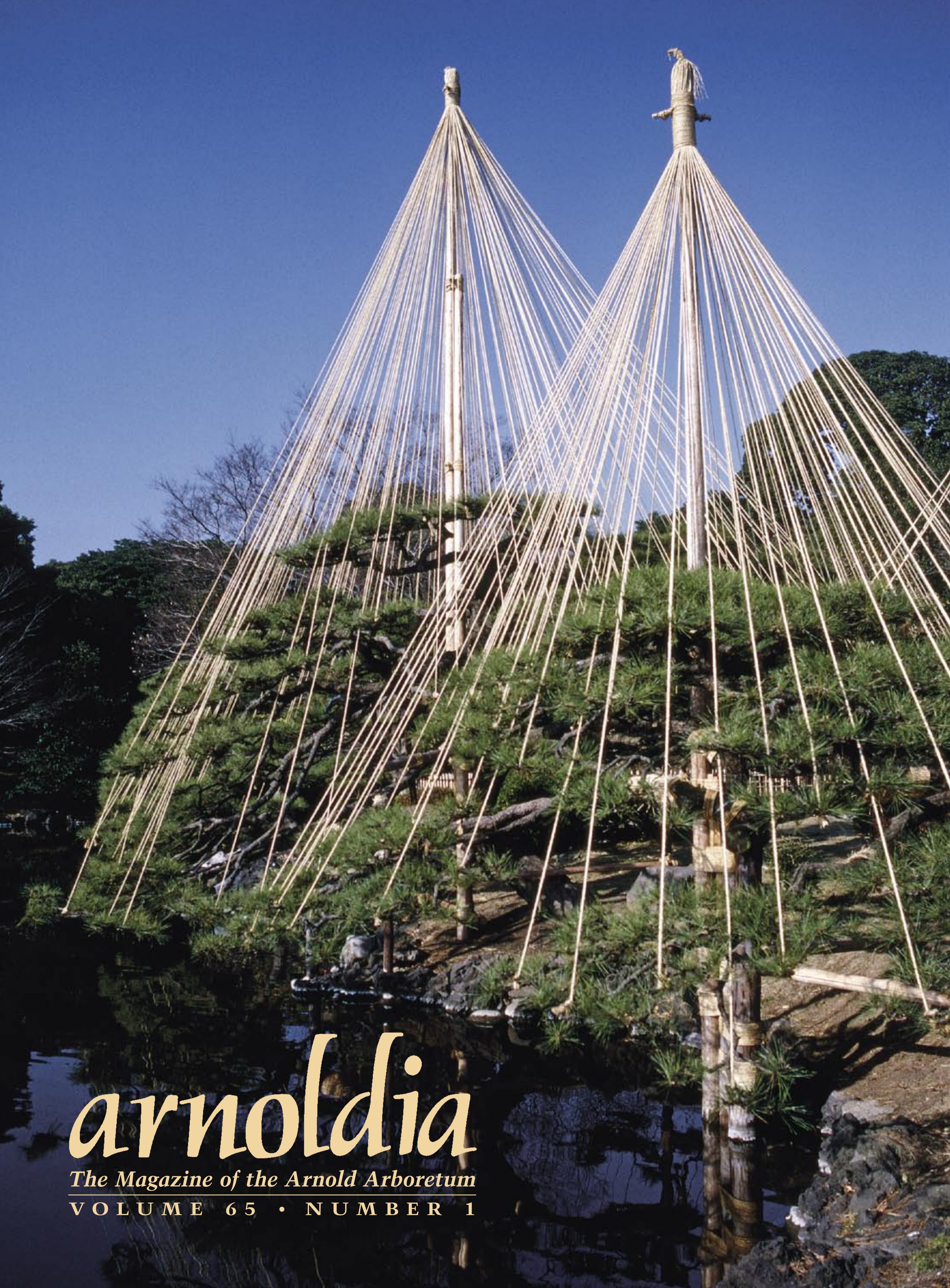

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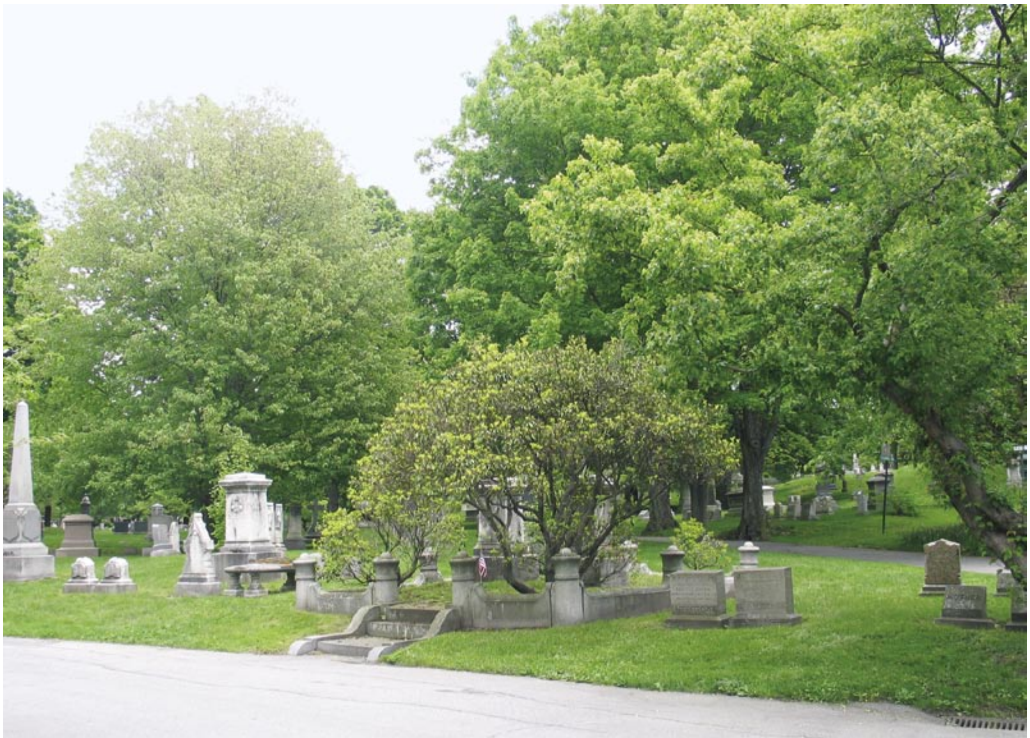
Front cover: Pine tree tent supports at Hama Rikyu, Tokyo, Japan, photographed by Marc Treib.

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.

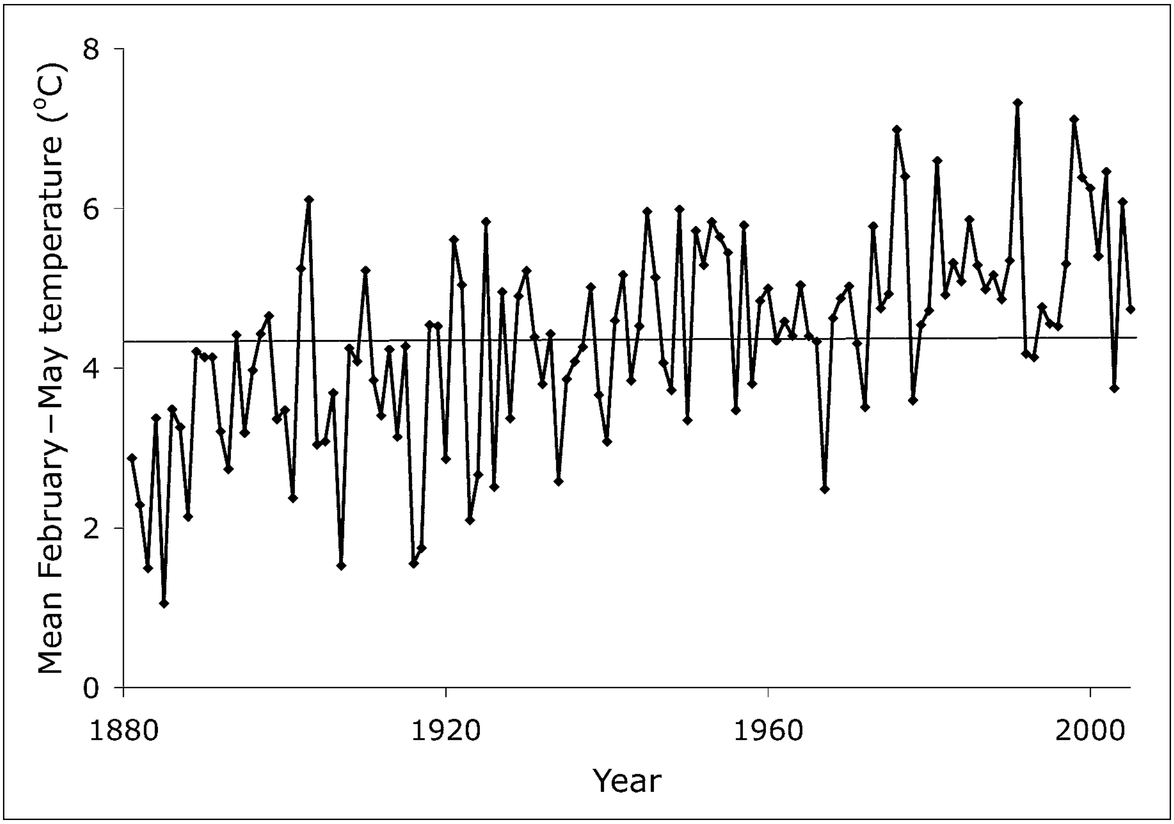
Clearly, current changes in plant phenology will have widespread impacts on critical ecosystem processes such as carbon dioxide storage in plants, interactions between land and atmosphere, and relationships among species. In the Netherlands, for example, dramatic declines in some populations of pied 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.

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

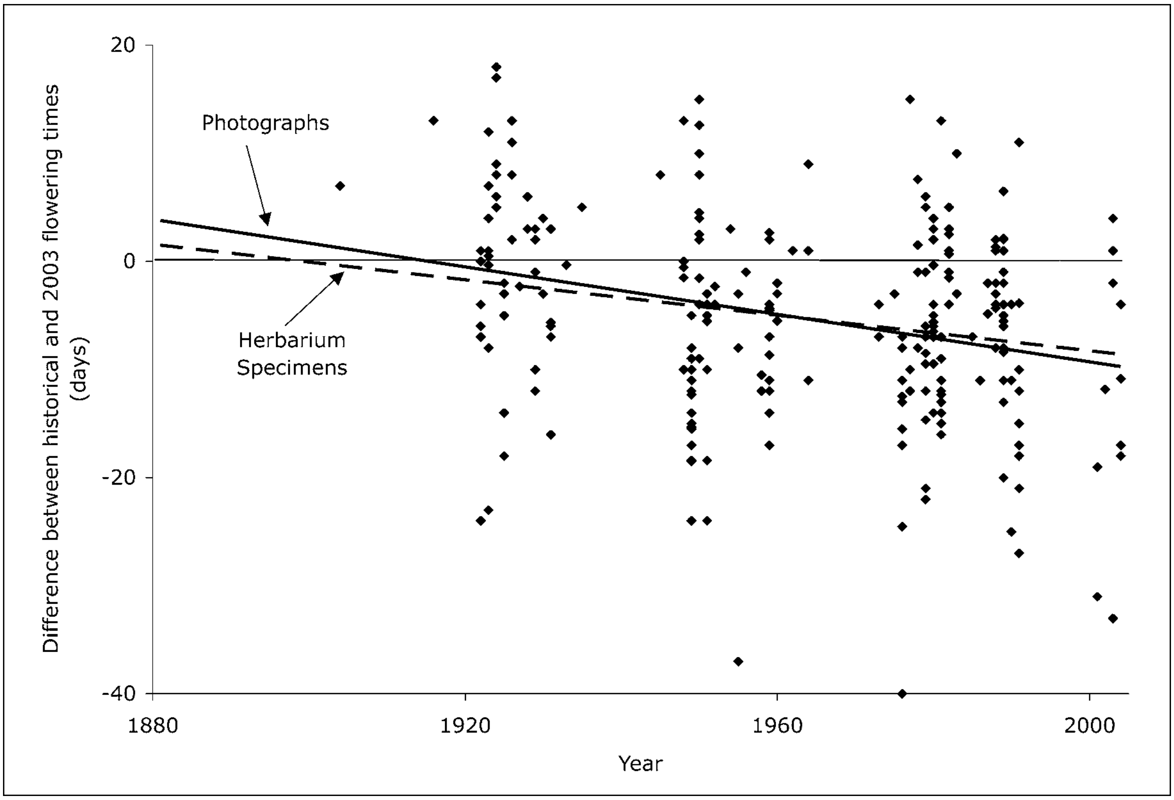
Another representative comparison of historical and recent photographs is this pair of native fringetrees (Chionanthus virginicus) *photographed at the Arnold Arboretum on June 20, 1926, and again in 2003, on May 7, when they flowered seven weeks earlier.*

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.

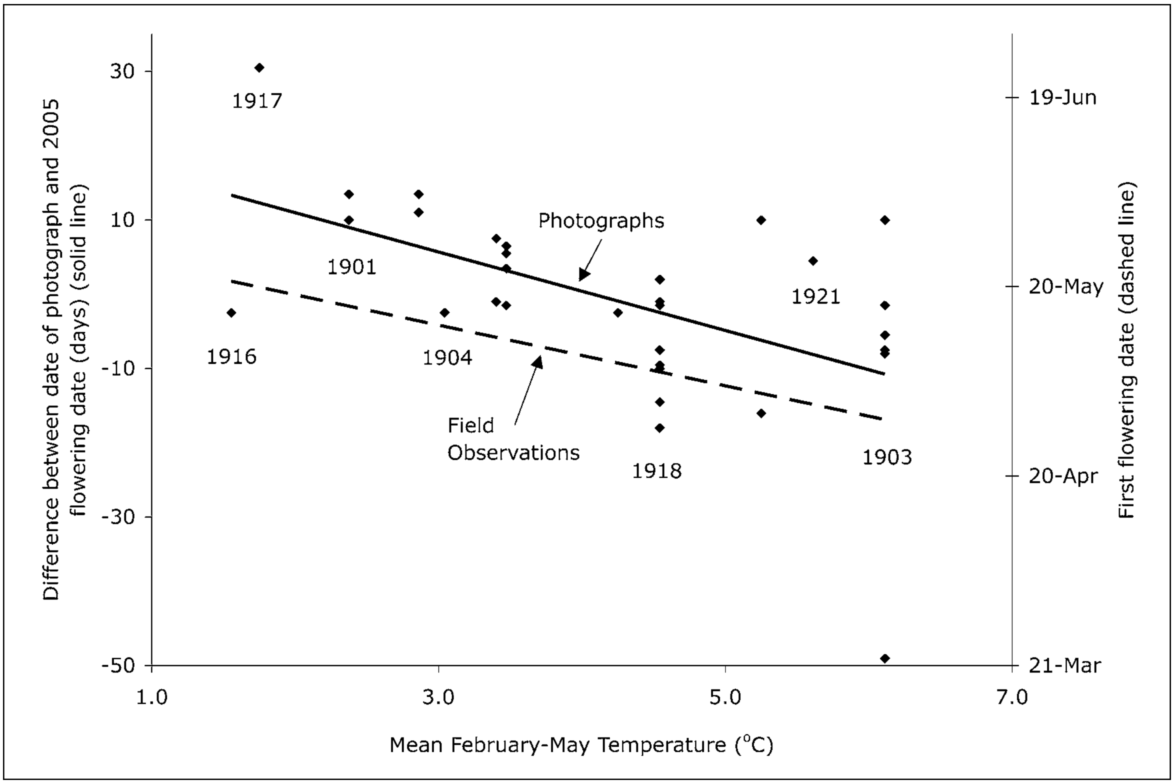
These findings were confirmed by the study of wild species in Concord. Flowering times as recorded in the Concord photographs were the same in 1921 as



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.

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

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

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.

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

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.

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.

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 fail-proof 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

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.

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.

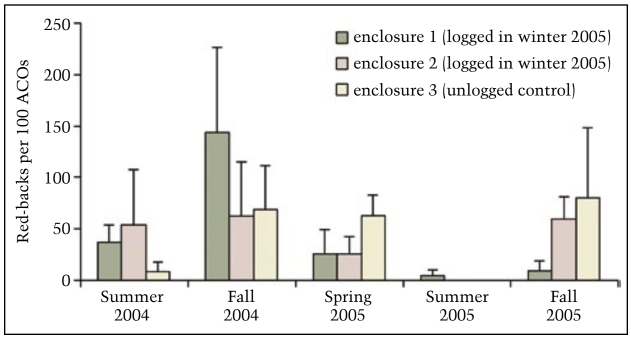
Reptiles and Salamanders Found on Hemlock Hill

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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Brooks Mathewson holds two masters' degrees, one in liberal arts with a biology concentration from Harvard University Extension School in 2004 and another from Harvard University, in 2006, in forest science. He has studied eastern red-backed salamander populations throughout north central Massachusetts, acquiring baseline distribution and abundance data in eastern-hemlock dominated and mixed deciduous forests in this region.

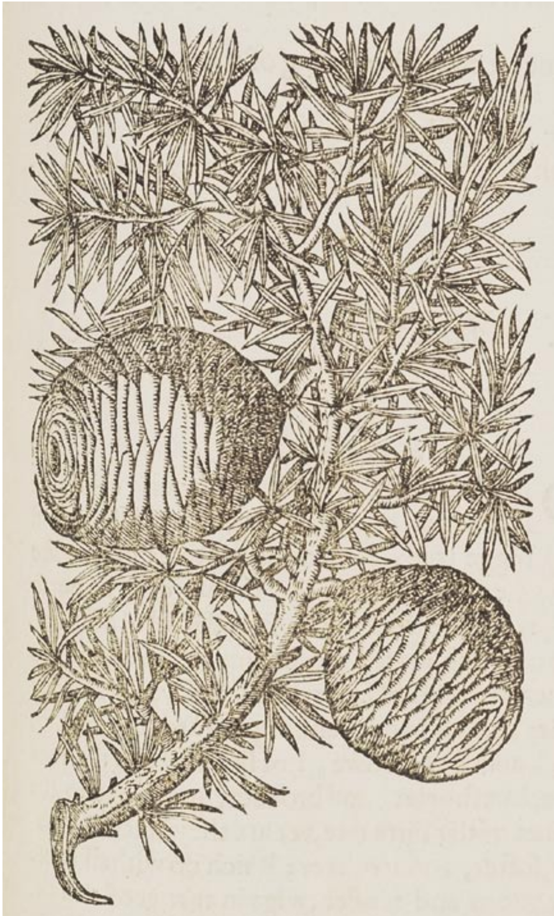
The Quest for the Hardy Cedar-of-Lebanon

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

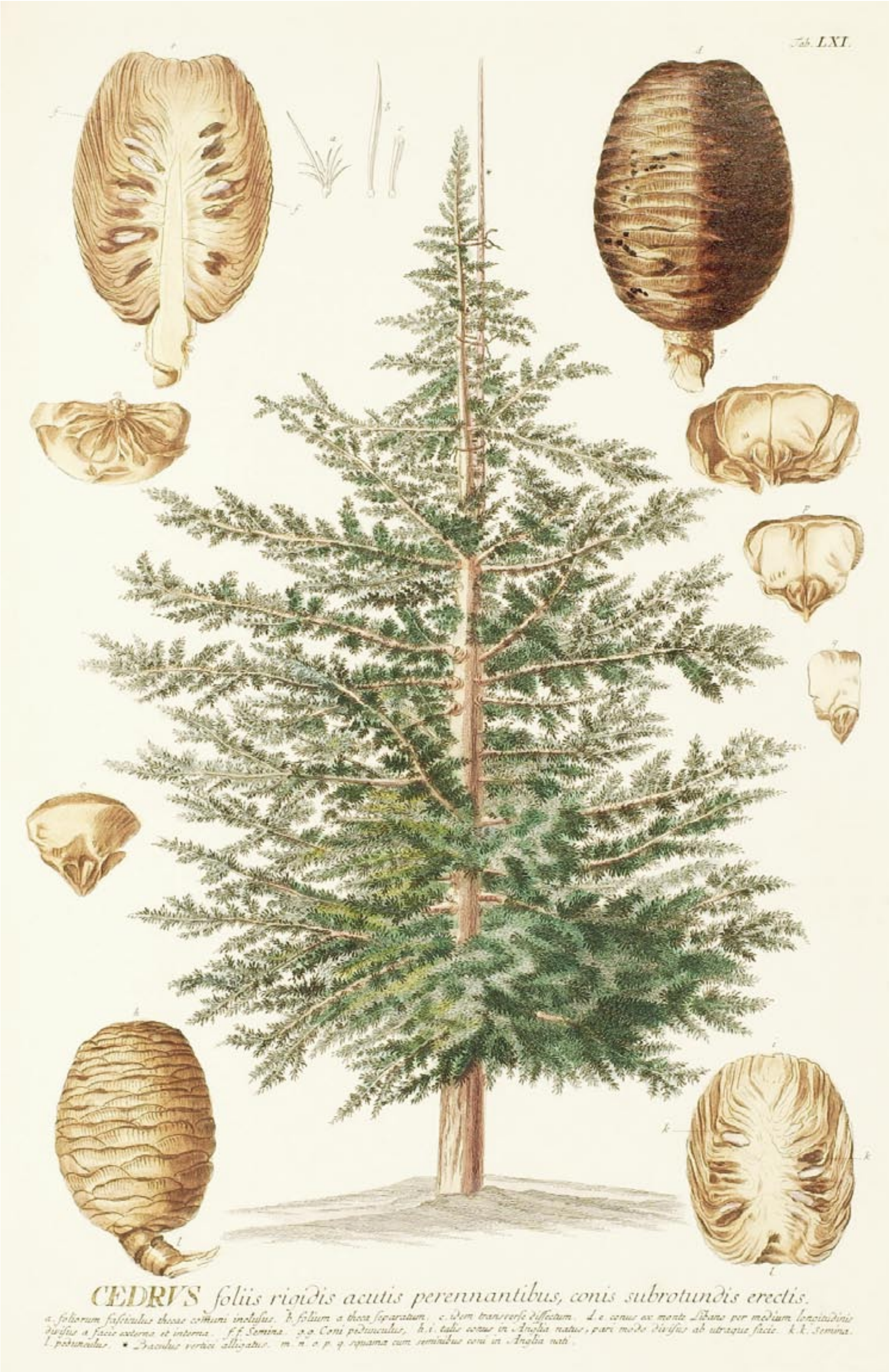


Image of Cedrus libani *from Trew's* Plantae Selectae, *1750–1773.*

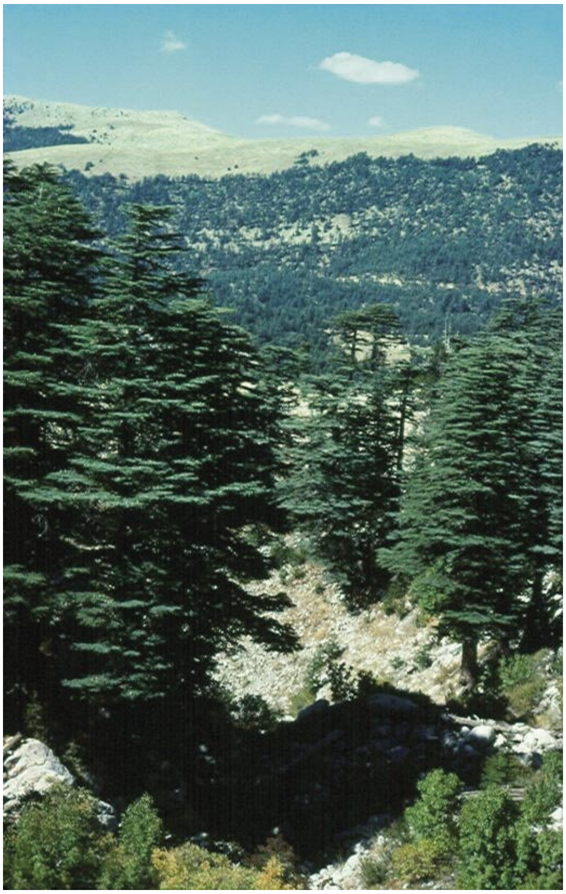
(not forming the flat "umbrella" top of other cedars) and to have shorter needles than those from Lebanon (Farjon 1990), although there is variability particularly in the former trait and is likely more a function of environment than pure genotype. The epithet *stenocoma* literally means "narrow hair,"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

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.

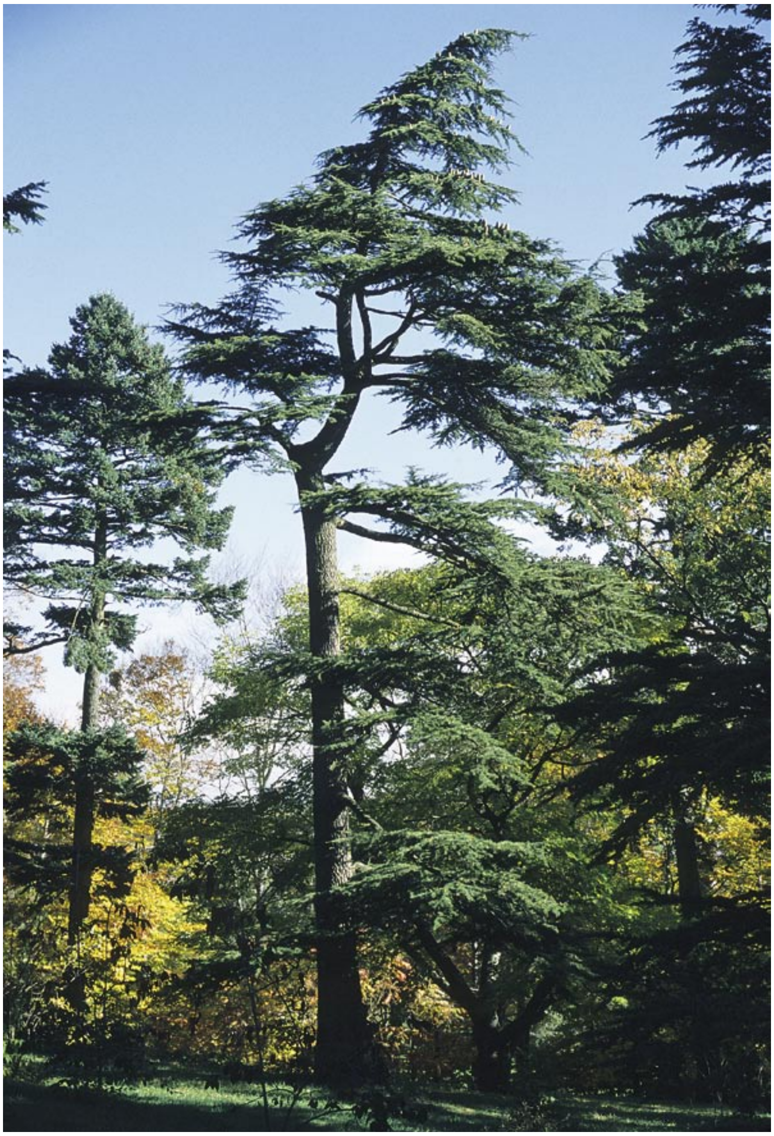
With this in mind, Sargent hired Walter Siehe to collect seed from trees in the Taurus Mountains and have these sent to the Arnold Arboretum. In a letter from Siehe to Sargent, dated 18 November 1900, from Mersina, Turkey, Siehe wrote:

> 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

PETER DEL TREDICI



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

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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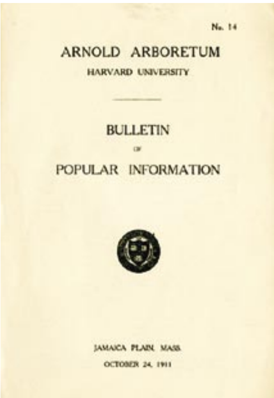
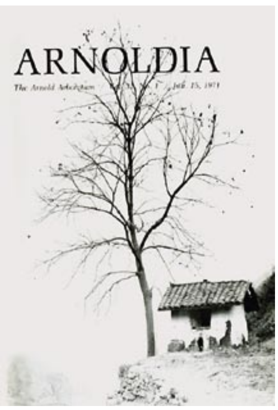
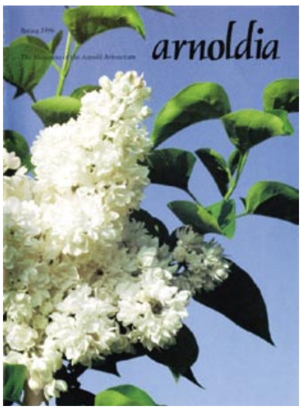
Arnoldia Online

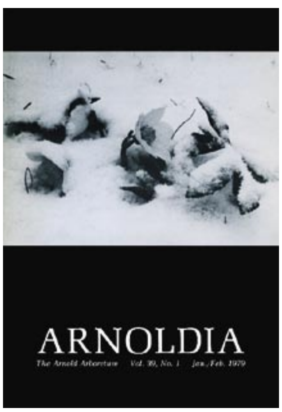
Ninety-five years and 13,000 pages of *Arnoldia* (1940–present) and its predecessor, *The Bulletin of Popular Information* (1911–1939), are now available on the Arboretum's website at www.arnoldia.arboretum.harvard.edu.

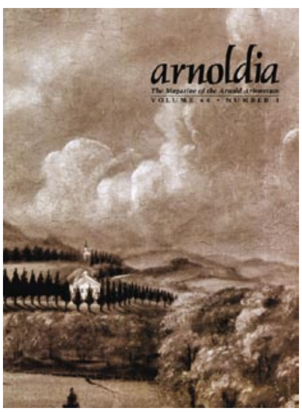
This trove of rich and varied content invites browsing by date, author, and title or by using the yearly indexes (1915–2006) and the two cumulative indexes (1941–1969, 1970–2000). Plants, places, and people are the chief but not the only constituents of the indexes, and they can be searched online in 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. Hydraugea quercifolia.

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