of the eastern forest where butternut has disappeared. Learning how to reintroduce and sustain viable populations of trees into habitats from which they have been lost remains an important and ongoing challenge (Broadhurst et al. 2008; Geburek and Konrad 2008).

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# A Closer Look at Fungi in the Arnold Arboretum

*Kathryn Richardson*

Walk into the Arnold Arboretum and you'll see a beautiful and historically important collection of trees and shrubs. With a closer look, other organisms become visible, including fungi. The world of fungi is vast, and many members of this diverse kingdom are found throughout the Arboretum. In an informal survey from spring through fall of 2008, Arboretum staff reported over 100 fungal sightings, and positive identifications were made for 40 species. A dozen species noted in the survey are profiled starting on page 15.

**Plants + Fungi**

The association between plants and fungi is sometimes beneficial, sometimes harmful, and sometimes a bit of both. Fungi can be indicators of a tree's declining health, but in other cases—such as mycorrhizae which aid roots with nutrient uptake—they are physiologically beneficial to plants. Identifying fungi and understanding their physiology is an important aspect of interpreting the health of the Arboretum's collections.

The Arnold Arboretum hosts an unknown number of fungi, many of which have specific relationships with certain plants. When a fungus is found growing on an accessioned tree, horticultural staff attempt to make an accurate identification, and often those known relationships aid in the identification process. For example, a shiny bracket fungus growing on eastern hemlock (*Tsuga canadensis*) is probably the hemlock varnish shelf (*Ganoderma tsugae*), and an oak tree with a massive cluster of sulphur-yellow mushrooms growing from its roots is likely to be chicken of the woods (*Laetiporus sulphureus*).

These fungi may live in their hosts for several years. As they feed, these fungi cause wood decay and often weaken the

## Fungi ID

PRECISELY identifying fungi can be challenging even for experts. Many morphological features from growth habit to the size and color of spores provide clues for identification. Often minute details are needed to confirm species identity.

Correct identification is critical when considering fungi as food, since the fungi kingdom contains species that are deliciously edible and others that are deadly poisonous. Though often stated, it's worth repeating: Never consume any mushroom without being absolutely sure of its identity.

SUSAN HARDY BROWN

**The distinctive lamellae (gills) of this mushroom mark it as a member of the phylum Basidiomycota, but much more information is needed to determine its exact species.**

structural integrity of the tree. Damage from fungi also weakens the tree's defenses and may enable entry for other pests and diseases which cause further injury. Arboretum trees flagged with potentially fatal fungi are carefully observed and notes are kept within the Arboretum's collections database. If the tree begins to decline, this information is useful in making a decision on its treatment or removal.

**The Fungal Life**

Fungi are neither plant nor animal and are placed in their own kingdom, though historically this was not always the case. Taxonomists initially placed fungi in the plant kingdom (Plantae) because, plants and fungi are both sessile (not free-moving) and have cell walls. However, fungi lack chlorophyll (and thus cannot make their own food via photosynthesis) and have walls made of chitin, not cellulose as seen in plants. Fungi are closely related to animals and bacteria and were once placed in the animal kingdom (Animalae), but fungi are not motile. Fungi proved to be unique life forms deserving their own kingdom.

Fungi cannot produce their own food and thus must acquire the nutrients they need from their hosts or substrates. Based upon their nutritional needs, fungi fall into three categories: saprobes, parasites, and mutualists. Saprobic fungi feed on dead organic materials and serve as the scavengers of the kingdom by recycling carbon, nitrogen, and other essential elements back into the soil. Parasitic fungi feed on living organisms and often harm them in some way. "Parasitize" sounds threatening, but the reality is that fungal parasites do not typically destroy their host quickly and may be present for some time before the host shows decline. Mutualistic fungi have a beneficial relationship with other living organisms. Examples of mutualists include lichens (fungi plus algae or cyanobacteria) and mychorrhizae (fungi and plant roots). Around 90% of all living trees have a mycorrhizal relationship with fungi.

The presence of fungal fruiting bodies on trees indicates that the fungus has reached the spore production stage of its life cycle. When released spores land on a substrate and germinate, threadlike hyphae grow and combine to form mycelia, the vegetative growth of fungi. Mycelia grow underground (sometimes spreading for miles), or within wood or other hosts. Mycelia grow even when no fruiting bodies are present, so the extent of damage caused by a fungus in the tree before the emergence of the fruiting body is sometimes unclear.

**Fungi to Know**

The largest groups of fungi are found in the phylum Basiodiomycota, often inclusively called the basidiomycetes. Many familiar fungi such as cap-and-stipe (stalk) mushrooms (including the cultivated "white button mushroom" [*Agaricus bisporus*] found in grocery stores), brackets, and puffballs are placed in this group. It is safe to say that if you are looking at a fungus that has either rib-like gills (lamella) or tiny pores on the underside of the cap, it's a basidiomycete. The microscopic rust and smut fungi are also basidiomycetes.

Basidiomycota produce basidiospores which have a single haploid nucleus. When these spores germinate they produce long, branching hyphae with a single nucleus in each compartment (area between cell walls). When two compatible hyphal strands come into contact with each other they unite to form a hyphal strand that now houses two nuclei in each compartment. A basidiomycete will spend most of its life in the vegetative mycelial stage until environmental cues, such as rain or temperature change, cause the growth of fruiting bodies (basidiocarps). Many basidiomycetes are decomposers, but others have a mycorrhizal partnership with forest trees.

Another fungal phylum, Ascomycota, includes the sac fungi or spore shooters. Unlike basidiomycetes that have structures (basidiophores) that drop spores from their fruiting bodies, ascomycetes have spores in sacs located within a structure called an ascocarp or ascomata. The spores are "shot" out of their sacs and dispersed into the air. Sac fungi are also decomposers and recyclers of organic matter. Many ascomycetes are parasitic including those that cause Dutch elm disease and chestnut blight. Ascomycetes include yeasts, which are used to make beer and wine, as well as mycelial fungi such as morels and black knot. Another interesting example of an ascomycete is the fungus that causes ergot, a damaging disease of grain crops. Ergot fungus contains a compound that is a precursor to the hallucinogen LSD. Though not proven, it has been suggested that ergot poisoning was a potential cause of the hysteria that led to the Salem witchcraft trials in the late 1600s.

Although no longer classified in the fungi kingdom, Myxomycetes (slime molds) are also mentioned here since they resemble fungi, are common at the Arboretum, and elicit many questions from visitors (see page 21).

## A Sampler of Arboretum Fungi

*Here are a dozen interesting fungi—plus one slime mold—that were found in last year's informal survey of fungi at the Arnold Arboretum*

COURTESY OF PAULA DESANTO

### Pheasant's-back Polypore or Dryad's Saddle (*Polyporus squamosus*)

In the spring of 2008, a very large pheasant's-back polypore appeared on a venerable cucumbertree magnolia (*Magnolia acuminata*, accession 15154-E) near the main entrance of the Arnold Arboretum. This magnolia has survived for over 100 years, but time has taken its toll and the doors are now open for various organisms, including fungi, to invade.

Growing out of an old limb-removal wound on the magnolia's trunk was an impressive bracket with a uniquely patterned cap. This species, the pheasant's-back polypore, can grow to 24 inches (61 centimeters) in diameter. It appears growing on stumps and dead hardwood trees in spring in the northeastern United States. It is easily recognized by its fan-shaped, tan to creamy yellowish cap with an array of brown scales that look like pheasant feathers—thus the species' common name. (Another common name, dryad's saddle, refers to its potential use by the tree-dwelling nymphs known as dryads in Greek mythology.) The white underside of the cap is dotted with thousands of small pores (*polyporus* means "many pores").

It was sad to see this particular polypore because it indicates that this magnolia's life is coming to an end. The Arboretum's horticultural staff had noted the tree's decline before the emergence of this polypore, but its presence told us more about the health of this tree. The pheasant's-back polypore is typically saprobic on dead trees but it can also parasitize the heartwood of living trees such as this magnolia. This polypore fungus had been living in this tree for an unknown period of time before it produced this fruiting body; the extent of internal rot is uncertain but the tree will continue to be monitored closely.

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## Witch's Butter (*Tremella mesenterica*)

Witch's butter is a member of the phylum Basidiomycota, but does not have the traditional cap and stem as do some other fungi in this group. This fungus is yellow to orange in color and appears as wavy, gelatinous folds. It can dry out to the point of appearing dead, but will rehydrate readily with rainfall or other applied water. Another interesting fact about witch's butter is that it feeds on other fungi, not on wood. It is often seen growing on downed logs or dead branches, where it parasitizes wood-decaying fungi. Witch's butter is widely distributed in temperate regions in North America, Europe, Asia, and Australia.

The name "witch's butter" comes from several European legends. One states that if the fungus was found growing near a home's entrance or front gate, then the homeowner had been hexed by a witch. The spell could be broken by plunging a pin into the fungus, causing the witch to feel the pinpricks, which in turn would cause her to return to remove the spell and the fungus. A legend of Swedish origin blames this fungus on a witch's cat. The cat, sent out to steal food from the neighbors, would gorge itself and then vomit "witch's butter" on the gardens, fences, gates, and homes of unsuspecting people. The name "witch's butter" is sometimes applied to any of a number of jelly-like fungi.

NIMA SAMIMI

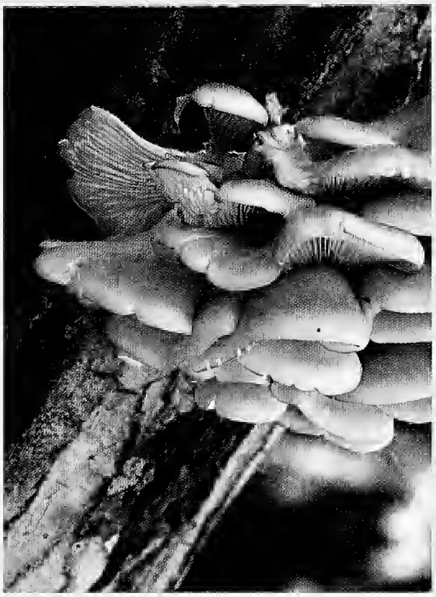
## The Stinky Squid (*Pseudocolus fusiformis*)

The stinky squid is a basidiomycete belonging to the Phallaceae, a family of fungi commonly known as stinkhorns. The stinky squid certainly lives up to its name both in scent and appearance—in late August 2008 this stinkhorn created quite a horrible smell in the Arnold Arboretum when it appeared in a few beds in the Leventritt Shrub and Vine Garden as well as in densely planted areas on Peters Hill.

Common to eastern North America, this species of stinkhorn has a fantastic appearance. Beginning its reproductive life as an egglike structure with white rhizomorphs attached to the base, its fruiting body quickly emerges, displaying three to five tapering arms. The arms may be free-standing or fused together at the tips, and are yellow towards the base and reddish orange towards the apex. It stands 1 to 3 inches (3 to 7 centimeters) in height with dark green spores lining the inner sides of its arms. (A broken-off fruiting structure is seen here.)

There's no question about how this fungus received its common name: it looks like a squid and has the odor of rotting flesh. Stinkhorns, including stinky squid, disperse their spores by attracting flies and other insects which land on the fungus and feed on the stinky slime. In the process, the insects collect spores on their bodies as well as ingesting them, then spread the spores to new locations.

### Common Oyster Mushroom (*Pleurotus ostreatus*)


NANCY ROSE

The common oyster mushroom—a familiar edible mushroom that can be found in grocery stores—is common in the Arboretum and appeared in large numbers last spring. Oyster mushroom species are typically found in the fall, winter, and early spring, though they are also sometimes seen in the summer under the right conditions. They grow on dead hardwoods and, less often, on conifers, and also on some living trees. Oyster mushrooms grow in dense clusters, have light brown to off-white caps, and display prominent, elongated white gills.

An interesting fact about species in this mushroom genus is that they are carnivorous; they trap, kill, and eat living organisms such as nematodes and bacteria in addition to the more typical fungus function of decomposing wood.


JOSEPH O'BRIEN, USDA FOREST SERVICE, BUGWOOD.ORG

### Chicken of the Woods (*Laetiporus sulphureus*)

Chicken of the woods belongs to the genus *Laetiporus,* which fairly recently has been separated into several species based on DNA analysis. When I first began identifying chicken of the woods in the Arboretum I assumed it was *Laetiporus sulphureus,* but most turned out to be the very similar-looking species *Laetiporus cincinnatus.* Both species have the common name "chicken of the woods" and are popular edibles for mushroom hunters. They are readily identified because of their bright yellow to orange color and appearance as masses or rosettes of wavy, blunt-rimmed plates. They are widely distributed east of the Rocky Mountains and often grow as parasites or saprobes on oaks (*Quercus* spp.). The main difference between the two species is the location of their fruiting bodies; *Laetiporus sulphureus* usually grows on tree stumps while *L. cincinnatus* grows from the roots of the infected host, giving the appearance that it is growing terrestrially.

The common name is appropriate for several reasons. The flesh of the caps is yellowish in color, almost like raw chicken. Also, the taste and texture of this fungus, when cooked, reportedly are similar to cooked chicken.

### Turkey Tail Fungus (*Trametes versicolor*)

The turkey tail fungus is one of the most commonly seen bracket fungi, occurring on dead trees in temperate zone forests all over the world. Turkey tail fungus is saprobic on dead hardwoods and can sometimes completely cover trunks and branches. A decomposer of wood, this fungus will sometimes work away for hundreds of years on a single host.

Turkey tail fungus is a polypore, having pores instead of gills, and has a hard exterior instead of the fleshy ones seen in traditional mushrooms. It is aptly named, displaying concentric colored bands that resemble a fanned turkey's tail. The colors of turkey tail fungus can vary, but the bands commonly appear in shades of white, brown, and tan, sometimes with more colorful bands in orange, cinnamon, or bluish tones. A close look reveals dense, downy hairs on the bracket's upper surface.

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### Shaggy Mane Mushroom (*Coprinus comatus*)

The shaggy mane—a type of inky cap mushroom—is readily observed from mid-spring to late summer. Found on lawns, in mulched beds, and in forests, the shaggy mane performs as one of nature's recyclers, feeding on soil, forest litter, decaying wood, and even dung. It slowly decomposes the organic matter on which it feeds.

One characteristic that makes this mushroom interesting is its method of spore dispersal. When the spores begin to mature, the shaggy oval cap begins to curl, becoming bell-shaped, as the gills deliquesce (liquefy). This gives the spores maximum exposure to the wind, which then transports the spores to new locations. The gills will continue to liquefy until they are virtually gone, leaving a flat, almost transparent cap. True to the name, the liquefied gills of this and other inky caps can be used as a semi-permanent ink.

### Bark Mycena (*Mycena* spp.)

There are many tiny, often-overlooked mushrooms growing in the Arboretum including several in the genus *Mycena*. This genus contains hundreds of species distributed worldwide. Most Mycena species are very small and have bell-shaped caps on slender stipes.

Walking along Meadow Road I came across an old painted maple (*Acer mono*) covered with these tiny mushrooms. Gray-brown in color with caps no larger than a few millimeters in diameter they covered the bark of this maple along with moss and lichens. At first it seemed sad to see such a fantastic old tree covered with mushrooms, but these fungi do not harm the tree. Bark *Mycena* live on the outer layer of a tree, feeding on the dead bark. They never move to the living layers of the tree and thus do no harm.


NANCY ROSE

## Bird's-Nest Fungi (species in several genera including *Crucibulum* and *Cyathus*)

Bird's-nest fungi are a group of unusual fungi in the order Nidulariales ("nidula" means small nest). They are very common in the Arboretum and can be found growing in almost every mulched bed as well as on debris in natural woodland areas. These harmless fungi are saprobic on substrates such as dead wood (including woodchips), leaves, and dung. They often grow in large expanses.

The common name describes these fungi perfectly. The mature peridia (fruiting bodies) resemble tiny nests. These nests contain tiny egglike peridioles which contain spores. Several species of bird's-nest fungi grow at the Arboretum and can be differentiated by the color, size, shape, and texture of their peridia as well as by the color of their peridioles which can vary from white to black with several shades of gray and brown in between.

Bird's-nest fungi exhibit an interesting spore dispersal method. When it rains, water droplets splash the "eggs" (peridioles) out of the nest and into the air. When this happens, a cord which attaches the egg to the nest breaks free and elongates. When the egg lands on nearby substrates the cord sticks and secures the egg to its new site.


ROBERT MAYER

## Hen of the Woods (*Grifola frondosa*)

Hen of the woods is a popular edible mushroom with sweet-tasting flesh. The clustered caps of this fungus resemble the ruffled feathers of a hen, and a full-grown specimen can reach a foot or more in diameter and weigh as much as 40 pounds (18 kilograms). Hen of the woods is commonly found growing on oak (*Quercus* spp.) trees from either the trunk or roots.

This mushroom is a parasite and will cause damage over time. It causes white rot which can compromises the structural integrity of the roots. A weakened root system can prove disasterous for a tree in wind storms, since lack of solid anchorage may allow the tree to topple over.

NANCY ROSE

## Black Knot Fungus (*Apiosporina morbosa*)

Black knot fungus is visible on several cherry trees by the Arboretum's Forest Hills gate. Black knot can infect a number of cherry and plum species (*Prunus* spp.). This ascomycete is a harmful fungus that damages both the health and appearance of its host. The visible part of this fungus, a black gall, is the result of the fungus disrupting the normal growth of the twig. Galls form at the site of infection. Black knot galls look something like burned marshmallows on a stick and may eventually grow to a foot in length if left unchecked.

Inside the galls are perithecia which produce ascospores, which, after overwintering in the gall, are ejected in the spring when warmer temperatures and adequate moisture arrive. The ascospores are then carried by wind and water to new host sites. Infection occurs on new plant growth and wounded tissues. These ascospores are able to penetrate through the green tissue of new growth and quickly begin to grow. New galls are brown, and can easily go unnoticed until the following year when they continue to grow and turn black. The galls continue to grow every year and the infection continues to spread further down the branch. Older galls often harbor borers which can cause even more problems for infected trees.

All trees at the Arnold Arboretum with black knot galls present are monitored. When a gall is found the infected branch is removed while the fungus is still dormant. This slows further spread on the host tree and also reduces the spread of infection to other trees.

## Hemlock Varnish Shelf (*Ganoderma tsugae*)

The Arboretum's Hemlock Hill offers visitors a chance to see the interaction between a fungus and a specific type of tree. The hemlock varnish shelf (*Ganoderma tsugae*) has a preference for conifers and specifically for hemlocks (*Tsuga* spp.). It is found on living and fallen trees on Hemlock Hill and was also reported growing in a mulch bed along Meadow Road. If seen growing on a living hemlock it is safe to say that the tree is not in perfect health.

ROBERT MAYER

The hemlock varnish shelf is a beautiful polypore. Its hard, shiny cap is dark red to reddish brown, sometimes with prominent concentric zones. Young specimens may show white and yellow segments also. This annual mushroom grows individually or, less commonly, in limited clusters. This species is closely related to the more common taxa *Ganoderma lucidum*, (sometimes known as reishi or lingzhi); extracts of both have been used in herbal medicine.


SUSAN HARDY BROWN

## Dog Vomit Slime Mold (*Fuligo septica*)

I have had Arboretum visitors ask me about "the lumpy yellow (or tan) stuff in the mulch bed that looks like vomit." Well, that's the descriptively named dog vomit slime mold, commonly seen in planting beds mulched with wood chips. *Fuligo septica* is a type of Myxomycetes, so not a true fungus. It is a plasmodial slime mold; this means that the "vomit" is actually a huge single cell containing millions of nuclei.

Dog vomit slime mold is motile, but moves quite slowly. It is not harmful to animals or plants and usually vanishes in a short period of time. This species and similar slime molds feed on bacteria, fungal spores, and smaller protozoa found on wood chips. Slime molds feed much like an amoeba feeds; they ingest their food and then digest it (unlike fungi, which digest and then ingest). If conditions are favorable, these slime molds will produce reproductive structures (sporangia) that produce spores. When conditions are unfavorable (loss of food, dry conditions), the plasmodium will form hard, dormant, protective structures called sclerotia. Inside the sclerotia the plasmodium will divide into "cells" containing up to four nuclei. When conditions become favorable each "cell" will form a new plasmodium.

Dog vomit slime mold is primarily an aesthetic problem in mulched garden beds. It can be physically removed, but more is likely to return. So, before panicking and taking your dog to the veterinarian, take a closer look and consider that that stuff is likely just *Fuligo septica* working away at cleaning the mulch.

**Acknowledgments**

Thanks to Susan Hardy Brown, Nima Samimi, Eric Youngerman, Bob Ervin, Marc Devokaitis, Nancy Sableski, and all staff for their help in surveying and photographing fungi at the Arboretum, and to Don Pfister for reviewing this article.

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Kathryn Richardson is a Curatorial Assistant at the Arnold Arboretum.

# American Chestnuts in the 21st Century

*Sandra L. Anagnostakis*

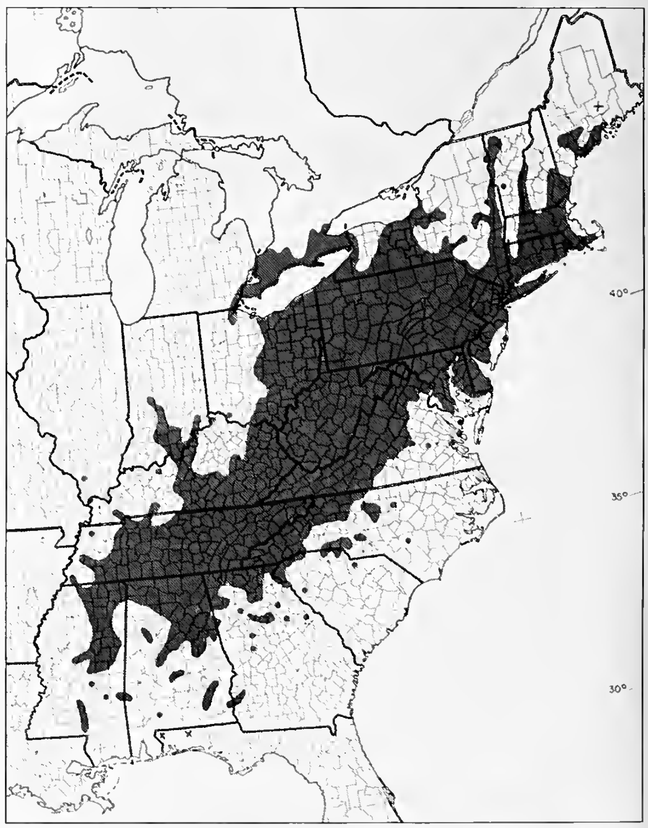
New England was heavily forested in 1600, and American chestnut (*Castanea dentata*) was commonly found in Connecticut and Massachusetts woodlands (Cogbill et al. 2002). At that time, American chestnut was abundant throughout its native range from southern Maine to northern Georgia, all along the Appalachian Mountains (Saucier 1973). In the following centuries, European settlers cleared land for farming and cut trees for fuel, and the forest cover was greatly reduced by 1850. This was followed by the introduction of coal as a fuel, which was brought easily to New England by the railroads. Once wood was no longer being harvested for fuel, and more fields were left fallow as people abandoned farms and moved west or into the cities, the trees started to take back their habitats.

When hardwood forests were harvested and left to resprout, the chestnuts grew faster than the oaks and maples with which they shared the land, and the number of chestnut trees greatly increased. Many woodlots became nearly pure stands of chestnut. A bulletin issued by the Connecticut Experiment Station in 1906 stated that regenerating hardwood forests covered most of the wooded area of Connecticut and "the most important tree of this type is the chestnut which constitutes fully one-half of the timber" (Hawes 1906). Forest surveys done at the turn of the last century show that there were about 130 million mature American chestnut trees in Connecticut alone.

These stands of chestnut trees were valued because chestnut is a strong wood that resists rotting. Chestnut was used extensively for framing and woodwork, and was also essentially the only wood used for telephone poles and most of the railroad ties laid as rail lines pushed westward (Pierson 1913).

### The Blight Arrives

The fungal pathogen causing chestnut blight disease (now called *Cryphonectria parasitica*) was introduced into the United States in the late 1800s on Japanese chestnut trees. The disease was spread up and down the east coast by mail-order sales of infected trees (Anagnostakis 2001, http://www.ct.gov/caes/cwp/view.asp?a=2815&q=376754). In 1908 chestnut blight disease started killing American chestnut trees in Connecticut (Clinton 1912), and




SAUCIER 1973

**Native range of American chestnut (*Castanea dentata*) in Eastern North America.**


**A pure stand of American chestnut in Connecticut in 1910.**

infections were reported in Cape Cod, Wellesley, and Pittsfield, Massachusetts (Metcalf and Collins 1909).

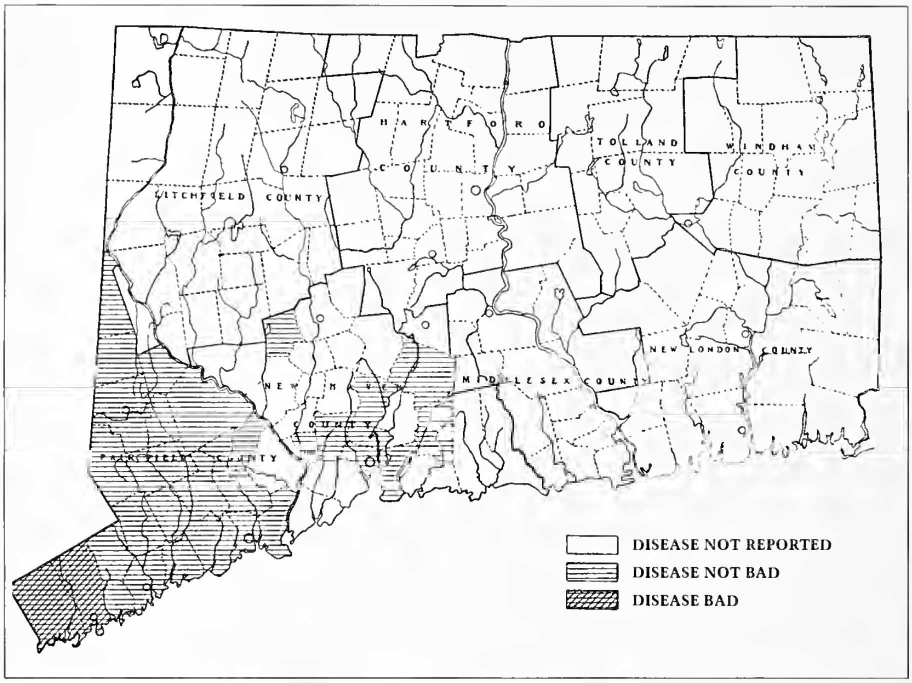
Chestnut blight disease has reduced American chestnuts to understory shrubs, which die back, sprout from the base, die back, and sprout again. This fungus is now present throughout the original range of *C. dentata*, and has spread to many of the Midwestern locations where chestnuts were planted.

## Chestnut Breeding

Chestnut trees are monoecious and bear separate male and female flowers on the same tree. As with many fruit trees, they must be cross-pollinated for fully formed nuts to develop. Without cross-pollination, burs with small, flat nuts comprised of all-female tissue are all that form. Although the size of the nuts formed is completely dependent on the female parent, the pollen parent influences the flavor of the nuts (Anagnostakis 1995a, Anagnostakis and Devin 1998).

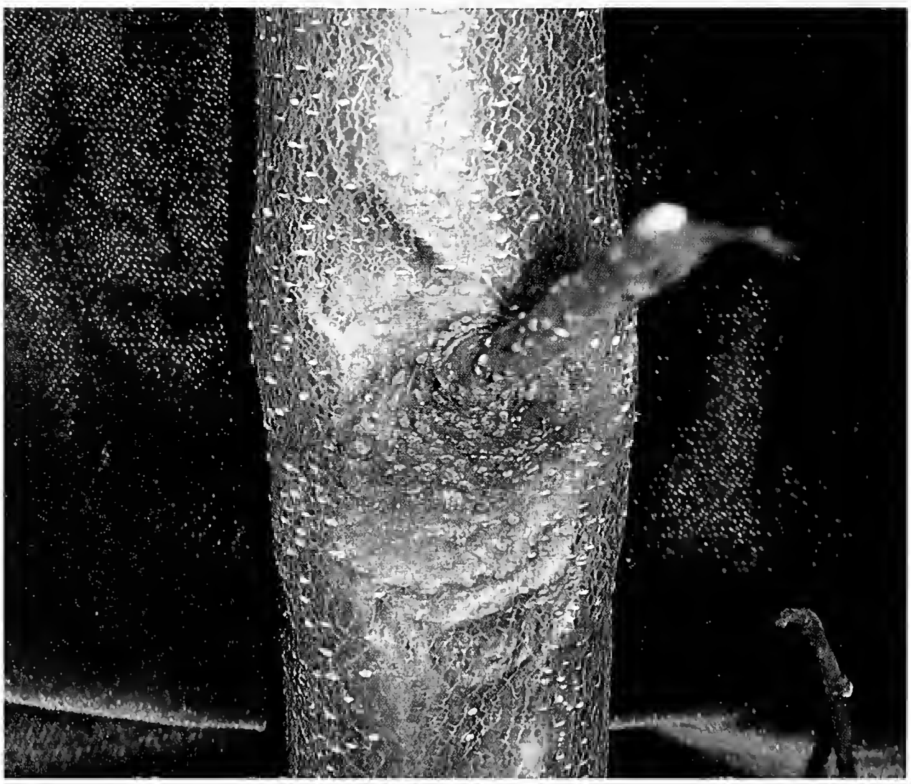
Growers interested in getting nuts as large as those of Japanese or European chestnut but with the superior flavor of American chestnuts started creating hybrids in the late 1800s. After chestnut blight disease began killing timber

CLINTON 1912




**This map shows the presence of chestnut blight disease in Connecticut in 1908.**

SANDRA ANAGNOSTAKIS



**Blight canker on an American chestnut tree; note the dead, sunken bark and lumps of fungal tissue that have broken through the surface where they will form spores.**

chestnut trees—and Asian chestnut trees were seen to be resistant to the disease—it was hoped that new hybrids could be developed that combined the upright, timber-producing form of American chestnut with the Asian species' resistance to blight.

Arthur Graves, a plant pathologist in Connecticut, began crossing blight-resistant Asian trees and susceptible American trees in 1930. He then tested these hybrids for resistance to chestnut blight disease (Graves 1937). He was soon joined by Donald Jones of the Connecticut Agricultural Experiment Station (CAES), who was a renowned geneticist with a great interest in chestnut. Many of those original hybrids are still alive, and CAES now has what is probably the finest collection of species and hybrids of chestnut in the world. These were planted on land left to the State of Connecticut by Graves, and at the CAES farm, both located in Hamden, Connecticut.

Trees with two forms are being chosen from our continuing breeding efforts at CAES: tall, straight trees with limited energy put into forming nuts but very well-suited for timber production, and short, spreading trees with maximum energy put into forming large, good-tasting nuts, making the trees suitable for commercial or backyard nut orchards. Both kinds of


COURTESY OF BRAD SMITH

**American chestnut flowers on a tree near Quabban Reservoir in Massachusetts.**

trees must have resistance to chestnut blight disease and be well adapted to the New England climate (Anagnostakis 1992). There is now interest in developing DNA tests for genetic maps of chestnut trees (http://www.fagaceae.org/web/db/index), and we are using specific crosses to study the genetics of resistance to diseases as well as to develop timber and orchard chestnut trees.

To make these crosses, we put waxed paper bags over female flowers in late June before they are fertile, then put selected pollen on the flowers in July and cover them up again. This allows us to know the parents of the nuts that form. During our breeding program we have found that many hybrids that are the result of crosses between two different species do not form functional pollen. These male-sterile trees produce male catkins with flowers that never bloom. Although this lack of pollen is a nuisance in the breeding program, it is a feature valued by commercial nut growers—they can plant orchards of male-sterile trees with a few pollen-producing trees and have yields of nuts that are very uniform.

When it became clear that at least two genes were responsible for resistance to chestnut blight, we began a back-cross breeding program based on the plan of Charles Burnham (Burnham 1988). Asian trees are crossed with American trees, and the hybrids (partially blight resistant) are crossed to American trees again. If there are two resistance genes, one out of four of the progeny from these back-crosses has one copy of both resistance genes, giving it partial resistance. If there are three genes for resistance, one

SANDRA ANAGNOSTAKIS

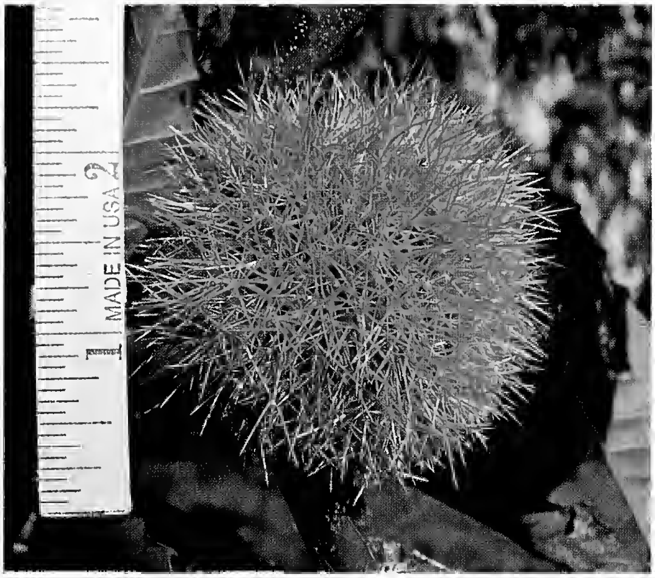
**A row of twelve-year-old chestnut hybrids selected for timber qualities.**

out of eight of the progeny will have one copy of all three resistance genes. Trees with partial blight resistance are crossed again to American chestnut trees. This repeated back-crossing increases the percentage of American genes in the hybrids, and selecting for partial resistance insures passage of the resistance genes. A final cross of two trees with partial resistance should result in one of sixteen trees having two copies of two resistance genes (or one of sixty four trees having two copies of three resistance genes), which will make them fully resistant to the chestnut blight fungus.

## Biological Control of Chestnut Blight Disease

In a 1992 *Arnoldia* article we described viruses, called "hypoviruses," that infect *C. parasitica* and keep the fungus from killing trees by reducing its virulence (Anagnostakis and Hillman 1992). Since 1972, when CAES imported

KEITH KANOTI, MAINE FOREST SERVICE, BUGWOOD.ORG




The densely spiny chestnut bur encloses several nuts, typically three.

SANDRA ANAGNOSTAKIS


American chestnut trees in this Hamden, Connecticut, orchard were treated with biocontrol strains from 1978 to 1981, and 15% of the 71 trees survive as the original trunks in spite of the presence of many cankers. Half of the trees continue to be in a repeating cycle of dying back and resprouting. About one third of the trees died back once, resprouted, and the sprouts are still surviving.

**Percentage of American genes in back-crossed (BC) hybrid chestnut trees.**

| PARENTS | AMERICAN GENES | HYBRID | | |
|---|---|---|---|---|
| 1. American | 100% American genes | egg | | |
| x | | + | = | 50% A F1 |
| Japanese | 0% American genes | pollen | | |
| 2. American | 100% American genes | egg | | |
| x | | + | = | 75% A BC1 |
| F1 | 50% American genes | pollen | | |
| 3. American | 100% American genes | egg | | |
| x | | + | = | 87.5% A BC2 |
| BC1 | 75% American genes | pollen | | |
| 4. American | 100% American genes | egg | | |
| x | | + | = | 93.8% A BC3 |
| BC2 | 87.5% American genes | pollen | | |
| 5. BC3 | 93.8% American genes | egg | | |
| x | | + | = | 93.8% A BC3-F2 |
| BC3 | 93.8% American genes | pollen | | |

virus-containing strains of the chestnut blight fungus from Europe, great strides have been made in understanding how these viruses can keep the fungus from killing trees. The genes of three kinds of these (dsRNA) viruses have been sequenced, and the viruses placed in the genus *Hypovirus* by Bradley Hillman and his collaborators (Hillman et al. 1994). We have studied the movement of both killing and curing strains of the fungus by birds and insects of several kinds (Anagnostakis 1990; Anagnostakis 1995b; Anagnostakis 2001). Although we have introduced hypovirulent strains of the fungus into forest plots, this biological control has not brought about a general recovery of forest chestnuts in Connecticut. However, it has been successful in an orchard of American chestnut trees at the CAES farm in Hamden, Connecticut, where we introduced hypovirulent strains into every canker that we could reach for four years from1978 to 1981. Now, although half of the trees continue to die back from chestnut blight (and sprout, and die back, etc.), about a third that died back once and sprouted now survive and flower even though they are covered with cankers, and about 15% of the trees are the surviving original stems.

## Synthesis of Breeding and Biological Control

The crosses that have produced blight-resistant trees for timber have, by necessity, used a rather narrow genetic base, even though different trees were used as parents in each generation. At CAES, this has involved crossing and back-crossing both Japanese and Chinese chestnut trees (*C. crenata* and *C. mollissima*) with locally adapted American chestnut trees. Our strategy has been to keep native chestnuts alive and flowering by using our biological control agent. This eliminates the need to search for American trees that have survived long enough to flower. It also lets us use populations in specific forest clearings. By planting resistant trees in the forests and treating the native trees with our biocontrol, native trees will survive to naturally cross with the resistant trees and will incorporate blight resistance and all of the native genetic diversity into the future generations. The first generation offspring will be intermediate in resistance, but subsequent generations will produce trees with full resistance.

## Chestnut Trees for the Orchard

In addition to selecting timber trees, we have continued to evaluate trees for their potential for orchard production in New England. A few acres of chestnut trees can produce enough nuts to sell at farmer's markets or to local stores. The only serious pest is chestnut weevil, which can be controlled by spraying insecticide when the nuts are ripening, or by allowing chickens or guinea fowl to range under the trees and eat the weevils and their grubs. Squirrel control is also essential and every nut farmer has his or her own method.

The most productive chestnut orchards are planted with named cultivars, which are vegetatively propagated clones of the original named trees selected for efficient nut production. Since cuttings of chestnut trees will not form roots, chestnut orchard cultivars must be grafted onto suitable rootstock for propagation. Although this increases the cost of the plants, the value in having proven clones makes the purchase price well worth it.

Another challenge faced by growers is that some splendid cultivars that do well in one part of the country do not do well in other places. For example, cultivars suited to the far south or to the far west may not do well in New England. Selections from Ohio have generally proven


**A basketful of nuts from a hybrid chestnut orchard.**

reliable in southern New England, as have the few cultivars released from CAES. Since I am the International Registrar for Cultivars of Chestnut, information on new trees usually crosses my desk, and I keep a list of the names used and some of their characteristics on our website (http://www.ct.gov/caes/cwp/view.asp?a=2815&q=376864).

The biggest challenge to development of a nut industry in New England is the lack of an established market—many people have never eaten chestnuts and are hesitant even to try them. Also, many who have bought chestnuts and then had weevil larvae crawl out of them will never buy them again. Efforts to develop markets and grower awareness in Michigan and Missouri are making some progress and can serve as examples for New England.

### The Next Problem

Even as progress was being made toward blight resistance, another serious chestnut pest arrived. The oriental chestnut gall wasp, *Dryocosmus kuriphilus*, was introduced into the United States in 1974 by a grower who evaded plant quarantine (Payne et al. 1976). The insect lays its eggs in leaf and flower buds, resulting in defoliated trees with no flowers. Entomologist Jerry Payne chronicled the devastation of orchards of Chinese chestnut trees planted in the state of Georgia. We have reports of infestations throughout Alabama, North Carolina, and Tennessee, and most recently in Columbus, Ohio.

As a consequence, breeding work must now include selection for resistance to this pest. Jerry Payne has observed that American and Chinese chinquapins (*Castanea pumila, C. ozarkensis,* and *C. henryi*) are resistant to infestation, as are some cultivars of *C. crenata*. Once again, the CAES collection of species and hybrids is being used for making new crosses, and progeny from these crosses are being tested in North Carolina where the insect is now endemic. These trees were examined by Stacy Clark of the United States Forest Service in 2006 and the preliminary results were encouraging. Of 93 trees planted in 1995, there were 53 that survived the droughts, deer, rabbits, and weed competition for 12 years. Among the survivors,

JERRY A. PAYNE, USDA AGRICULTURAL RESEARCH SERVICE, BUGWOOD.ORG

**Developing gall and damaged chestnut shoot caused by the Oriental chestnut gall wasp.**

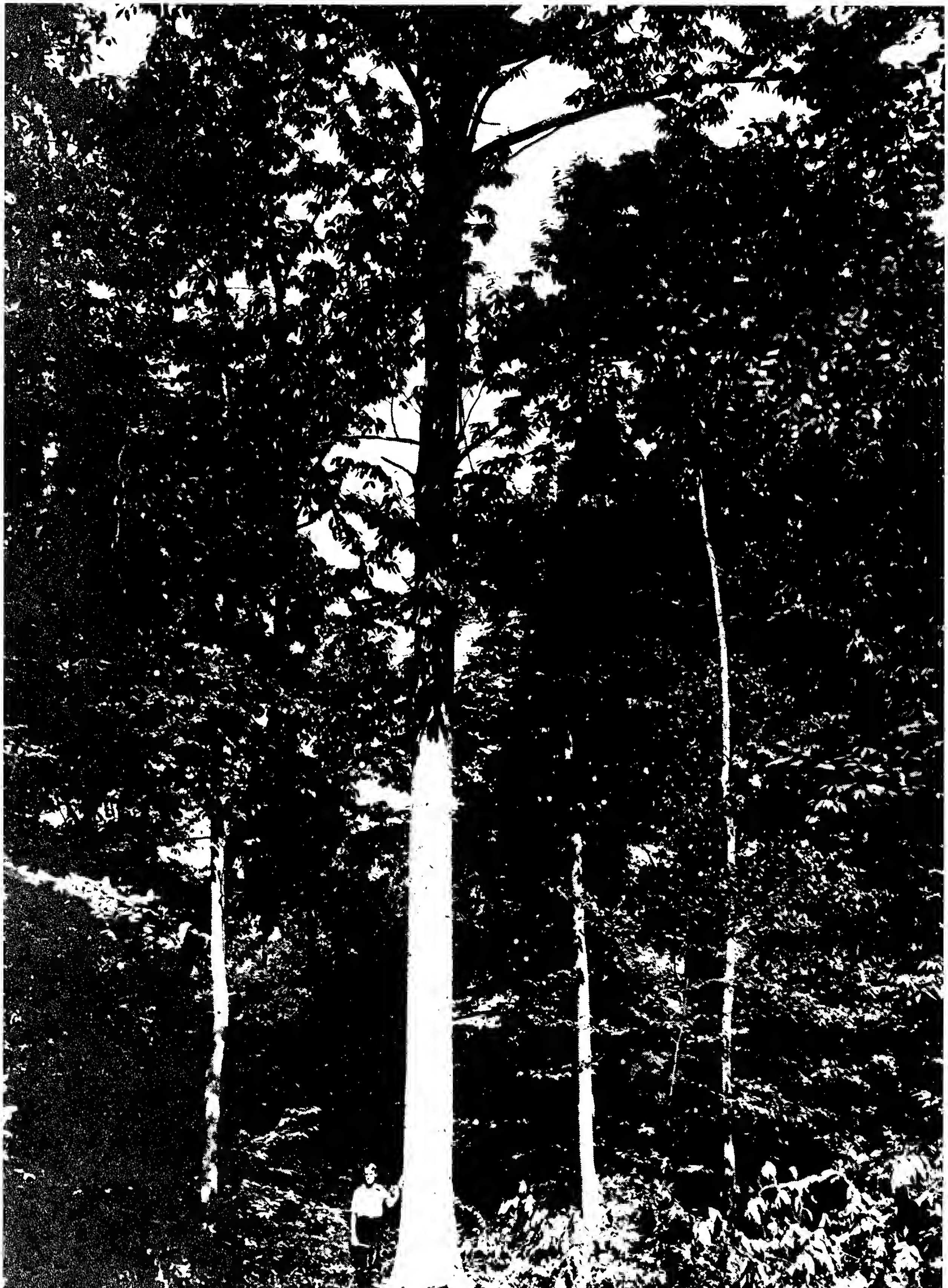
11 had no wasp galls and 25 had few galls. We hope to understand how resistance is inherited and will incorporate this resistance into our trees as quickly as possible.

The other ray of hope for dealing with gall wasp is that Asian parasites released by Jerry Payne seem to be moving with the wasp (Payne et al. 1976). Lynne Rieske recently reported that parasites were now in the Ohio population (Rieske 2007). If these parasites continue to improve as control agents for gall wasp, it is possible that only stressed trees will be seriously damaged by wasp infestation.

### What's Next?

We will soon have timber chestnut trees that can survive in New England. These trees will provide another source of lumber and will also increase the diversity of tree species in forests. We are learning about growing chestnuts in orchards in New England and selecting better

FROM CONNECTICUT EXPERIMENT STATION BULLETIN



**This 1905 photograph shows the tall, straight trunk of a then 103-year-old American chestnut in Scotland, Connecticut.**

nut-producing cultivars to make a new niche crop for farmers.

The work goes slowly, but is very satisfying. When I talk to scientists who conduct laboratory research, and expect results within months, they are often astonished that I have been working at this research for more than 40 years. There are no quick solutions to the complicated problems in the environment, and trees take a long time to grow. When many factors are interacting they must all be considered. We can make crosses of our trees, wait 10 years for the seedlings to mature, select them, make more crosses, wait 10 years, and still miss some crucial clue in the soil or the weather or animals or insects that will affect our hoped-for outcome. When talking with students I try to emphasize the need for patience, keeping an open mind, and noticing everything. "Publish or Perish" and "More Grant Funding for Survival" are still driving forces that tempt scientists to focus on small things that can be examined in isolation and written up quickly for scientific journals or granting agencies, but it is important to keep looking at the big picture.

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Sandra L. Anagnostakis continues her research at the Connecticut Agricultural Experiment Station in New Haven. She is still having too much fun to consider retiring.

# Book Review: *American Chestnut: The Life, Death, and Rebirth of a Perfect Tree*

*Heather D. Heimarck*

*American Chestnut: The Life, Death, and Rebirth of a Perfect Tree*
Susan Freinkel. University of California Press, 2007. 284 pages.
ISBN 978-0-520-24730-7

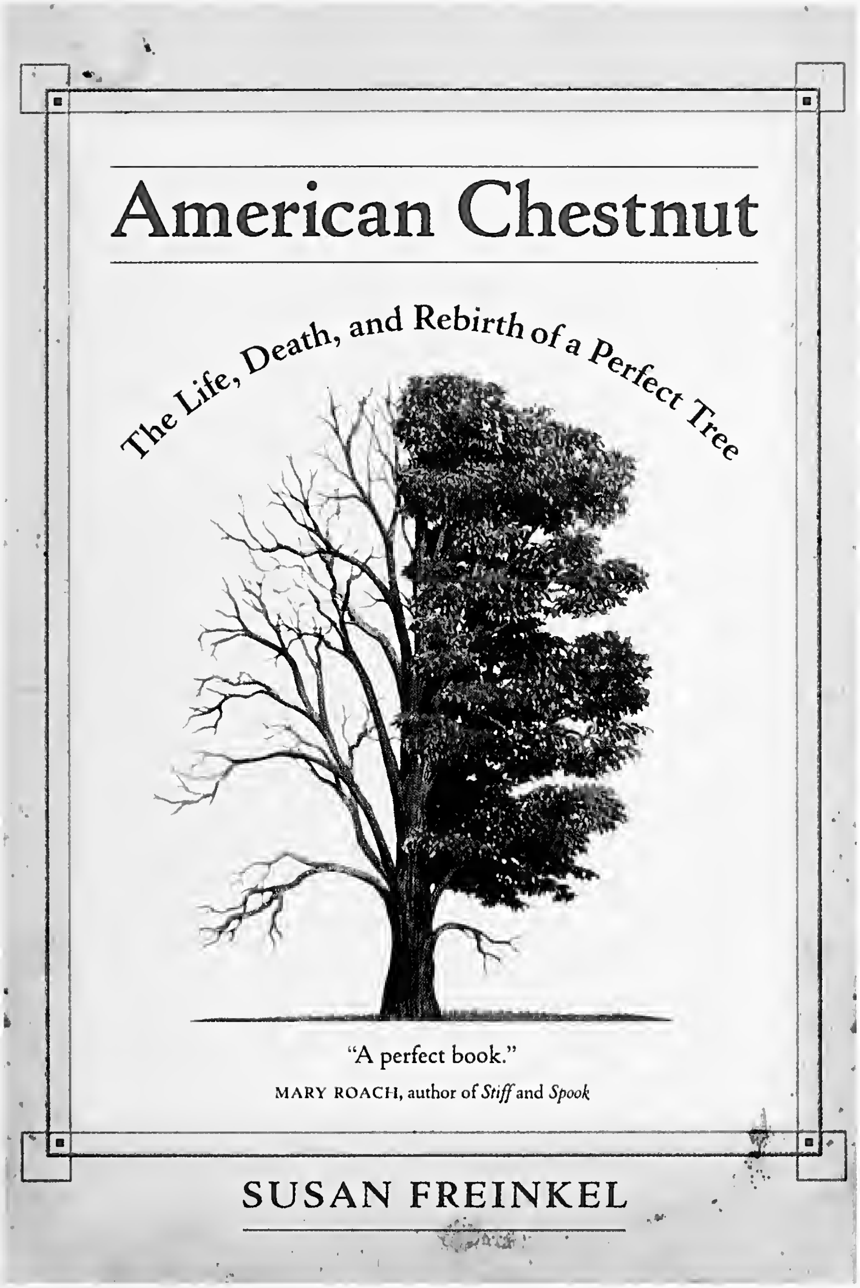
*American Chestnut: The Life, Death, and Rebirth of a Perfect Tree* chronicles the history of chestnut blight, a devastating fungal disease first identified in 1904 by Hermann Merkel, Chief Forester of the New York Zoological Park, and studied by William Murrill, a mycologist at The New York Botanical Garden. The fungus—reclassified in 1978 as *Cryphonectria parasitica*—swept rapidly through American chestnut's native range, nearly annihilating this once-dominant tree species. By mid-century the blight had reached the southernmost part of the range—Alabama, Mississippi, and northern Georgia. Freinkel notes, "A map produced by Gravatt in 1943 showed the scope of the pandemic as a long ellipse stretching nearly the full length of the Atlantic seaboard. Within that ellipse, 50 to 99 percent of the chestnuts were dead... All told, it is estimated the blight killed between three and four billion trees, enough to fill nine million acres. That is enough trees to cover Yellowstone National Park eighteen hundred times over."

Susan Freinkel presents ethnobotanical information on the cultivation of the American forests, first by Native Americans and later by rural inhabitants. She describes an Appalachian culture benefiting from an economy based on collecting chestnuts from family "orchards"—actually chestnut stands in the wild that loosely belonged to different families by tradition or proximity. With little else to use as barter, Appalachian families used chestnuts in trade for store goods at mountain exchange posts. The tree's carroty flavored nut was considered superior to other endemic nut species, and its lumber was straight, strong, and rot resistant. The Appalachian voices in this book provide a soliloquy to the species, which was once so abundant that a squirrel could supposedly pass from "Maine to Georgia" in its branches.

The American chestnut—in diminished form—still lives on more than one hundred years after the blight was first diagnosed. But the species is on a life line, as the author details, waiting for a positive outcome from the experimental strategies of back breeding and guided natural selection. Freinkel conveys the tale of American chestnut through the facets of rural and suburban culture, focusing primarily on Appalachia, New York City, and Pennsylvania. She details the endeavors of the nascent forestry and agricultural departments, observant naturalists and scientists, and well-intentioned legislators. The book portrays key agents and events in the American chestnut's struggle to survive.

Many of the chapters are defined by singular people with some intuitive knowledge and skill who bucked common opinion in their methods. They were agents in early control measures like fungal identification, eventual experiments to fight fungus with fungus, and later breeding and scientific efforts to improve the chestnut gene pool. This legacy is mostly borne by a few tenacious individuals, many of whom receive well-deserved public recognition in this book. They were the architects of experimental nurseries and laboratories working on breeding projects or fungal experiments whose results are clocked in a life cycle longer than that of human generations. These efforts, not yet abandoned, may still succeed.

This wonderful book is paced like a mystery novel, complete with fascinating characters. The plot line of chestnut's survival includes




serendipitous interventions such as that of a cross-country skier turned horticulturist who recognized a surviving stand of chestnut trees in Michigan, or the observant tourist who did helpful comparative research on the European chestnut blight. The history also includes unfortunate, foolhardy visions borne of the spirit of the times such as seed irradiation or the advice given to the struggling public to cut down every tree while the lumber value still yielded a profit. The effects of such commerce consequently spread the blight and reduced the gene pool. The story of the American chestnut showcases a chapter of scientific history, human history, and a change in environmental consciousness.

Susan Freinkel combines an easy narrative style with a factual yet poetic voice that elevates this material beyond dry science to make it a compelling, addictive read. As the author points out, in a world where a species is lost every minute, the survival and potential comeback of the American chestnut is a victory song for the unsung soldier. The beauty of this book is that at its heart it is a tale of the heroic spirit of individuals who have dedicated careers to work on a solution against great odds. Her observations focus the dialogue on the evolution of a consciousness about an enemy that had not been understood or apprehended. It became an enemy that schooled young foresters, botanists, ecologists, enthusiasts, and scientists on how to work on a problem of vast scope. To the author's credit, she refrains from moralizing or predicting the future. She turns the problem around for proper examination from all sides. An old riddle is answered—yes, if a tree falls in the forest and there is no one there to hear it, it does make a sound.

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Heather D. Heimarck is Director of the Landscape Institute of the Arnold Arboretum.

## 2008 Weather at the Arboretum

The autumn of 2007 was so dry that fall transplanting had to be postponed, so moisture was a major concern as 2008 arrived. Fortunately, the year brought greater than normal rainfall which provided optimum conditions for our moisture-starved collections.

January was marked by warmer than normal temperatures, including a balmy 65°F on the 8th, and only one snowstorm (on the 14th and 15th) which produced 6 inches of snow, the total for the month. • February was mild and wet with over 8.5 inches of total precipitation including 15 inches of snow. • Only 2 inches of snow were recorded in March, well below normal, but rainfall added up to nearly 6 inches. • April started warm, with some rain, but became dry as the month progressed, causing concern for the imminent spring transplanting season. Our concerns diminished as we received 2 inches of rain toward the end of the month. • May was quite dry with only 1.5 inches of rain, and irrigating our new plantings was a priority as we feared a repeat of the dry summer of 2007. Though May's total rainfall was low, a string of days with brief late afternoon or evening showers (which left foliage wet overnight) led to ideal

### Arnold Arboretum Weather Station Data • 2008

| | Avg. Max. (°F) | Avg. Min. (°F) | Avg. Temp. (°F) | Max. Temp. (°F) | Min. Temp. (°F) | Precipitation (inches) | Snowfall (inches) |
|---|---|---|---|---|---|---|---|
| JAN | 38.4 | 22.3 | 30.4 | 65 | 4 | 3.23 | 6 |
| FEB | 39.6 | 23.5 | 31.6 | 62 | 9 | 8.53 | 14.7 |
| MAR | 44.2 | 30 | 37.1 | 60 | 11 | 5.65 | 2 |
| APR | 58.7 | 37.9 | 48.3 | 72 | 28 | 3.78 | |
| MAY | 65.8 | 46.8 | 56.3 | 83 | 31 | 1.59 | |
| JUN | 78.4 | 59.8 | 69.1 | 99 | 51 | 3.97 | |
| JUL | 84.2 | 65.7 | 75 | 94 | 61 | 7.65 | |
| AUG | 75.6 | 60.8 | 68.2 | 87 | 53 | 5.25 | |
| SEP | 69.2 | 55.5 | 62.4 | 87 | 42 | 7.24 | |
| OCT | 60.3 | 40.9 | 50.6 | 74 | 26 | 1.82 | |
| NOV | 59 | 33.2 | 41.1 | 69 | 19 | 4.38 | |
| DEC | 42.3 | 24.6 | 33.5 | 63 | 8 | 7.84 | 15 |

**Average Maximum Temperature** ............. **59.6°**
**Average Minimum Temperature** ............. **41.8°**
**Average Temperature** ..................... **50.7°**
**Total Precipitation** ..................... **60.93"**
**Total Snowfall** .......................... **37.7"**
**Warmest Temperature** ..................... **99° on June 11**
**Coldest Temperature** ..................... **4° on January 4**
**Last Frost Date** ......................... **32° on May 1**
**First Frost Date** ........................ **32° on October 24**
**Growing Season** .......................... **176 days**

SUE PFEIFFER

**Putnam Fellow Abby Hird installs one of eighteen weather recording units that were placed on the grounds in 2008. Data from these units will be used to create maps of the microclimates within the Arboretum.**

NANCY ROSE

**2008 was an excellent year for fall color. The foliage of this 105-year-old sweet birch (*Betula lenta* 17679-A) was in full golden glory on October 29th.**

JULIE COOP

**Anthracnose, a fungal disease, was common on the foliage of *Fraxinus* (seen here), *Cornus*, *Platanus*, and *Quercus* in spring 2008.**

SUE PFEIFFER

**Heavy rain on frozen ground led to flooding along Willow Path in December 2008.**

conditions for several fungal diseases including anthracnose. • Fears of drought subsided as June was on the wet side with about 4 inches of rain. The temperature on June 11th reached 99°F, our high for the year. • July was wet and warm, with rainfall and mean temperature above normal. • August ended wet and cool with no readings over 90°F. These two summer months brought many thunderstorms and buckets of rain—an astonishing total of 12.9 inches for July-August. Flooded roads and streams (and clouds of mosquitoes) were common at the Arboretum and throughout the region. The moist summer allowed us to concentrate on watering only new plantings and not the entire collection, and we did very little supplementary watering overall. • September continued our "above average rainfall" theme as we transitioned into fall. Heavy rains occurred at the end of the month, totaling about 4 inches in four days. • October was sunny, cool, and dry with less than 2 inches of rain—a perfect fall month. The fall foliage display was one of the best the region had seen in many years. • The first half of November was mild, but a cold and wet second half transitioned us to what would lie ahead. • December was slightly warmer than normal but several major storms piled up a total of 15 inches of snow. Heavy rain (over 2 inches) on the 11th and 12th fell on frozen ground, causing stream flooding and some damage to Arboretum paths; fortunately, no collections plants were damaged.

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Bob Famiglietti, Horticultural Technologist, compiled the 2008 weather data and wrote the month-by-month weather summary. Additional weather-related information was provided by Stephen Schneider, Manager of Horticulture, and Julie Coop, Manager of Plant Health.

# Japanese Clethra: A Hidden Gem

*Richard Schulhof*

At the edge of the Arnold Arboretum's Central Woods, far from most visitors, grows an exceptional specimen of Japanese clethra (*Clethra barbinervis*, accession 13087). I first became enamored with this species as a student at Longwood Gardens, where I admired its elegant form as part of the backdrop to the famed Flower Garden Walk. While I later saw several very fine examples of Japanese clethra in the great gardens of the Delaware Valley, none approached the singular beauty and character of the Arnold Arboretum's specimen.

Like many plants in the Arboretum's collections, this accession comes with an impressive pedigree, tracing back to Japan in 1886. In that year, William Penn Brooks, a Massachusetts native and valedictorian of the state agricultural college class of 1875, sent seeds of several species to the Arnold Arboretum. Brooks, then a teacher and administrator at Sapporo Agricultural School, found time to survey the surrounding countryside of Hokkaido for interesting plants, several of which came to enrich the Arboretum, including katsura tree (*Cercidiphyllum japonicum*) and hardy kiwi (*Actinidia arguta*).

Of these plants, the Japanese clethra accession is Brooks's greatest Arboretum legacy. At 122 years of age, the specimen is over 20 feet (6 meters) tall and nearly 15 feet (4.5 meters) wide. In the forests of Japan and Korea, Japanese clethra is said to attain heights of over 30 feet (9 meters), but in North America I have seen few specimens larger than the Arboretum's accession.

Although its American cousin, summersweet (*Clethra alnifolia*), is better known to gardeners, the Arboretum's E. H. Wilson considered *C. barbinervis* to be the finest ornamental in the genus. Unlike summersweet, Japanese clethra is more a small tree than a shrub. Judicious pruning can emphasize the small-tree form; when trained as such, it displays sinuous single or multiple trunks broken by floating tiers of foliage. This treatment also shows the tree's exquisitely mottled cinnamon, salmon buff, and slate grey bark to full advantage.


RICHARD SCHULHOF

Japanese clethra's leaves are deep green through summer. Autumn color tends to be unreliable. I have seen outstanding tints of red and burgundy on specimens in both southeastern Pennsylvania and here at the Arnold Arboretum, but in other years have noted little color change before the leaves fall away inconspicuously. Japanese clethra's white flowers are similar to those of summersweet, but they are borne in 4 to 6 inch long panicled racemes that nod forward and gently twist. Japanese clethra blooms around mid July at the Arboretum, about two weeks before our native, and though some consider the fragrance inferior to summersweet, my nose finds it ample in portion and delicious in scent; if anything, too much of a good thing.

*Clethra barbinervis* is listed as hardy to USDA Zone 5 (average annual minimum temperature -10 to -20°F [14 to -4°C]). Our venerable specimen has survived the coldest of Boston winters, but has proven vulnerable to drought. During a very dry summer in the early 1990s, the death of this specimen seemed certain, with each leaf appearing as if torched to a crisp. Phoenix-like, it recovered, living on as one of the Arboretum's most distinguished, and best-hidden, centenarian plants.

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Richard Schulhof is Deputy Director of the Arnold Arboretum.


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